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Multidimensional Journal Evaluation

Analyzing Scientific Periodicals beyond the Impact Factor

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Chapter 1
Introduction

This book focuses on scholarly journals and deals with their role as the primary means of formal communication in the sciences. Their standing in the scientific community is evaluated from the perspective of quantitative informetric indicators. Two main research questions are investigated:

- Are there different dimensions of journal evaluation? If so, what indicators can be applied to represent each dimension of journal evaluation? How do metrics differ and what data can be used to adequately indicate journal impact?
- Various stakeholders of journal evaluation, i.e. scholarly authors, readers, librarians, publishers and editors, have different interests in using methods of journal evaluation. What indicators of what dimensions will each of the stakeholders find most valuable and apply in practice to journal selection?

In the form of a case study, a set of 45 physics journals will be used to demonstrate the various journal metrics and informetric methods in terms of practicability, validity and informative value.

Formal communication in the sciences depends primarily on the publication of research results and comprehensive reviews in the form of journal articles. Since the first scholarly journal was founded in the 17th century, the scientific periodical has become the most important medium in science, technology and medicine (STM). Through its fast and wide dissemination the peer-reviewed journal is the preferred formal publication outlet of researchers in these fields. In the social sciences and humanities its influence is growing. With constant growth in the number of scientists, research institutions and publications, the number of scholarly journals and the number of articles in them increases, too. The academic world has to deal with the problem of massive information overload. The current number of scientific peer-reviewed periodicals is estimated to be approximately 24,000 titles (Tenopir & King, 2009). Researchers are confronted with the impossible task of keeping up with the amount of information available (Moens, 2000; Keller, 2005).

> [I]nformation overload occurs when information received becomes a hindrance rather than a help when the information is potentially useful. (Bawden, Holtham, & Courtney, 1999, p. 249)

Bawden and Robinson (2009) quote a report based on experience from the area of biomedical research in 1986:

> Many medical practitioners have abandoned 'keeping up with the literature'. They are paralysed by the sheer enormity of the task: more than 20,000 journals in biomedicine are published each year and a consultant in a single medical subspeciality may need to read fifteen to twenty publications a month to keep up to date. (Bawden & Robinson, 2009, p. 183)

Price (1963) claims that "scientists have always felt themselves to be awash in a sea of scientific literature" (Price, 1963, p. 15). He was also the first to provide support for the subjective perception of the information flood in science by objective statistics on the number of scholarly journals. With the emergence of electronic publishing the number of documents available has further increased. With an ever growing output the challenge is to manage this information overload and select the most suitable sources. It is not only the reader who has to choose. Since they are evaluated on the basis of their publications, researchers need to develop a publication strategy and select the best periodicals in their role as authors as well. Scientometric indicators can help with these selection processes.

Informetrics and the sub-areas of scientometrics and bibliometrics represent an approach forcoping with the growing flood of scholarly literature by means of objective statistical methods (Tague-Sutcliffe, 1992; Stock & Weber, 2006; Bar-Ilan, 2008). Bibliometric methods quantitatively evaluate the structure of and processes involved in formal scholarly communication, in which the scientific journal plays a paramount role. Scientometric analysis of periodicals arose out of the need to identify significant sources of information. Initially, journal evaluation was applied with a local focus by librarians for collection management purposes. With the development of the Science Citation Index (SCI) and the advent of systematical journal-based research evaluation, journal rankings have become important and are applied by authors, readers, editors, publishers and research managers alike.

> The evaluation of scholarly journals is important for selection and cancellation decisions by librarians, the evaluation of faculty and librarians for promotion and tenure as well as annual performance reviews, manuscript submission decision by authors, monitoring of their journals by editors and publishers, and familiarizing new doctoral students or outsiders (such as members of a university-wide promotion and tenure committee evaluating faculty from other departments) with a field's journals. (Nisonger & Davis, 2005, p. 341)

> Journal citation measures are designed to assess significance and performance of individual journals, their role and position in the international formal communication network, their quality or prestige as perceived by scholars. Scientific journals may differ with respect to their importance of their position in the journal communication system, their status or prestige. (Glänzel & Moed, 2002, p. 171)

The most widely used indicator for selecting the most influential journals in a scientific field is the impact factor listed in the Journal Citation Reports (Stock, 2001). Developed by Eugene Garfield (1955) as a criterion to select a discipline's core journals for his citation indices, the impact factor has become a popular measure to indicate a journal's standing in the scientific community (Garfield, 1972). Librarians use the impact factor to compile literature within their budget, authors make use of it to choose the best suited journal for publication, readers use it to identify central sources of information, and editors and publishers apply it to analyze the market and observe competitors. The impact factor has become the most popular bibliometric indicator used inside and especially outside the scientometric community (Glänzel & Moed, 2002). As an average citation rate it is, however, not able to reflect all the aspects that contribute to a scholarly journal, not to mention its methodological shortcomings. As the impact factor became popular, so, too, did its misuse. It is often applied directly to the articles a journal contains or even to the contributing authors. Publications in high-impact journals are rewarded financially, and with the help of cumulative impact factors, research grants are provided or careers decided upon (Jennings, 1998; Al-Awqati, 2007).

While alternatives exist and new and improved methods are being created by the bibliometric community, in the evaluation of journals by its users the influence, quality and prestige of a serial are mainly based on the impact factor. The journal's value is limited to a single quantitative indicator which divides the number of received citations by the number of published articles. Further methods and possibilities of journal evaluation are more or less disregarded by users outside the bibliometric community. Journal evaluation is unidimensional and therefore not able to reflect the actual impact of a scholarly periodical (Rousseau, 2002; Coleman, 2007).

This book argues that only a method that incorporates all facets of journal evaluation can adequately represent the journal's standing in the scientific community. Five conceptual dimensions are defined which contribute to the value of scholarly journals and are therefore to be included in a comprehensive and adequate approach to journal evaluation. The goal of this study is to provide the users with a variety of indicators to choose the most suitable method for their individual purpose regarding journal selection. Since the purposes of journal evaluation are individual (Björk & Holmström, 2006), it is not the aim to provide a cure-all or all-in-one device but to systematically review various metrics of journal evaluation including a transparent description of possibilities and shortcomings. The work focuses on the users of these methods, i.e. researchers in their role as authors and readers, librarians, publishers and editors, rather than the experienced bibliometrician and tries to guide them through the "maze of indicators" (Wouters, 1999, p. 128). This book tries to solve the lack of transparency of bibliometric methods and journal metrics, which causes users to restrict themselves to the well-known and readily available but limited and flawed impact factor. Whether or not alternative or complementary indicators are used depends above all on these indicators being known and understood by their potential users.

> What will ultimately determine which of this new battery of measurements succeed and which fail, either individually or as composite measures, is likely to be how strongly they resonate with the communities they serve. The best ideas do not always make the best products, but instead simplicity and transparency can be the difference between success and obscurity. (Craig & Ferguson, 2009, p. 188 f.)

This book tries to provide transparency and lets the user choose from a toolbox of indicators and combine the most suitable for his particular needs, i.e. an author to select the most appropriate publication venue, the reader to select journals to fulfill his information needs, a librarian to compile a collection, and an editor and/or publisher to monitor the performance of his own journals and that of competitors.

In the following, the scholarly journal is defined and its emergence as the most important form of formal scholarly communication briefly described. Afterwards section 1.2 provides an overview of the usage and users of evaluation methods. Section 1.3 introduces the five dimensions of multidimensional journal evaluation, which are discussed and analyzed in detail in the respective chapters. Section 1.4 describes the 45 physics journals which throughout the study function as a test set to apply and compare various indicators.

1.1 The Scholarly Journal

Since the founding of general science journals over 300 years ago, the publishing landscape has grown, specialized and become more and more heterogeneous and unmanagable for a researcher to cover. After an attempt to define what constitutes a scholarly journal (section 1.1.1), a brief historical overview of the emergence and development (section 1.1.2) is given.

1.1.1 Definitions

As this work is based on the evaluation of scholarly journals, a definition of it is due. Although a vast amount of literature exists, an exact, formal definition of the scholarly journal is, however, lacking. Most works assume that it is understood. In addition, the terms 'journal', 'periodical' and 'serial' are used synonymously (Buchet, 2004; Keller, 2005; Mierzejewska, 2008). Page, Campbell, and Meadows (1997) define 'serial' and 'periodical' as follows:

> **Serial**: a publication issued in successive parts, bearing numerical or chronological designations and intended to be continued indefinitely.
>
> **Periodical**: a publication appearing at stated intervals, each number of which contains a variety of original articles by different authors. (Page et al., 1997, p. 1)

In this study, the terms 'journal', 'periodical' and 'serial' are used synonymously and all refer to scholarly or learned journals which, on a regular basis and to a great extent, publish original research articles and/or reviews and apply some form of peer review. Academic journals can be clearly distinguished from popular magazines and newspapers and so-called trade journals which, on the one hand, publish current, non-technical and unscholarly content often written by in-house writers and commissioned journalists and, on the other hand, inform members of one particular industry sector or branch of trade.[1] As electronic journals or e-journals are merely a new form of appearance of the same medium established 300 years ago, no distinction is made between print and electronic journals. Even though future visions of the electronic journal predicted significant changes of scholarly communication tapping the full potential of the digital age, the concept of the academic journal has so far hardly been altered by its electronic form (Keller, 2005). Although the electronic, i.e. PDF, format improves access, searchability and intra- and inter-document navigation, the scholarly article as such, and hence the academic journal, has not changed.

In the area of STM, academic journals play the major role in formal scholarly communication. The extent to which scholarly output is published in journals, varies between disciplines. As table 1.1 shows, over 80% of all scientific output in the biological, chemical, physical and medical research fields is published in journals, while in the social sciences and arts and humanities, where book publications play a more significant role, it is less than half as much. As bibliographical databases such as the Web of Science (WoS) and Scopus are limited to periodical literature and not able to cover the entire scholarly output, the databases' ability to reflect formal scholarly communication depends on the discipline-specific publication behavior, on the one hand, and database coverage, on the other. Due to these field differences, this study

1 http://www.unity.edu/library/scholarly_journal.htm

focuses on physics journals (see section 1.4), but methods and indicators can be equally applied to periodicals in any other STM research field. When evaluating social sciences and arts and humanities journals, one should be aware of capturing only a fraction of the scholarly output. In order to adequately reflect formal scholarly communication in non-STM research, books have to be considered as well.

Table 1.1 Percentage ($P_{\%}$) of references (of articles and reviews published in 2002) per discipline published in journals and covered by WoS (WoS). Source: Craig and Ferguson (2009, p. 163).

Discipline	$P_{\%}$ in journals	$P_{\%}$ in WoS	$P_{\%}$ WoS coverage
Molecular biology and biochemistry	96	97	92
Biological sciences related to humans	95	95	90
Chemistry	90	93	84
Clinical medicine	93	90	84
Physics and astronomy	89	94	83
WoS average	*84*	*90*	*75*
Applied physics and chemistry	83	89	73
Biological sciences (animals and plants)	81	84	69
Psychology and psychiatry	75	88	66
Geosciences	77	81	62
Other social sciences (medicine and health)	75	80	60
Mathematics	71	74	53
Economics	59	80	47
Engineering	60	77	46
Social sciences	41	72	29
Humanities and arts	34	50	17

As major communication channels in STM, academic journals fulfill the four basic functions of registration, certification, dissemination and archiving (Mierzejewska, 2008). Through publication researchers are able able to publish their findings quickly and claim priority. Peer review and editorial processes guarantee quality control and validity of published contents. The journal provides a platform of wide dissemination in the scholarly community and at the same time makes findings permanent through archiving (Mabe & Amin, 2002; Meier, 2002). While registration, certification, awareness and archiving represent the primary functions of an academic periodical, secondary functions can be identified as well. They mainly refer to social aspects of scientific communities, i.e. forming and developing communities by providing a communication platform, identifying and empowering influential authors through editorial board membership and by providing the framework for scientific evaluations (Mierzejewska, 2008).

1.1.2 Emergence and Development

The first scholarly journals emerged in the 17^{th} century in order to make science more efficient. Journal publishing was intended to serve the purpose of avoiding duplication and advance scientific knowledge by building on results of colleagues (Mierzejewska, 2008). Published in France in January of 1665, Le Journal des Sçavans is said to be the first scholarly journal since it published articles and news items on many different topics for scholars. Only shortly after, the first issue of Philosophical Transactions of the Royal Society of London appeared, which had a greater resemblance to the modern scholarly journal since it consisted of 407 instead of 20 pages (Keller, 2005; Tenopir & King, 2009). Philosophical Transactions was launched by the Secretary of the Royal Society, Henry Oldenburg

> to inform the Fellows of the Society and other interested readers of the latest scientific discoveries. As such, Philosophical Transactions established the important principles of scientific priority and peer review, which have become the central foundations of scientific journals ever since.[2]

The emergence of scholarly journals in the 17th century fundamentally changed the entire process of scholarly communication, which up to that point had been carried out through society meetings, books and letters (Price, 1963; Zuckerman & Merton, 1971). Although the latter represented a timely method of publishing results and claim priority for discoveries, scientific letters were still a personal form of communication and thus limited in terms of distribution (Keller, 2005; Tenopir & King, 2009). Price (1963) emphasizes the initial purpose of the newly founded journals as

> monitoring and digesting of the learned publications and letters that now were too much for one man to cope with in his daily reading and correspondence. (Price, 1963, p. 15)

Scientific communication advanced from personal correspondence and became structured and distributed on a regular basis. This made it possible to keep a record of and archive knowledge systematically. In addition, publication in a journal allowed researchers to claim their discoveries (Keller, 2005).

Since the founding years of the scholarly journal, the number of titles has increased, although Price's famous estimations of exponential growth which predicted one million titles in 2000 did not occur (compare chapter 2). Annual growth rates increase gradually rather than exponentially (Mierzejewska, 2008). Mabe (2003) calculated an almost constant annual growth rate of 3.46% of active refereed scholarly journal titles from 1665 to 2001 listed in Ulrich's Periodicals Directory , and Tenopir and King (2009) conclude from listings in the same database that in 2008 61,620 scholarly journals existed (i.e. were still actively publishing), of which 23,973 were refereed. Placing the number of scholarly, peer-reviewed journals at 24,000 seems a conservative but fair estimate of the number of journals available, which is supported by results of other studies (Mabe, 2003; Morris, 2007; Craig & Ferguson, 2009; Tenopir & King, 2009).

Today the landscape of scholarly journals is characterized by its heterogeneity. Further growth and specialization of science demands specialization of publication venues, which contributes to the foundation of new journals or the splitting up of existing ones (Meier, 2002; Mierzejewska, 2008). The increasing specialization and further development of science has led to a flood of information which is difficult for a single researcher to access or manage (Keller, 2005). As it is not possible for a

2 http://rstl.royalsocietypublishing.org/

researcher to read all the relevant literature, it is now more than ever crucial to select the most important resources so that relevant content is not missed. Journal evaluation can help to identify the most suitable journals.

1.2 Application and Developments of Journal Evaluation

Scientometric analysis of periodicals arose out of the need to identify significant sources of information. Bibliometric indicators were first and foremost developed to cope with the flood of information created by an increasing specialization and differentiation of science and the growth of research output. With the amount of literature available, the scientific landscape has become complex and the chances are that relevant content is missed (Keller, 2005). Quantitative methods provide focus (Craig & Ferguson, 2009) and are applied to help researchers in their role as readers and authors to select the most suitable journals satisfying their information needs, on the one hand, and communicating their results, on the other.

At the beginning, journal evaluation was applied locally by librarians for collection management purposes. Gross and Gross (1927) are considered to be the first describing a reference-based journal analysis for managing library holdings by objective, quantitative methods (Archambault & Larivière, 2009). Bradford (1934) further influenced librarians and collection management through his famous law of scattering stating that the majority of documents on a given subject are concentratively published in a few core journals.

With the development of the SCI by the Institute for Scientific Information (ISI), journal evaluation transcended local library collection management and was applied on a global scale. With the impact factor, the first widely applied indicator for journal evaluation was developed, although, initially it was constructed as a means to identify the most frequently cited journals per discipline for the SCI rather than a journal metric on its own. As a multidisciplinary citation index, the SCI was in the first instance not developed for evaluational purposes but for the retrieval of scientific information (Garfield, 1955, 1998).

The SCI has, however, fostered the culture of research evaluation. The impact factor is no longer a simple metric to identify candidates for database coverage, but has become a synonym for journal prestige powerful enough to influence scholarly communication and even researchers' careers. In these times of journal-based research evaluation, the ranking of periodicals is central and the impact factor has become a cure-all indicator used and misused by authors, readers, editors, publishers and research policy makers alike (Adam, 2002; Rogers, 2002; The PLoS Medicine editors, 2006).

As the limitations of the impact factor and its inability to fulfill various information needs and fully represent a journal's standing in the scholarly community became obvious, many alternative metrics were proposed from within and outside the bibliometric community. Figure 1.1 shows the growth of publications on journal evaluation[3] and their impact. During the 30 years between 1980 and 2009 almost 3,500 documents on

3 3,497 documents retrieved in January 2011 from SCI, SSCI, A&HCI and CPCI-S published between 1980 and 2009, matching the following query: ti=("impact factor*" or (journal$ and (evaluat* or analy* or measur* or indicat* or cited or citing or citation* or rank* or scientometr* or bibliometric* or informetric*))).

journal evaluation were published, 10% of which were published in 2009. While new or newly named indicators emerge regularly within the bibliometric community, in applied journal analyses evaluation methods are mostly limited to the impact factor, which is largely due to its simplicity and availability (Seglen, 1997; Glänzel & Moed, 2002; Moed, 2002; Favaloro, 2008).

> Apart from the impact factor, the use of other journal citation measures is rather occasional. [. . .] All other attempts to improve, substitute or supplement the impact factor have encountered serious obstacles to wider application. On the one hand, the achieved 'accuracy' is often at the expense of simple interpretation. On the other hand, several alternative journal citation measures could not always be rendered accessible to a broader audience, or at least not regularly be updated like in the case of the IF through the annual updates of the JCR. In lack of regular updates, these indicators could not be readily reproduced by other research centres. (Glänzel & Moed, 2002, p. 177 f.)

In order to be used, alternative metrics have to be understood. This work aims to provide a systematic overview of possibilities of multidimensional journal evaluation with a focus on the applicability and limitations of existing indicators. In addition, new data sources such as bookmarks of and tags assigned to journal articles by users of specific web 2.0 platforms are introduced as alternatives to represent the readers' perspective (Haustein & Siebenlist, 2011). It will be shown that one journal metric, such as the impact factor, is not able to fulfill the various requirements for journal evaluation of the different user groups.

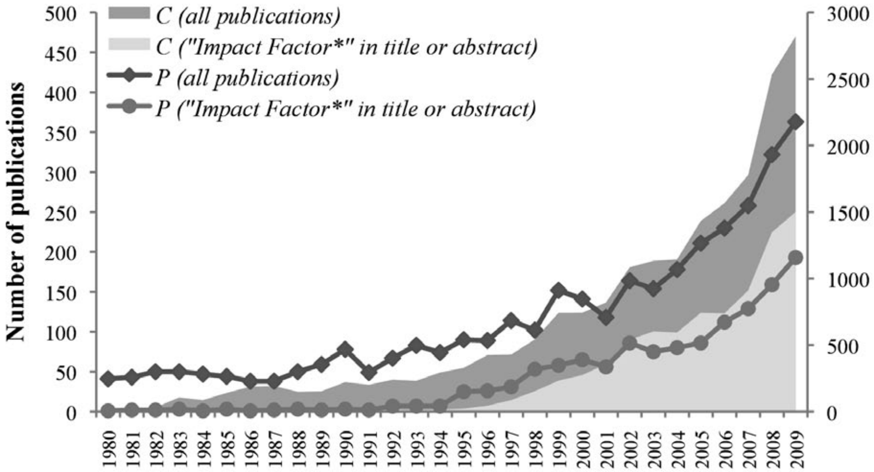

Figure 1.1 Number of publications (*P*) and citations (*C*) of journal evaluation literature 1980 to 2009.

In the journal publication landscape, five groups of participants can be identified: researchers (i.e. authors), gatekeepers (i.e. editors), publishers, libraries and users (i.e. readers). These groups "may significantly influence the functioning and success of academic journal publishing" (Mierzejewska, 2008, p. 7). These participants represent actual and potential users of journal evaluation. In the process of evaluating scholarly journals, four stakeholders can be identified, i.e. academic authors selecting a publication venue, readers choosing a suitable source of information, librarians managing a collection, and editors and publishers evaluating journal performance and observing competitors (Garfield, 1972; Todorov & Glänzel, 1988; Nisonger, 1999; Glänzel & Moed, 2002; Rousseau, 2002). Research evaluators at universities, government offices and funding agencies can be identified as a fifth stakeholder. However, their purpose in evaluating journals is secondary in so far that they rank journals as a means of evaluating the researchers and institutions publishing in them. Thus, policy makers are not treated as a distinct user group in this study.

Each of the four user groups has different requirements for identifying and ranking scholarly journals (Moed, Van Leeuwen, & Reedijk, 1998). Depending on these needs, one indicator might be more suitable for one stakeholder than another. The same set of periodicals might even be ranked differently from the readers' and authors' perspectives.

> The quality of a journal is a multifaceted notion. Journals can be evaluated for different purposes, and hence the results of such evaluation exercises can be quite different depending on the indicator(s) used. (Rousseau, 2002, p. 418)

Journal evaluation depends on the individual purpose and requirements of the user. The four stakeholders are introduced in the following together with the differences and similarities of their positions in journal evaluation.

Readers

Readers of scholarly literature can be divided into two groups, namely publishing and pure readers (Rowlands & Nicholas, 2007). The former can be considered as active researchers who use the scholarly journal as a means to communicate their research by publishing results which then influence and improve further research and technological development. These publishing readers need to select a set of journals to be informed about the research front. In journal selection they give priority to the topicality, scholarliness and high quality of journal content guaranteed through peer review. The group of pure readers includes those readers who do not actively participate in research but read scholarly literature to apply in their everyday worklife and teaching. Students make up a large part of pure readers. Pure readers primarily select review journals to obtain an overview and and be generally informed (Rousseau, 2002).

In general, researchers in their role as readers wish to read as little as possible to fulfill their information needs. Due to the evaluation culture, in their role as authors the same researchers, however, aim to publish as much as possible and to be read by as many people as possible. This schizophrenic behavior (Meier, 2002), described by Mabe and Amin (2002) as 'Dr Jekyll and Dr Hyde', is also reflected in journal selection.

Authors

Publishing research results in the form of journal articles is the final step in the scholarly communication process. In the role of an author, researchers seek to publish in the most suitable publication venue in order to reach out to a particular target audience and diffuse results as far as possible. In general, the target readership can be defined as the scholarly community of the particular field, although sometimes authors may wish to address researchers or practicioners from outside their research area. The target audience can, above all, be identified thematically through the journal's scope and topics published, but also geographically through the nationality of publishing authors and readers. Usually an author chooses a publication venue where he can reach as large an international audience as possible (Swan & Brown, 1999).

A survey by Rowlands and Nicholas (2005) showed that a journal's reputation has become even more important to submitting authors than potential readership. Now that researchers are evaluated on the basis of the periodicals they publish in, the journal's standing, often substituted by the impact factor, plays a paramount role in submission decisions. Authors seek to gain recognition and personal prestige by publishing in high-quality journals, which helps them to advance their careers (Swan & Brown, 2004; Mierzejewska, 2008).

Since authors publish to claim priority of their findings, a fast review process and short publication lag, i.e. time between acceptance and publication, is crucial. Thorough peer review helps to improve the quality of the submission and assures potential readers that quality control has been applied. Journal prices hardly influence an author's decision whether to submit his manuscript to a periodical. The opportunity to publish open access in order to reach as large a readership as possible may, however, influence the author in the journal selection process. Methods of journal evaluation are able to reflect various aspects from journal scope to readership, publication delay, impact and prestige. Journal metrics can help authors to identify the most suitable publication venue from a large number of periodicals and optimize publication strategies (Moed et al., 1998).

Librarians

Libraries are mandated to provide broad access to scholarly information to scientists for them to further develop and improve their research (Meier, 2002). In order to optimize collections, i.e. choose the most useful and suitable sources of information, librarians were the first users of journal rankings. Monitoring usefulness by usage statistics, surveys and citation analysis are applied for purposes of collection management. Confronted with budget cuts and increasing subscription prices, the need to select the best journals within a limited budget is crucial to a librarian. Although citation or reference analyses such as the first one by Gross and Gross (1927), conducted to optimize a college library's subscriptions by objective, quantitative methods, may be helpful to obtain an overview of the scholarly publication landscape, global citation rates may be insufficient to fulfill particular demands by librarians based on specific local requirements (Rousseau, 2002).

> Users of journals read, but many actually publish little or nothing at all. In this context, it is important to investigate the relation between in-house use and citation use. (Rousseau, 2002, p. 419)

Hence, indicators reflecting journal usage at the local institution are particularly important to librarians. Time-based metrics show obsolescence patterns of literature and are thus able to provide information about access to older volumes. As journal prices are crucial to librarians, cost-performance ratios are helpful to maximize purchase in terms of content received (Van Hooydonk, Gevaert, Milisproost, Van de Sompel, & Debackere, 1994; Mierzejewska, 2008).

Editors and Publishers

Journal editors and publishers seek to monitor journal performance from the scientific and economic perspective. Impact factors are regularly discussed at editorial board meetings (Craig & Ferguson, 2009). For editors it is important to analyze the extent to which the periodical is able to attract authors and readers in comparison to competing serials. While commercial publishers want to maximize revenues, non-profit publishers have to monitor financial sustainability.

> From a publisher's perspective, we are interested in pursuing activities which maximize the quality and visibility of our journals, ensuring they reach as many interested users as possible, and are attractive to potential authors seeking to publish their highest-quality research. To this end, scoring highly in various systems of ranking is crucially important to the long-term success of a journal. (Craig & Ferguson, 2009, p. 160)

It was Garfield (1972) who highlighted the potential use of journal citation analysis to editors:

> Editors and editorial boards of scientific and technical journals may also find citation analysis helpful. As it is, those who formulate editorial policies have few objective and timely measures of their success. A wrong policy, or a policy wrong implemented, may have serious effects on revenue and prestige, and the work of regaining readers and reputation can be difficult and expensive. (Garfield, 1972, p. 477 f.)

Besides citation analysis, which indirectly evaluates journal performance in terms of scholarly impact, other metrics such as the rejection rate or publication delay are able to reflect the editorial performance and journal management more directly. The rejection rate mirrors whether the journal is able to choose high-quality manuscripts from a large number of submissions, which increases its attractiveness for readers. Monitoring publication delay can be helpful to optimize the review process and thus guarantee fast publication to authors.

Optimizing such aspects of editorial management means attracting new authors and readers (Nisonger, 1999). Journal performance and rankings are used for advertising and marketing purposes by the publishers (Hecht, Hecht, & Sandberg, 1998; Craig & Ferguson, 2009). Since the impact factor has become a powerful tool which "will influence the future 'success' of [a] journal" (Favaloro, 2008, p. 8), editors and publishers are interested in monitoring the performance of their own titles and observing competitors.

1.3 Multidimensional Journal Evaluation

As journals reflect formal scholarly communication in the sciences and are influenced by many different factors, their evaluation should be multifaceted as well. Citation-based indicators are widely used by the different stakeholders of journal evaluation. However, they only tell a part of the story (Rowlands & Nicholas, 2007). In the following, a brief overview of previous studies of journal evaluation beyond the citation impact is given (section 1.3.1), before the multidimensional approach of this work is introduced and the structure of this book is outlined (section 1.3.2).

1.3.1 Inability of a Single Metric

Various authors have addressed the inability of a single metric to reflect a journal's impact and prestige and the need for a multidimensional approach to research evaluation in general and scholarly journals in particular (Rousseau, 2002; Van Leeuwen & Moed, 2002; Moed, 2005). Rousseau (2002) briefly reviews various aspects of journal evaluation including journal prices and usage and gives an overview of journal citation measures with a focus on different versions of the impact factor from a theoretical perspective. Glänzel and Moed (2002) provide a state-of-the-art report on citation-based journal metrics and Moed (2005) discusses journal citation indicators and explains shortcomings with practical examples.

These authors emphasize that a complex concept such as scholarly impact cannot be reflected by the average number of citations.

> [S]cholarly communication is a multi-phased process that is difficult to capture in citation statistics only. The scholarly cycle begins with the development of an idea, eventually resulting in its publication and subsequent citation. Citations only occur at the end of this cycle [. . .]. (Bollen, Van de Sompel, & Rodriguez, 2008, p. 231)

Moreover, complex structures and multiple aspects cannot be captured by one indicator, but should rather be represented by a range of metrics. Multiple indicators should be used to reflect the multifaceted notion of journal quality (Glänzel & Moed, 2002; Rousseau, 2002; Coleman, 2007). To preserve the multidimensionality information should not be conflated into one ranking.

> [I]t would not be wise to concentrate too strongly upon developing the single, 'perfect' measure. Journal performance is a multi-dimensional concept, and a journal's position in the scientific journal communication system has many aspects. It is questionable whether all dimensions can be properly expressed in one single index. A more productive approach is to develop and present a series of indicators for the various dimensions, and highlight their significance and limitations. (Moed, 2005, p. 105)

> [S]everal indicators rather than one are needed to provide users of bibliometric journal impact measures in their specific decision making processes with sufficient and valid information. (Van Leeuwen & Moed, 2002, p. 265)

Although there are some studies (e.g., Todorov and Glänzel (1988); Glänzel and Moed (2002); Rousseau (2002); Bonnevie-Nebelong (2006); Bollen, Van de Sompel, Hagberg, and Chute (2009)) which have listed a number of journal indicators, there is no comprehensive multidimensional analysis of all aspects applied to one set of journal indicators. Above all, the existing overviews address experts from the bibliometric community. Users of journal evaluation are confronted with an excessive number of new or renamed indicators. This book tries to solve the lack of transparency causing users to restrict themselves to the well-known and readily available but limited and flawed impact factor. Whether or not alternative and complementary indicators are used, depends above all on them being known and understood by potential users.

1.3.2 Multidimensionality

This work is built upon a conceptual definition of five dimensions reflecting all the factors which make up and influence scholarly periodicals. The concept is based on work by Grazia Colonia (2002), Stock (2004), Schlögl (2004), Schlögl and Stock (2004), Schlögl and Petschnig (2005) and Juchem, Schlögl, and Stock (2006). The five dimensions are journal output, journal content, journal perception and usage, journal citations and journal management. It is argued that in order to appropriately reflect the standing and impact of a journal in the scientific community, methods from all of these dimensions should be considered. Figure 1.2 provides a schematic representation of this conceptual approach. At this point, a brief overview of these five dimensions is given, while the following chapters describe these and related journal metrics in detail.

Journal Output

The dimension of journal output is concerned with the direct evaluation of the periodical in terms of its publication output. It includes an analysis of the journal size with regards to how much and what kind of content is published by whom each year. Possibilities of evaluating journal output are described in chapter 2.

Journal output can be analyzed in terms of the number of issues per year, documents per issue (section 2.1.1) or pages per document (section 2.1.2). Different types of publications serve different purposes. By examining the frequency of document types published, the journal's scope and aims can be distinguished (section 2.1.4). An analysis of the cited references listed in the documents published in a periodical can reveal the structure, diversity and age of its imported knowledge and its level of scholarliness (section 2.1.5). The language of published documents can be analyzed to reveal the national focus of authors and readers (section 2.1.6).

Journal output is shaped by the contributing authors. Authors represent the smallest level of aggregation of contributing units to be analyzed (section 2.2.1). The development from little science to big science describes the development from small to large groups of collaborating researchers which is reflected in an increasing number of co-authors per document. An analysis of unique authors publishing in a periodical reveals whether or not the journal is able to attract the most prestigious authors in the field. On the meso level, the same can be done for research institutions, which provide the infrastructure that is necessary to produce the results described in the publications (section 2.2.2). The highest, i.e. the macro, level of aggregating journal output is the country level (section 2.2.3). By evaluating the distribution of contributions per country, it is possible to determine the level of internationality of the particular journal.

Figure 1.2 Schematic representation of multidimensional journal evaluation.

Journal Content

The dimension of journal content represents the thematical scope of a periodical and the topics covered in its publications. Journals can cover a broad field of science and publish more general topics or focus on a specific area of research. Journal content is shaped by the contributing authors, on the one hand, and by editors and referees, on the other, who decide whether a submission fits the scope of the particular periodical.

Content analysis can reveal the specific topics dealt with in the journal. It helps readers to find the most suitable source of information to satisfy specific information needs. Authors can find out if the journal suffices as an adequate publication venue read by the target audience for their submission.

Various methods of subject indexing can help to analyze and depict journal content. Methods which can be used to reflect various aspects of journal content are described in detail in chapter 3. Section 3.1 provides the theoretical background of different indexing methods, i.e. classification systems and thesauri (section 3.1.1), author keywords (section 3.1.3), citation indexing (section 3.1.4), automatic indexing (section 3.1.5) and social tagging, which is introduced as a new approach to reflect the readers' point of view on journal content (section 3.1.6).

In section 3.2.1 and section 3.2.2, various methods of subject indexing are applied on the journal and article level, respectively. Since journal classification systems put entire journals into broad categories, they provide a general overview, which can help students to enter a new research field and librarians in collection management. Subject indexing on the document level is able to give a more detailed insight as to the particular topics covered by single articles. Aggregated on the journal level, frequency distributions of index terms assigned to single documents provide information about focus areas. If accumulated per year of publication, term frequencies highlight shifts of emphasis over time. Such a content trend analysis is described in section 3.3.

Content similarity can be discovered on the basis of common index terms or through methods of citation analysis such as bibliographic coupling and co-citation analysis through contextual relatedness of citing and cited literature. Journals are analyzed regarding content-based similarity in section 3.4.

Journal Perception and Usage

In order to reflect a journal's impact and prestige in the scientific community, an analysis of its readership is essential. The dimension of journal perception and usage thus focuses on the evaluation of the readers. This is described in chapter 4. In contrast to the dimension of journal citations, which is limited to the evaluation of journal usage by publishing readers only, it fully covers the whole readership including the pure, i.e. non-publishing, readers.

Reading statistics and reading behavior can be collected through reader surveys (section 4.1). Participants can be asked to rank journals by subjectively perceived importance, or which journals they read how frequently and how exhaustively. Moreover readers can be asked to indicate in how far journal content influences their work. Demographic data can provide information about the composition of the readership. Differences in reading behavior of particular groups can be discovered. Conducting reader surveys is, however, time consuming and depends on the participation of readers. It is limited regarding space and time and biased in terms of subjectivity.

Through electronic publishing it has become possible to monitor access to journal content and compute usage statistics based on log files (section 4.2). Almost simultaneously it can be evaluated which article is downloaded where and how many times. Provided that download and click rates indicate usage, reader-based journal usage can be monitored on the local (section 4.2.1) and global scale (section 4.2.2). While local download rates can help librarians to optimize collection management, global usage can help authors to submit their manuscript to the most suitable publication venue. In analogy to citation-based metrics, download indicators are able to reflect the journal's impact on its readership (section 4.2.3). Due to the lack of appropriate and comprehensive statistics of worldwide journal usage, social bookmarking services are introduced as an alternative source for article-based readership data in section 4.3.

Journal Citations

The dimension of journal citations is concerned with the part of formal scientific communication which is visible through citations received. A citation reflects that one source has influenced another. Citation impact is thus a way of measuring scholarly impact. Bibliometric indicators are based on the general assumption that the more citations a publication, an author or a journal receives, the greater is their influence in the scholarly community.

In terms of journal evaluation, the impact factor is the most widely used citation metric. Originally developed as an indicator which, as a ratio of the number of citations received by a journal and the papers published, was to identify the most important periodicals in a scholarly field to be covered by the SCI, it is now used and misused for research evaluation purposes. Although many problems exist concerning the impact factor's construction and methodology, which make it unsuitable to entirely reflect a journal's scholarly impact, the impact factor remains the most widely used journal indicator and other methods are often disregarded.

Chapter 5 describes and applies various indicators. A detailed analysis and comparison make it possible to discover the advantages and disadvantages of the measurements and individually combine different alternatives that best reflect scholarly impact in terms of citations.

There are a number of alternatives for indicating journal citation impact. Chapter 5 distinguishes between basic (section 5.1), weighted (section 5.2) and normalized (section 5.3) journal metrics. Some basic metrics are mean citation rates such as the impact factor, but which try to improve on some of its technical shortcomings by alternating the publication and citation windows or document types covered (section 5.1.1), while others evaluate the citation distributions instead of conflating the information to an arithmetic mean (section 5.1.2). Time-based indicators analyze citedness over time to reflect how long journal content stays relevant (section 5.1.4).

PageRank-like algorithms account for the prestige of the citing sources (see section 5.2) and citing-side normalization approaches such as the fractionally-counted impact factors aim to normalize discipline-specific citation behavior to allow cross-field comparisons (see section 5.3). Due to their complexity, these weighted and normalized approaches are, however, not used very often outside the bibliometric community.

Journal Management

The dimension of journal management subsumes all aspects associated with the management of scholarly journals by editors and publishers. Journal management involves general journal characteristics such as the publication history of a journal, its publisher affiliation and scope (section 6.1). While a long publishing tradition and the publisher can to a certain extent indicate the standing of the periodical in the scientific community, the scope can be regarded as a means of self portrayal trying to attract readers and authors.

Editors undertake the powerful function of the serial's gatekeepers who decide which content is published and which authors' manuscripts are rejected (section 6.2).

Analyzing the composition of the editorial board in terms of size (section 6.2.1) and nationalities represented (section 6.2.2) provides information about the quality of the gatekeeping process and the international influence of the journal.

By analyzing the process from submission to publication, the review process, which represents the quality control of published content, can be further examined (section 6.3). The time between submission and publication is known as publication delay and can be subdivided into the time for the review process and the phase from acceptance to publication that is caused by paper backlog, on the one hand, and the time to put together a journal issue, on the other. Although a thorough review process takes some time, authors and readers are interested that delays are kept to a minimum since they slow down the entire communication process. The length of the time from submission to publication can thus indicate the overall up-to-dateness of the periodical (section 6.3.2).

While the rejection rate indicates whether or not the journal is in a position to reject a certain proportion of submitted manuscripts and is thus able to publish only those of the highest quality (section 6.3.3), the correction rates identifies the share of errata published and can be used to estimate the thoroughness of the review process (section 6.3.4).

The business model and journal prices are addressed in section 6.4. As typical information goods, journals have high fixed and low variable costs. However, the journal market has atypical characteristics, since suppliers, i.e. authors, are not paid and buyers, i.e. readers, only pay indirectly through libraries and are thus isolated from the purchase (section 6.4.1). Two major forms of business models are the reader-pays model, where production costs are covered by subscriptions and pay-per-view, and open access, where the author pays publication fees so that the content can be provided free of charge (section 6.4.2). Journal subscription prices are analyzed in detail in section 6.4.3.

1.4 Case Study

In order to explain, apply and compare different indicators for each of the five dimensions, a set of journals is defined. Since scholarly communication processes vary between different fields and sub-fields of research, it is vital to choose periodicals from a narrow scientific field. There are different journal classification systems which could help to select a set of journals that are similar in terms of publication and citation behavior. However, none of these top-down approaches is perfect (compare section 3.2.1). Thus, a reference-based bottom-up approach was chosen. Due to the differences in publication and citation habits of different scientific disciplines, it is important that compared items are subject to similar processes or that differences in circumstances are compensated for (section 5.3). Since the majority of journal indicators do not apply normalization regarding discipline-specific differences of scholarly communication, the selected journals have to be similar in terms of publication and citation behavior. Since differences occur not only between disciplines but also between sub-disciplines, the area of solid state physics research was chosen.

The selection process consists of a reference analysis of the total number of documents published by researchers at the Institute of Solid State Research (IFF)[4] at Forschungszentrum Jülich between 2004 and 2008. The institute specialized in research into the physics of condensed matter. Its most prominent member is Peter Grünberg, who received the Nobel Prize in Physics in 2007 together with Albert Fert "for the discovery of Giant Magnetoresistance" (*The 2007 Nobel Prize in Physics – Press Release*, 2007). References were chosen as it is believed that these are more diverse and less biased. While an analysis based on publications is influenced by barriers such as manuscripts being rejected, referenced journals are used as sources of information without restrictions.

The main focus of the test set definition was not to analyze the publishing landscape of solid-state research but to select a number of similar journals to calculate journal metrics under realistic conditions. Hence, the test set does not claim to include the most important periodicals of the research field but emphasizes applicability and thus availabilty of data to compute journal metrics. Thus, certain thresholds were applied to narrow the preliminary periodicals to a set for which data was available. For comparable citation information, Thomson Reuters' citation indices were chosen as a database. From the journals referenced by the IFF researchers, non-ISI journals were hence excluded. In order to limit the set to core journals of solid state physics, infrequently cited, i.e. peripheral, periodicals were excluded. The initial set of referenced journals was thus further reduced to periodicals referenced at least 15 times by IFF authors from 2004 to 2008. To avoid the inclusion of multidisciplinary and interdisciplinary sources, the set of frequently cited serials was limited to those filed exclusively under DDC subject group 530 (Physics). The catalogue of the Zeitschriftendatenbank[5] (ZDB) was used to determine the DDC classification. Since electronic usage data plays a significant role in the evaluation of journal perception and usage in chapter 4, the journal set was further restricted to those titles for which local COUNTER statistics were available at Forschungszentrum Jülich.

The final test set of solid-state research journals consists of 45 periodicals. As this particular area of research is not restricted to publications in specialized solid-state serials but is present in broad physics journals as well (Pinski & Narin, 1976), the set under analysis includes both specialized and general physics journals. Bibliographic and citation data for the total number of 168,109 documents published in these 45 journals during a 5-year period between 2004 and 2008 was downloaded from WoS. This data provided the basis for the case studies.

Each of the following chapters investigates one of the five dimensions in detail. Starting with the dimension of journal output (chapter 2), various metrics will be applied to the set of 45 solid-state physics journals per dimension in order to gain comprehensive insight into the informative value, applicability and validity of the impact measures.

4 http://www2.fz-juelich.de/iff/e_iff

5 http://www.zeitschriftendatenbank.de/

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Chapter 2
Journal Output

Scientific output is increasing constantly. In scholarly publishing, growth can be observed in the number of researchers, institutions, publications and journals (Cope & Kalantzis, 2009). The increase in the number of periodicals is always accompanied by a specialization of scientific disciplines. New journals are founded in order to focus on a narrower area of research or one periodical is split into two more specialized ones. The latter is referred to as 'twigging' or 'parenting' and happened to one of the first scholarly journals Philosophical Transactions (compare section 1.1), when it was split into sections A and B in 1886 to focus on the physical and life sciences, respectively.[1] The set of 45 analyzed journals also contains a few 'sibling journals' derived from the same parent (see section 6.1.1), e.g. Phys Rev A, Phys Rev E and Rev Mod Phys, which together with Physical Review B, C, D and Physical Review Letters emerged from the Physical Review (see figure 6.2 in section 6.1.1) founded in 1893, "as the fields of physics proliferated and the number of submissions grew"[2].

Electronic publishing has also contributed to the increase in journal output by speeding up the processes of scholarly communication (Tenopir & King, 2009). It has not only lead to an increase in the number of periodicals with the introduction of purely electronic journals but has also led to growth in the number and length of documents.

As the first to put the increase in scientific output into numbers, Price (1963) estimated the number of scholarly journals in the 1960s and predicted that they would reach one million in the year 2000 as can be seen in his famous figure (figure 2.1) depicting the number of journals founded since 1665 (Price, 1975). Although his prediction has not come true, constant growth in number of titles can still be observed.

Determining the actual number of periodicals is, however, not as easy as it sounds. Estimates suggested as many as 80,000 periodicals in the 1990s (Meadows, 2000). Such high numbers, however, overestimate the quantity of scholarly journals because they include magazines and newsletters. As Mabe (2003) concludes, Ulrich's Periodicals Directory seems the most reliable source when it comes to determining the number of scholarly journals (Mabe, 2003; Tenopir & King, 2009). He evaluated the number of all titles classified as active (i.e. currently publishing), reviewed, scholarly journals from 1665 to 2001 and discovered an almost constant annual increase of 3.46% in the number of titles, which means that the number of active journals doubles every 20 years. Recent evaluations by Tenopir and King (2009) confirm these results and report a total of 23,973 refereed scholarly journals active in February 2008, which account for 38.9% of all 61,620 active titles listed in Ulrich's Periodicals Directory as scholarly or academic. The evaluation of journal output is, however, not restricted to the

1 http://rstl.royalsocietypublishing.org/
2 http://publish.aps.org/about

number of scholarly periodicals but examines differences in the number of publications, publication frequency (section 2.1.1), document length (section 2.1.2), differences in document types (section 2.1.4) and publication language (section 2.1.6). Number of references are analyzed (section 2.1.5) to determine the level of scholarliness and the journals' knowledge import. In section 2.2 the producers of journal output are examined on the micro, meso and macro level, i.e. authors, institutions and countries, in order to analyze the contributors of journal output and the internationality of the particular periodicals.

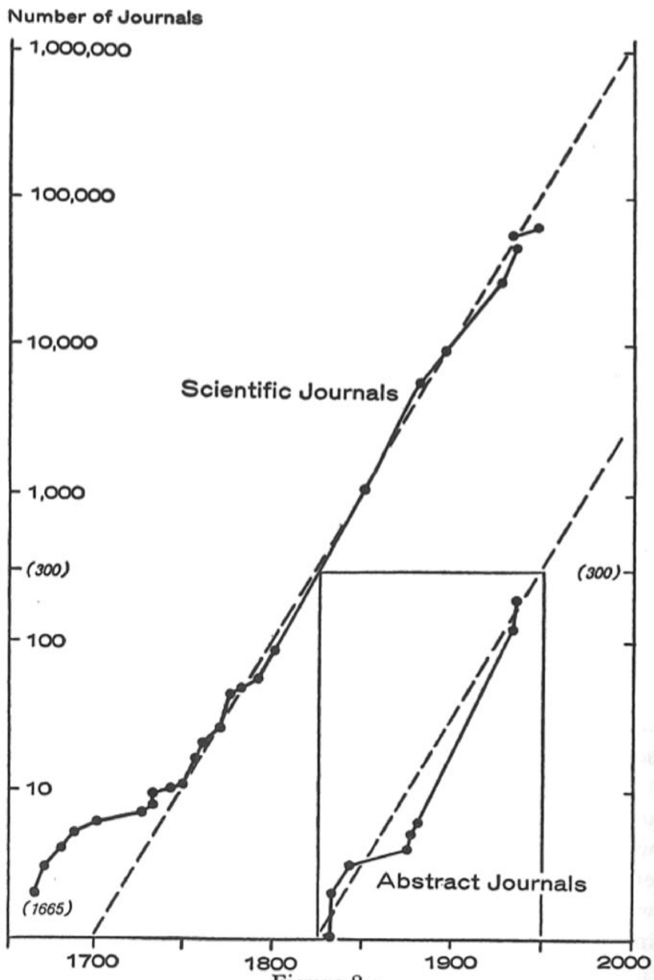

Figure 8.1
Number of journals founded (*not* surviving) as a function of date. The two uppermost points are taken from a slightly differently based list.

Figure 2.1 Analysis by Price (1975) of the number of journals founded per year. Source: Price (1975, p. 166).

2.1 Output Indicators

The most basic and commonly applied indicator in bibliometric studies is the number of publications *P*, which represents the absolute size of formally published research output. Variants of *P* include the disaggregation of or limitation to certain document types or normalization regarding length, number of references or co-authors.

P is usually accumulated over a particular period of time. It can be aggregated on the level of authors, institutions, countries or journals. The simplest but most time-consuming method to determine the number of published output of research is by manual aggregation, e.g. through author's CVs or table of contents of journal issues. Bibliographic databases allow for more convenient data collection but never contain all scholarly publications of all disciplines worldwide. The suitable data source is usually determined by the particular research question.

The set of journals under evaluation has been limited to periodicals covered by the WoS so that all data regarding journal output can be collected without difficulty. A total of 168,109 documents have been published in the 45 journals under analysis. The distribution among journals is, however, heavily skewed: journal output differs in terms of publication frequency, document length and type, scholarliness and producers of output. Therefore journals have to be analyzed in detail regarding output and normalization needs to be applied to allow for a suitable comparison of journal output.

2.1.1 Number of Issues and Documents

Besides the constant rise in the number of active periodicals, journal output has also grown with respect to the number of documents published per year and pages per document. Although the growth of scientific output reflects to a large extent progress in R&D, one can observe certain tendencies in publishing behavior, where the contribution to knowledge is taken to the point of absurdity:

> In physics there has been much discussion of the "least publishable unit" in which efforts are made to subdivide projects and expand personal bibliographies. (Abt, 1992, p. 445)

This phenomenon is known as 'salami slicing' or 'salami publishing', where researchers tend to split their results into many different publications and leave no thought unpublished in order to increase measurable output (Baggs, 2008; Cope & Kalantzis, 2009; Lifset, 2010). This publishing tactic has been criticized for creating redundant papers which do not contribute to scientific progress but waste valuable resources by adding to the flood of information (Spielmans, Biehn, & Sawrey, 2010). However, some have also argued in favor of publishing small units due to timeliness (Refinetti, 1990, 2011). On the one hand, reasons for salami publishing can be found in the author's wish to enlarge his or her publication output for evaluative purposes, to gain visibility and present results to a broad audience by using different publication venues (Buddemeier, 1981; Lifset, 2010). On the other hand, editors encourage least publishable units by limiting article length (Roth, 1981; Tzamaloukas, 2002).

During the five years under analysis the 45 journals published 168,109 documents. The number of publications per journal is highly skewed: with a total of 173 documents Rev Mod Phys generated the smallest output, while Appl Phys Let had 25,983 publications. Cope and Kalantzis (2009) do not only report an increase in the number of scholarly journals but discover that the average output per journal increases as well. Although the analyzed time span was limited to five years, an increase of overall output by 14.9% can be observed from 2004 to 2008 for all documents . While the number of documents was almost constant in 2004 and 2005 an increase can be registered in 2006 and a decrease in 2008 (figure 2.2).

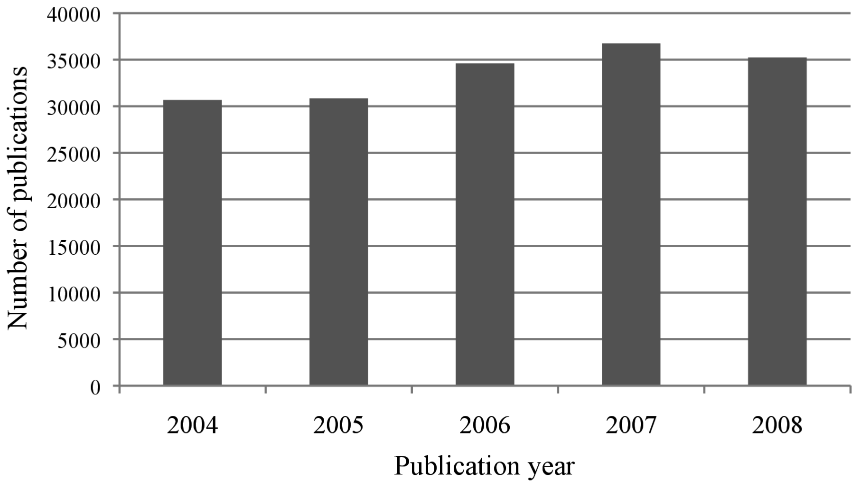

Figure 2.2 Number of publications per year in all 45 journals.

Annual growth rates differ considerable between the journals from 2004 to 2008. Comput Mater Sci, J Phys D, J Stat Mech, Nanotechnol and New J Phys more than doubled their annual output from 2004 to 2008. As the only journal founded during the period of analysis in 2005, Soft Matter started out in its founding year with only 58 documents and reached an output of 298 in 2008. In terms of growth from 2004 to 2008, the 45 journals can be divided into three groups: 18 periodicals which increased output over time (> +10% growth), 17 journals, which showed a large negative growth rate from 2004 to 2008 (> -10%) and 10 that showed only minor changes (+/-10%) of output (table 2.1). Although there are almost as many journals that showed a strong decrease in output in 2008 compared to 2004 as there were periodicals with positive growth rates, the latter showed much higher values. While J Magn Magn Mater was the journal that showed the highest decrease (-64.4%), there were seven journals that increased their output by more than two thirds of the initial number of documents published in 2008. Soft Matter, which was founded in 2005 showed the highest increase of output of 413.8% from 2005 to 2008, which is probably a phenomenon typical of newly founded periodicals.

Table 2.1 Total number of documents (P) from 2004 to 2008, publication frequency, i.e. number of issues per year and mean number of documents per issue.

Journal	***P***	**Issues per year**	**Mean number of *P* per issue**	**Growth rate of *P* from 2004 to 2008**
J Magn Magn Mater	7549	24	63	-64.4%
Physica C	3947	31	25	-54.1%
Phys Rep	341	60	1	-52.4%
Nucl Instrum Meth A	7670	42	37	-48.7%
J Vac Sci Technol A	1580	6	53	-44.4%
Ann Phys	296	12	5	-34.1%
Supercond Sci Technol	1685	12	28	-29.5%
Hyperfine Interact	1006	28	7	-26.5%
Phys Stat Sol B	2691	12	45	-25.1%
Solid State Ion	2270	24	19	-19.1%
Nucl Instrum Meth B	5973	22	54	-18.8%
Rep Prog Phys	220	12	4	-18.6%
Act Cryst A	326	6	11	-17.2%
Pramana	1258	12	21	-16.0%
J Rheol	347	6	12	-15.2%
J Stat Phys	1049	12	17	-10.1%
Appl Phys A	2685	12	45	-10.1%
Phys Today	1780	12	30	-7.3%
Phys Stat Sol A	2721	15	36	-6.0%
Phys Solid State	1970	12	33	-5.0%
Phys Scr	2543	15	34	-2.1%
Eur Phys J E	707	12	12	+2.2%
Act Cryst B	493	6	16	+2.3%
Phys Rev E	12117	12	202	+2.8%
Phys Fluids	2702	12	45	+5.9%
JETP Lett	1487	24	12	+6.2%
Eur Phys J B	2056	24	17	+6.7%
Physica B	5561	24	46	+18.5%
J Phys A	5244	50	21	+20.9%
J Phys Condens Matter	7427	50	30	+22.9%
J Low Temp Phys	1260	12	21	+24.8%
Rev Mod Phys	173	4	9	+32.3%
Phys Lett A	5328	52	20	+41.7%
Int J Thermophys	757	6	25	+44.0%
Appl Phys Let	25983	52	100	+46.5%
Phys Rev A	11027	12	184	+48.7%
EPL	3291	24	27	+52.1%
J Appl Phys	17827	24	149	+55.4%
IEEE Nanotechnol	519	4	26	+67.6%
Comput Mater Sci	1299	12	22	+140.5%
J Phys D	4554	24	38	+171.6%
J Stat Mech	958	12	16	+175.0%
Nanotechnol	4852	50	19	+206.5%

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Journal	P	Issues per year	Mean number of P per issue	Growth rate of P from 2004 to 2008
New J Phys	1926	22	18	+236.5%
Soft Matter	654	12	14	+413.8%

Apart from the size of annual output, periodicals also differ in frequency of issues per year. Publication frequency ranges from four issues per year (IEEE Nanotechnol and Rev Mod Phys) to more than one issue per week (Phys Rep). The most common frequency of publication is, however, monthly. 17 journals appear once a month, 8 every other month and 5 twice a month. The advantage of high frequency publication is its speediness. The time from acceptance (i.e. after successfully passing the review process) is not artificially prolonged, but information is passed on to the reader as soon as possible.

In times of electronic publishing, journals do, however, make preprints available online before the actual publication date. These 'online first' versions eliminate delays and reduce the importance of the actual publication of journal issues. Output statistics are, however, still based on the documents which are actually published. Regardless of the publication format, i.e. print, electronic or both, publication counts rely on the year of publication as determined by the particular volume and issue of the journal (Meier, 2002). So a document which was published online in October 2007 but appeared in the January issue of 2008 will be counted for 2008. The publication delay, i.e. the period between online availability and actual publication date, is evaluated in section 6.3.2.

2.1.2 Document Length

One can argue that the number of publications is a somewhat arbitrary measurement because a document can vary in length from one to several dozens or even hundreds of pages. Apart from number of documents, number of pages can also be the unit for measuring journal output.

Differences of average paper length can be observed between fields of science, i.e. an average medical journal publications has 4.6 pages, while an article in mathematics is on average 12.6 pages long (Abt, 1992). Of course, differences can also be observed within disciplines and even within one periodical. This variations can be explained by different kinds and aims of documents, e.g. research article, review, editorial or short communication (compare section 2.1.4).

It can be argued that counting pages is a measure of output as arbitrary as counting publications because even the content printed on one page can vary to a certain extent as well. An average mathematical journal publication is reported to contain 510 words while a document in an astrophysical periodical contains 1190 words on average (Abt, 1992). These differences do, however, not only occur between disciplines but, influenced by formatting, page length varies from one journal to another as well. This argumentation can be taken ad absurdum: should one count words or even letters? How is non-textual material to be treated? How are figures and tables to be weighted? Due to these problems page counts seem the best alternative especially because these statistics do not have to be elaborately extracted from the full text but – on the basis of the first and last page – are already available through the bibliographic information of the particular documents.

For the 168,109 documents published in the 45 journals between 2004 and 2008 the mean article was 6.9 (median = 5) pages long with a large deviation (standard deviation = 6.97). The longest publication contained 431 pages and was a review about boost-phase intercept systems for missile defense published in Rev Mod Phys in 2004 by a group of twelve authors from ten US institutions. It has not been cited.

Table 2.2 Mean, median and maximum number of pages per document and standard deviation per year.

Publication year	**Mean**	**Median**	**Max.**	**Std. dev.**
2004	7.0	5	431	7.67
2005	7.2	6	387	7.90
2006	6.7	5	312	6.96
2007	6.8	5	202	6.38
2008	6.8	5	241	5.99
all years	*6.9*	*5*	*431*	*6.97*

Due to the above-mentioned differences, the values for article length differ between journals. Cope and Kalantzis (2009) and Tenopir and King (2009) report an 80% growth in document length from 1975 to 2007 due to the need to manage the flood of information. The average length of documents published in the 45 journals between 2004 and 2008 did not increase during the five years but stayed almost constant, as can be seen in table 2.2.

A low maximum number of pages and standard deviation characterize typical letter journals: for Appl Phys Let, EPL and JETP Lett article length did not exceed 4, 7 and 12 pages, respectively. Publications were longest for Phys Rep, Rep Prog Phys and Rev Mod Phys. High mean, median and maximum page numbers and high values of standard deviation characterize them as typical review journals. The median number of pages of a document published in Phys Today is only 2 pages. This can be explained by the large number of news items published in Phys Today.

The number of pages per journal correlates highly positively with the number of documents published (Pearson's $r = 0.836$), figure 2.3 does, however, reveal differences for particular journals. Appl Phys Let, which is the journal with the largest output based on number of documents ($P = 25,983$), does not publish articles longer than four pages and is thus placed behind J Phys Condens Matter, which published 7,427 documents with an average of 9 pages. With a median of 63 pages, Phys Rep publishes the longest documents and is thus ranked 17th if output is based on pages, while it is 41st in terms of document count (figure 2.3).

Table 2.3 Total number of pages ($\sum$) and mean, median, maximum (Max.) and standard deviation (Std. dev.) of pages per document by journal.

Journal	$\sum$	**Mean**	**Median**	**Max.**	**Std. dev.**
Phys Today	4,166	2.34	2	125	4.224
Appl Phys Let	76,984	2.96	3	4	0.248
J Magn Magn Mater	26,450	4.43	4	48	2.781

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Journal	∑	Mean	Median	Max.	Std. dev.
Physica B	18,558	4.76	4	23	2.437
Physica C	33,422	4.70	4	41	2.472
Appl Phys A	6,914	5.47	5	30	2.079
J Appl Phys	10,002	5.86	5	103	2.952
JETP Lett	14,686	4.65	5	12	1.223
Nucl Instrum Meth A	34,507	6.60	5	82	4.620
Nucl Instrum Meth B	18,061	5.78	5	32	2.544
Phys Scr	13,574	5.34	5	48	2.972
Phys Stat Sol B	50,650	6.71	5	47	3.915
Supercond Sci Technol	104,500	5.94	5	27	2.563
EPL	19,766	6.01	6	7	1.202
Hyperfine Interact	32,930	7.00	6	48	3.489
IEEE Nanotechnol	13,994	6.70	6	21	2.673
J Low Temp Phys	3,475	9.61	6	81	7.811
J Phys D	30,383	7.22	6	49	3.803
J Vac Sci Technol A	9,593	6.07	6	30	2.495
Nanotechnol	11,646	6.26	6	23	2.124
Phys Lett A	7,037	6.18	6	19	2.325
Phys Solid State	32,864	5.91	6	36	2.456
Phys Stat Sol A	17,187	6.32	6	56	3.366
Solid State Ion	12,114	6.16	6	20	2.309
Comput Mater Sci	5,011	8.00	7	33	3.456
Eur Phys J B	10,391	7.64	7	39	3.579
Phys Rev A	15,707	7.44	7	42	3.959
Soft Matter	82,063	7.66	7	28	3.674
Act Cryst A	2,743	8.41	8	23	4.132
Act Cryst B	6,315	8.74	8	43	3.752
Eur Phys J E	4,310	8.93	8	29	3.741
Phys Rev E	98,723	8.15	8	43	4.116
J Phys Condens Matter	11,543	10.65	9	103	6.418
Pramana	79,097	9.18	9	31	4.541
Phys Fluids	27,951	10.34	10	34	5.246
Ann Phys	4,021	13.58	11	147	13.574
Int J Thermophys	10,130	13.38	12	49	5.723
J Phys A	72,463	13.82	12	109	8.278
New J Phys	30,504	15.84	14	89	7.818
J Stat Mech	18,333	19.14	16	102	10.821
J Rheol	6,574	18.95	18	70	7.211
J Stat Phys	26,067	24.85	22	161	15.513
Rev Mod Phys	7,701	44.51	48	431	37.198
Rep Prog Phys	11,790	53.59	51	269	30.639
Phys Rep	25,008	73.34	63	387	56.131

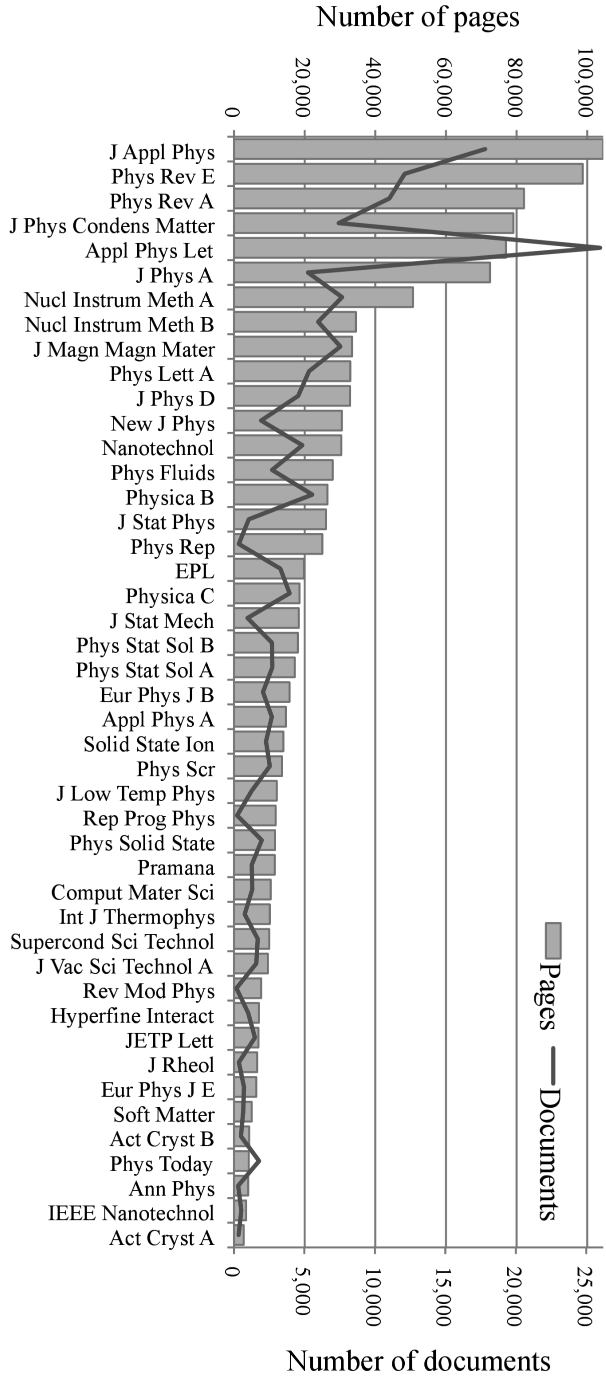

Figure 2.3 Differences in journal output based on document and page count.

2.1.3 Document Titles

A number of studies have focused on the structure of the titles of documents as they are the most important factor to attract readers.

> [I]n order to gain the required and desired attention amongst the scientific recipients, there are a number of conceivable mechanisms that can be employed. One such mechanism comes from classical marketing and advertising and consists of choosing an attractive, attention-grabbing heading. (Ball, 2009, p. 668)

Studies on article titles examine title length in relation to the number of co-authors (Kuch, 1978) and document length (Yitzhaki, 2002) or evaluate the usage of special characters such as question marks (Ball, 2009), hyphens, parantheses or colons (Hartley, 2007; Buter & Van Raan, 2011). Most studies aim to analyze title structures with regards to information retrieval and expected citation impact in order to make recommendations for authors to improve visibility through a specific phrasing of titles. Sagi and Yechiam (2008) examined the degree of amusement of titles of documents published in two psychological journals and showed that the most amusing titles were cited significantly less than average.

Buter and Van Raan (2011) showed that for a 5% sample of documents published between 1999 and 2008 listed in WoS, the most frequently used non-alphanumerical characters were hyphen, colon and comma, followed by parantheses and semicolon. In contrast to previous findings they found that the share of documents with at least one non-alphanumerical character in the title remains almost constant (66% to 68%) over the ten years analyzed and that the effect of using them in terms of citation impact depends on the discipline. While in clinical medicine documents with non-alphanumeric characters in the title have a higher citation impact compared to those without, the effect is reversed for biological publications.

2.1.4 Document Types

Journals publish different kinds of documents. Document types primarily vary in terms of purpose, which entails diversity in length, number of references and authors. The main distinction with respect to purpose can be made between documents presenting and discussing new research results (i.e. articles, proceedings papers, letters), documents reviewing and summarizing previous research (i.e. reviews, literature reviews, bibliographies) and news related items rounding off the journal's contents, which are usually written by journal editors and in-house authors (i.e. editorial material, news items, biographical material).

Table 2.4 shows the eleven different types that occurred in the 45 journals as labeled by WoS . The number of documents *P* emphasizes the skewness of their occurrence. The research article is by far the most important document type: 76.2% of all publications are classified as 'article', followed by 'proceedings paper' with 19.7%. 'Review' (1.1%), 'editorial material' (1.0%), 'corrections' (0.9%) and 'letters' (0.6%) play only a secondary role in terms of publication count. The other five document types, i.e. biographical and news items, reprints, bibliographies and book reviews, can be largely disregarded, since together they merely comprise 0.4% of the total.

Table 2.4 Differences of document length between document types: number of publications (P), total number of pages ($\sum$) and mean, median, minimum, maximum and standard deviation (Std. dev.) of number of pages per document type.

Document type	**P**	$\sum$	**Mean**	**Median**	**Min.**	**Max.**	**Std. dev.**
Article	128131	906982	7.1	6	1	161	5.08
Bibliography	3	84	28.0	33	3	48	22.91
Biographical Item	341	879	2.6	2	1	29	2.58
Book Review	3	6	2.0	2	2	2	0.00
Correction	1513	1851	1.2	1	1	23	1.20
Editorial Material	1721	3804	2.2	2	1	29	1.67
Letter	1067	2388	2.2	2	1	12	1.81
News Item	322	583	1.8	2	1	6	0.82
Proceedings Paper	33175	173472	5.2	5	1	64	3.20
Reprint	8	47	5.9	5	1	17	5.06
Review	1825	69812	38.3	26	3	431	36.98

Moreover, table 2.4 shows significant differences between the publication types in terms of document length. Due to their lengths review articles increased in influence: they account for 6.0% of output in terms of page count as opposed to 1.1% in terms of publication count. Proceedings papers, on the contrary, are less influential if journal output evaluation is based on the number of pages. The median of five pages per document shows that the length of proceedings papers is often limited. The value of 64 pages thus seems rather unusual for a document that appeared in conference proceedings. As the page count depends on the beginning and end page of the particular document as listed in WoS, inconsistencies (i.e. typing errors in the bibliographic data) can cause erroneous page counts. The median number of pages per document can thus be regarded as a more reliable measure since it is not affected by outliers.

As mentioned in section 2.1.2, the longest review article does indeed contain 431 pages. With 26 pages, the median length of reviews is significantly higher than that of any other document type. This divergence can be explained by the intended purpose of a review: it functions as a summary of a whole area of research and thus needs to consider a large number of published results. Due to their overview function, review articles address a particular large audience and are thus often heavily and in comparison to other document types more frequently cited (Moed, Van Leeuwen, & Reedijk, 1996). Garfield underlined the importance of reviews by comparing them to “an important opinion rendered by the chief justice of the Supreme Court” (Garfield, 1987, p. 5).

Although reviews do play an important role when it comes to reaching paradigmatic consensus, it is problematic to compare them directly with articles and proceedings papers, which contain new research results and thus contribute to the further advancement of science and the knowledge base. Since basic citation indicators like the impact factor do not further differentiate between the share of document types, they always rank review journals higher than periodicals that primarily publish research articles (Moed et al., 1996; Bensman, 2007; Craig & Ferguson, 2009). For a detailed comparison of citation indicators refer to chapter 5.

The 45 journals differ regarding their particular shares of types of publications. Through the analysis of document type distributions, one can distinguish different kinds of journals. Although only 0.2% of all 168,109 documents were classified as news items, Phys Today published almost all of them: 16.4% of its 1,780 publications belonged to this category. Phys Today thus differs to a great extent from the other journals.

Table 2.5 Percentage of document types per journal by page count. ”Others” includes Bibliography, Biographical Item, Book Review, Correction, Editorial Material, Letter, News Item and Reprint.

Journal	**Article**	**Proceedings Paper**	**Review**	**Others**
Appl Phys Let	99.3	0.0	0.0	0.7
EPL	99.3	0.0	0.0	0.7
JETP Lett	99.2	0.0	0.1	0.7
Phys Lett A	99.0	0.1	0.1	0.8
Phys Rev A	98.5	0.0	0.7	0.8
Phys Rev E	98.4	0.0	1.0	0.6
J Rheol	97.8	0.6	1.1	0.5
Phys Fluids	97.1	1.7	0.1	1.2
Act Cryst B	96.4	0.2	3.2	0.3
New J Phys	96.1	0.0	3.9	0.0
J Stat Mech	95.9	0.1	2.7	1.3
Appl Phys A	95.9	3.6	0.4	0.1
Eur Phys J B	95.7	3.0	0.9	0.4
Eur Phys J E	94.0	3.1	1.3	1.6
J Stat Phys	93.0	5.1	1.7	0.2
Nanotechnol	92.2	6.8	0.7	0.3
J Appl Phys	91.2	7.1	1.5	0.2
Phys Solid State	90.0	8.2	1.6	0.1
Act Cryst A	87.3	4.9	6.9	1.0
J Phys A	86.6	8.9	4.0	0.5
J Phys D	82.2	8.9	8.4	0.5
IEEE Nanotechnol	81.4	16.8	1.1	0.8
Ann Phys	81.2	6.7	8.2	3.9
Supercond Sci Technol	71.6	23.6	4.4	0.4
Comput Mater Sci	71.1	27.9	0.3	0.8
J Phys Condens Matter	70.5	18.9	10.0	0.7
Soft Matter	70.1	0.0	28.1	1.8
Phys Scr	69.3	28.4	0.7	1.6
J Vac Sci Technol A	59.6	37.9	1.8	0.7
Solid State Ion	59.5	38.9	1.4	0.3
J Magn Magn Mater	58.2	39.6	1.1	1.1
Int J Thermophys	55.7	42.5	1.5	0.2
Physica B	53.6	45.2	0.9	0.3
Nucl Instrum Meth A	53.1	45.4	0.8	0.7
Phys Stat Sol B	51.6	43.2	4.5	0.7
Pramana	51.6	47.2	0.4	0.8

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Journal	Article	Proceedings Paper	Review	Others
Hyperfine Interact	51.2	47.1	0.7	1.1
Phys Stat Sol A	49.3	47.7	2.3	0.6
J Low Temp Phys	48.4	47.5	3.4	0.7
Physica C	36.8	61.5	1.5	0.2
Nucl Instrum Meth B	35.2	63.6	0.5	0.7
Phys Today	33.1	0.3	0.0	66.6
Rev Mod Phys	6.3	0.0	92.8	0.9
Rep Prog Phys	0.1	0.0	99.7	0.2
Phys Rep	0.0	0.2	99.6	0.2
all documents	*78.2*	*15.0*	*6.0*	*0.8*

Due to the differences in document length of the different kinds of publication, the distribution of document types within a journal should be examined based on page instead of document count. Based on page count the journals' focuses can be defined in terms of document type. Table 2.5 lists the percentage of document types by page count (i.e. sum of pages) for all 45 journals. All journals with more than 60% of all pages listed as 'article' are thus referred to as research journals. This applies to 28 journals from EPL and Appl Phys Let (both 99.3%) to Phys Scr (69.3%). Nucl Instrum Meth B and Physica C are dominated by proceedings papers, while 11 journals focus on both research articles and proceedings papers (i.e. J Vac Sci Technol A, Solid State Ion, J Magn Magn Mater, Int J Thermophys, Physica B, Nucl Instrum Meth A, Phys Stat Sol B, Pramana, Hyperfine Interact, Phys Stat Sol A and J Low Temp Phys). Rep Prog Phys, Phys Rep and Rev Mod Phys can be clearly identified as review journals, since more than 90% of their content is defined as review papers if based on page count. Phys Today stands out because it publishes a considerable share of five different document types: 33.1% articles, 21.1% letters, 19.1% editorials, 13.2% news and 12.3% biographical items.

The analysis of document types also shows that journal names can be misleading in terms of their actual scope and coverage: despite their titles Phys Rev A and Phys Rev E are not review journals. The same applies to geographical names: Appl Phys Let is no less international than Int J Thermophys (compare section 2.2.3). Carrying an 'international' in its title can be an attempt to hide a national focus, while on the contrary a number of truely international journals exist, which are labeled 'American Journal of' (Zsindely, Schubert, & Braun, 1982; Braun, 2004).

2.1.5 References

Reference analysis examines the information sources used by a journal as a foundation for producing new output. Where information comes from can be determined. For example, which journals are frequently cited or whether knowledge is imported from other disciplines. A high self-reference rate indicates isolation of the journal in the field (Bonnevie-Nebelong, 2006). The number of references per publication can measure the level of scholarliness of the published content (Price, 1970). Citing half-life (Burton & Kebler, 1960) and the Price index (Price, 1970) measure the currentness of the literature used and analyzing the cited sources can shed light on the degree of the diversity regarding the journals' knowledge bases (Bonnevie-Nebelong, 2006).

References per Article

Price (1970) introduced the number of references per publication as a measure of its scholarliness. He argued that the number of sources a document cites indicates how well researched it is and defined ten references as a criterion to separate unscholarly from scholarly papers and labeled documents with more than 20 references as a review (Vastag & Montabon, 2002). Lipetz (1999) proposed updating the thresholds according to publication growth.

Table 2.6 Basic statistics for number of references per document type

Document type	P	Mean	Median	Min.	Max.	Std. dev.
Article	128131	24.9	22	0	301	13.54
Bibliography[3]	3	0.0	0	0	0	0.00
Biographical Item	341	0.6	0	0	31	2.02
Book Review	3	1.0	1	1	1	0.00
Correction	1513	1.8	1	1	106	4.45
Editorial Material	1721	4.8	1	0	197	10.13
Letter	1067	5.5	2	0	58	8.36
News Item	322	0.2	0	0	8	0.78
Proceedings Paper	33175	15.2	12	0	448	13.48
Reprint	8	10.3	2.5	0	64	21.89
Review	1825	164.2	123	3	1289	137.83
all documents	168109	23.8	20	0	1289	25.01

Differences of number of references between document types can be seen in table 2.6, which displays the mean, median, minimum and maximum and standard deviation for number of references for each of the 168,109 publications. There are large differences between the average number of references of document types. As to be expected, the median number of references is highest for review articles (123). Proceedings papers on average cite 12 and articles 22 references. It is however hard to differentiate between document types on the basis of references alone. Defining a value that automatically classifies documents by number of references is impossible: there are articles with more than 100 references and there are reviews listing as few as 3 sources (table 2.6). A dictionary definition of scholarliness by Diodato (1994) refers to the approach by Price (1970) as:

> [a] characterization of how well researched a document is. Scholarliness can be quantified as the number of citations that the document lists in its footnotes or list of references. (Diodato, 1994, p. 142)

Due to the considerable overlap between different document types, a reference count with absolute numbers does not solve the problem of determining a periodical's level of scholarliness. Windsor and Windsor (1973) simply differentiate between documents with or without references:

3 Counterintuitively the number references of documents labeled 'bibliography' is 0. Although bibliographies contain only of cited references, the WoS does not formally count these as such.

> The ratio of papers without references to those with references is proposed as a measure of the scholarly status of a field. (Windsor & Windsor, 1973, p. 381)

This can be used to determine journals with a large number of unscholarly publications. In order to determine the level of scholarliness of a journal, the median number of references per page is applied. The normalization of references by number of document pages balances differences between long and short papers. The median of the size-normalized reference count is 4.7 for reviews, 3.9 for articles and 3.0 for proceedings papers with much lower values of standard deviation. Thus, normalization helps to reduce differences in document types: short research papers do not appear less scientific in contrast to long review papers and distributions of references are less skewed.

Table 2.7 Percent of documents without references and median of number of references per pages indicating scholarliness of journal.

Journal	**Documents without references**	**Median of references per page**
Appl Phys Let	0.1%	5.7
Soft Matter	1.1%	5.6
Rev Mod Phys	2.9%	5.4
Nanotechnol	0.8%	4.5
Phys Rev A	0.2%	4.1
J Appl Phys	0.2%	4.1
Phys Scr	2.0%	4.0
Eur Phys J B	0.5%	4.0
Appl Phys A	0.2%	4.0
EPL	0.1%	3.8
Phys Rev E	0.0%	3.8
Phys Lett A	0.1%	3.7
J Phys D	0.7%	3.7
Rep Prog Phys	0.9%	3.7
Eur Phys J E	0.7%	3.6
J Vac Sci Technol A	0.6%	3.6
JETP Lett	0.1%	3.6
Act Cryst B	0.0%	3.5
Act Cryst A	1.8%	3.4
Supercond Sci Technol	1.1%	3.4
Solid State Ion	0.7%	3.4
IEEE Nanotechnol	2.1%	3.1
Physica B	0.6%	3.1
Phys Stat Sol B	1.4%	3.0
J Phys Condens Matter	1.4%	3.0
Physica C	0.8%	3.0
Comput Mater Sci	1.1%	2.9
Phys Solid State	0.0%	2.8
Phys Stat Sol A	1.2%	2.8
Phys Rep	2.9%	2.8
Nucl Instrum Meth B	1.1%	2.8
J Magn Magn Mater	0.3%	2.7

continued on next page

Journal	Documents without references	Median of references per page
Phys Fluids	0.7%	2.6
Ann Phys	6.1%	2.4
New J Phys	0.0%	2.3
Pramana	3.3%	2.0
J Phys A	0.5%	1.9
J Rheol	0.9%	1.8
J Low Temp Phys	1.7%	1.8
J Stat Mech	0.1%	1.8
Hyperfine Interact	1.9%	1.8
Nucl Instrum Meth A	1.6%	1.8
Int J Thermophys	0.7%	1.3
J Stat Phys	1.5%	1.1
Phys Today	54.7%	0.0
all documents	*1.1%*	*3.6*

Table 2.7 lists the results of the percentage of unscholarly publications according to Windsor and Windsor (1973) plus the size-normalized reference count to indicate the level of scholarliness for each of the 45 journals. 1.1%, i.e. 1,921 of all analyzed documents did not contain any references and are thus defined as unscholarly according to Windsor and Windsor (1973). The normalized indicator, i.e. the median number of references per page was 3.6. Both measures show a low negative Pearson correlation of $r = -0.432$, which indicates that periodicals can contain unscholarly publications, while the research papers show a high level of scholarliness. While Act Cryst B, New J Phys, Phys Rev E and Phys Solid State did not publish any documents without references, Phys Today stands out with 54.7% of documents that did not cite any sources. Phys Today thus qualifies as a rather non-scholarly journal, as was already indicated by the distribution of document types in section 2.1.4. For more than half of the journals the percentage of documents without references was below 1%. Scholarliness is highest for Appl Phys Let, where the median number of references per page was 5.7. It is followed by Soft Matter (5.6) and Rev Mod Phys (5.4). J Stat Mech publications on the other hand cited only 1.8 sources per page, although only one out of 958 documents did not list any references.

Reference Age

The age of a journal's cited literature can indicate the up-to-dateness of the informational resources. Citing half-life and the Price index are indicators used to measure the age of references.

Burton and Kebler (1960) introduced literature half-life analogous to radioactive half-life to examine the age distribution of cited articles and thus obsolescence of scholarly literature. Citing half-life as listed in the JCR[4] is a synchronous approach, which evaluates the age distribution of all reference in the particular year under analysis and determines the number of years from the current year backwards to the year where 50% of all cited references were published (Burton & Kebler, 1960; Diodato, 1994;

4 http://admin-apps.isiknowledge.com/JCR/help/h_ctghl.htm#jcrnlc

Egghe & Rousseau, 2000). The citing half-life $T_{\frac{1}{2}}^{\text{citing}}$ of journal j in the year t is thus defined as

$$T_{\frac{1}{2}}^{\text{citing}}(j,t) = y + \frac{(a-b)}{(c-b)} \tag{2.1}$$

where a is half of the number of references in year analyzed t, y is the number of years from t to the subcritical year, i.e. the year before the critical year, which is the year up to which half of all references (a) were published. b is the accumulated number of references published between t and the subcritical year and c is the accumulated number of references published between t and the critical year.

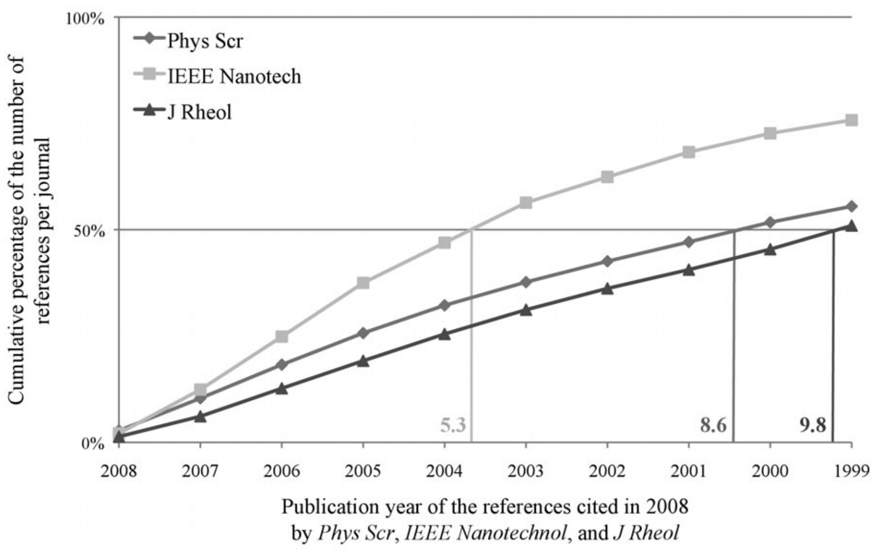

Figure 2.4 Cumulative percentage of cited references and citing half-life values for IEEE Nanotechnol, J Rheol and Phys Scr in 2008. Perpendicular line marks median age of cited articles, i.e. citing half-life.

Figure 2.4 displays the cumulative percentages of references cited by IEEE Nanotechnol, J Rheol and Phys Scr in 2008 in reverse chronological order by publication year of the referenced articles. The perpendicular lines mark the point in time when the cumulative percentage reaches 50% and marks the citing half-life value for the journals in 2008. For example, the citing half-life for Phys Scr was 8.6 in 2008, which means that half of the source articles cited by Phys Scr in 2008 were no older than 8.6 years, i.e. published in and after 2001.

Burton and Kebler (1960) conclude that rapidly changing literature, i.e. short half-lives, indicates changes of interests and/or techniques, but they also note differences between and within fields of research:

> It is possible that the periodical literature of a subject field is similarly composed of two or more distinct types of literature each having its own half-life. There is, for example, in most fields, a body of literature which is referred to as the

> classic literature. Presumably this classic literature has a relatively longer half-life than so-called ephemeral literature such as is found in weekly news publications. (Burton & Kebler, 1960, p. 20)

Stock (1980) observed that literature obsolescence is not a steady process such as radioactive decay so that it could be helpful to observe not only the median age of references but also further percentiles as well. The ratio between the specific half lives such as the 50^{th} and the 75^{th} percentile can be analyzed to indicate delays and acceleration of the particular obsolescence periods.

The citing half-life values for 2008 for the 45 analyzed journals are displayed in figure 2.5, which also includes the number of unique journals cited in the particular year. Since the JCR displays the age distribution of the references only for ten years, a citing half-life above 10 cannot be determined based on JCR data. This applies to seven journals, namely Phys Rep, Phys Fluids, J Stat Phys, Pramana, Phys Solid State, Act Cryst A and Ann Phys. The shortest half-life is 5.1 and represented by Appl Phys Let, which can be explained by the timeliness of the topics discussed in this typical letter journal. IEEE Nanotechnol and Nanotechnol both have a citing half-life of 5.3 years, which is typical of nanotechnology literature.

Citing half-life shows low negative correlations (Pearson's $r = -0.341$) with journal scholarliness as measured by the median number of references per page, which indicates a tendency towards the phenomenon that the more references are included in a document, the younger they are. If articles contain only a small number of references, they seem to cover the classical literature. An extensive reference list covers a large number of recent publications. No correlation can be found between citing half-life and journal self-reference rate ($r = 0.016$).

Another indicator which examines the age of cited references is the Price index. Price (1970) introduced it as a measure of the 'hardness' of science and analyzes the percentage of younger, i.e. less than 5-year old, references in contrast to all references cited by a journal during one year. From a study of 162 journals, he concluded that the Price index was able to distinguish between hard science, soft science and nonscience. Physics and biochemistry journals topped the scale with values between 60% and 70%. Moed (1989) proposed to measure the Price index on the article level to account for differences between the documents published in a journal.

Cited Sources

As depicted in figure 2.5, the 45 periodicals differ regarding the number of unique journals they cite, which can indicate a difference in diversity or specialization of the information sources. Since the number of cited journals depends on the total number of references, normalization is needed to further examine the structure of the sources a particular journal cites. Bonnevie-Nebelong (2006) introduced the analysis of the journal citation identity by the citations/citee-ratio, which divides the total number of references by the number of unique source journals:

> If the set contains many different journals, the ratio will be lower. Consequently a low average signifies a greater diversity in the use of journals among the authors as part of their scientific base, and thus a wider horizon. (Bonnevie-Nebelong, 2006, p. 411 f.)

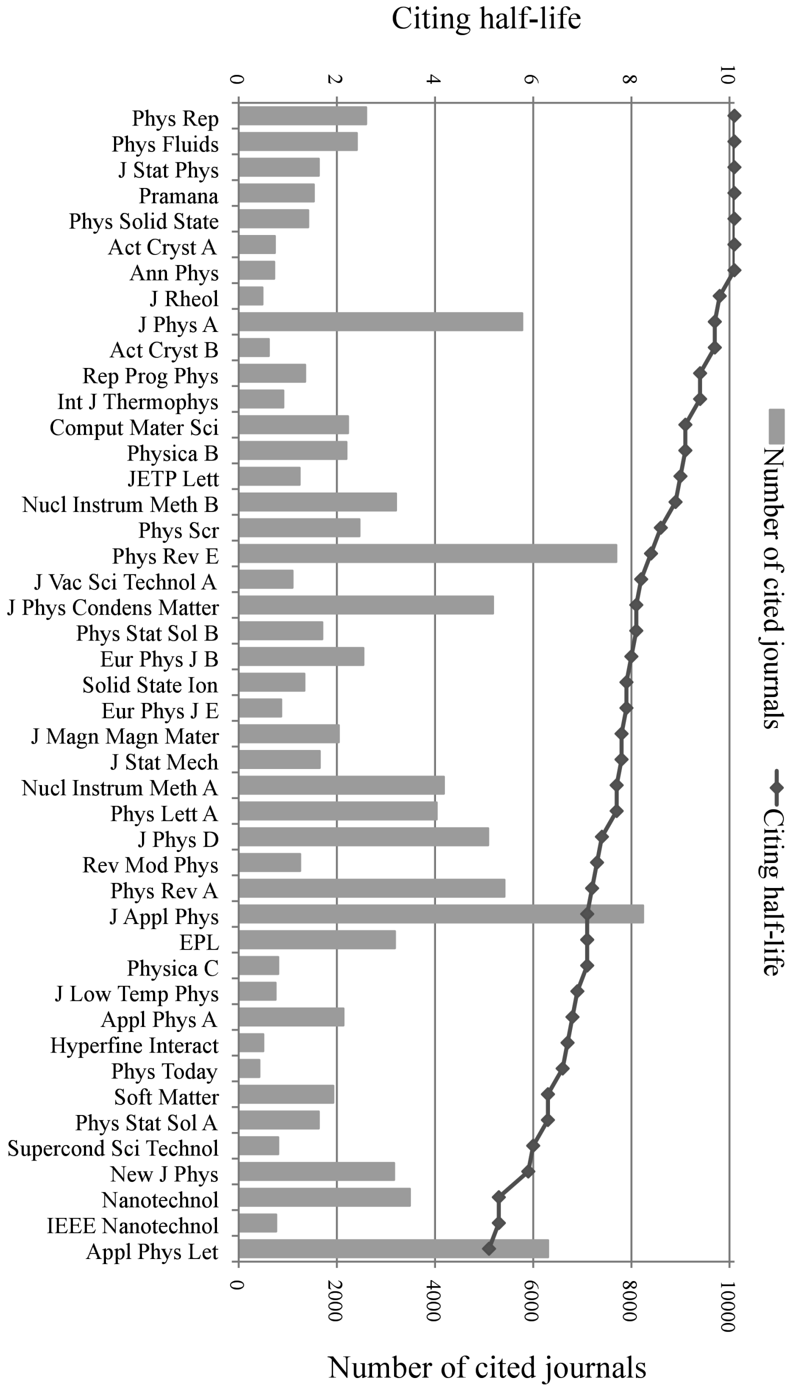

Figure 2.5 Citing half-life and number of cited journals for 45 journals in 2008.

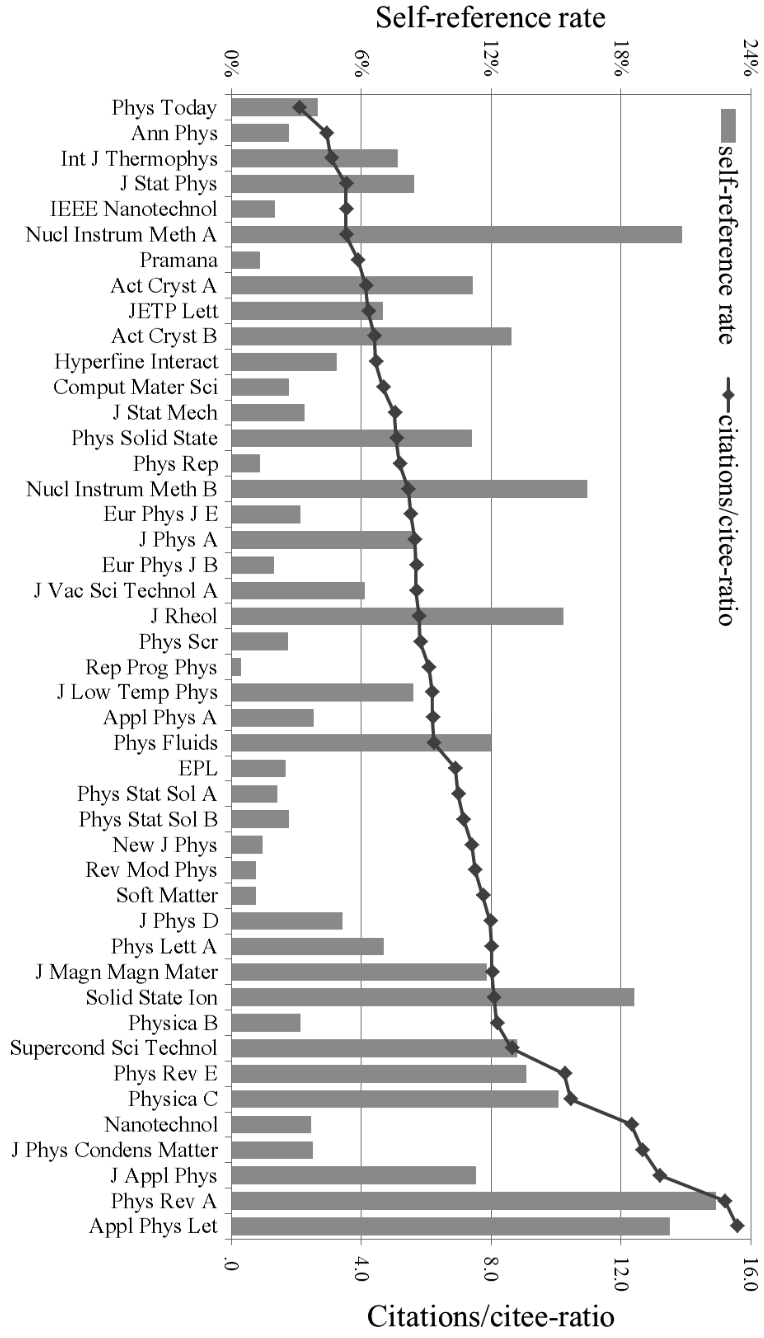

Figure 2.6 Citations/citee-ratio and journal self-reference rate for the 45 journals in 2008.

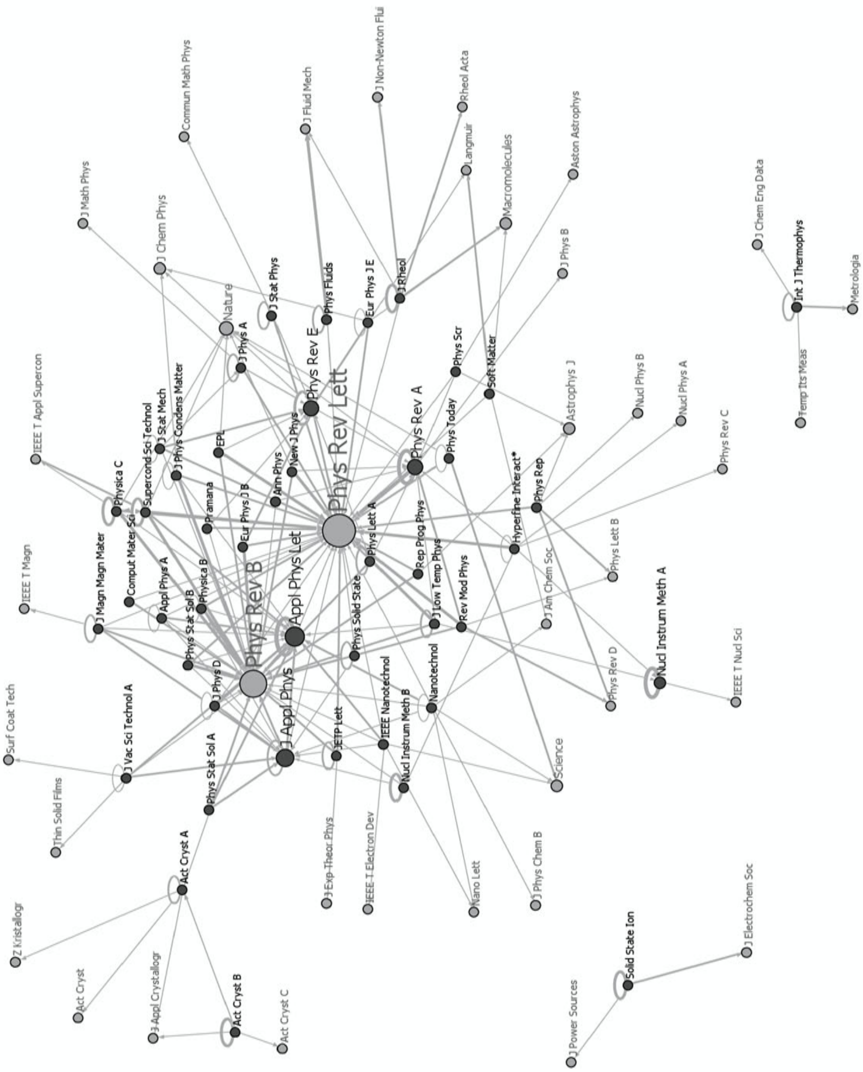

Figure 2.7 Reference network of 45 journals and most frequently cited journals in 2008. Includes those journals which contained more than 3% of all cited publications of the citing journal in 2008. The 45 citing journals are represented by the darker nodes.

The values of the citations/citee-ratio for the 45 journals can be seen in figure 2.6 together with the level of self-reference rate. In contrast to the self-citation rate, which is part of journal citation (chapter 5) instead of reference analysis, analyzes the number of references from the particular journal to its own articles in contrast to all its references during a certain period of time. The self-citation rate compares the same value to the total number of received citations. Both indicators evaluate the position of the journals in their citation environment.

> Many self-citations among the references may signify isolation of the journal in the scientific domain (high rate). A low rate of self-citations may indicate a high level of influence in the scientific community. (Bonnevie-Nebelong, 2006, p. 412)

The correlation between the two indicators, i.e. citations/citee-ratio and self-reference rate, is very low (Pearson's $r = 0.358$), which indicates that there are journals with a low self-reference rate and a low citations/citee-ratio, i.e. high citing diversity (e.g., Rep Prog Phys, Phys Rep, Pramana) and there also are periodicals which cite themselves frequently but at the same time make use of many other sources as well (e.g., Nucl Instrum Meth A). Journals like Phys Rev A and Appl Phys Let can be identified as isolated in terms of knowledge import because they receive their knowledge from a small number of sources and at the same time cite their own sources frequently.

Apart from these indicators, the structure of a journal's knowledge import can also be depicted by reference networks to gain a more detailed overview of the cited sources. Figure 2.7 depicts the 45 journals and the most frequently cited sources. It includes all cited journals which received at least 3% of all references from the particular journal in 2008. Arc size represents the relative number of references from one journal to another. Loops depict self-references. If one of the 45 journals (represented by the dark nodes) had a self-reference rate below 3%, no loop is shown.

The structure of the reference network clearly shows that two journals function as the main sources of information (authorities) for the 45 journals under evaluation, namely Phys Rev B and Phys Rev Lett. The fact that they are not part of the initial set of 45 journals, shows that the test set does not cover the whole area of solid state research, as described in section 1.4. Moreover, the network graph depicts the peripheral positions of Act Cryst A, Act Cryst B and Nucl Instrum Meth A, which have only a few connections to the well-connected journals in the center, and the isolation of Solid State Ion and Int J Thermophys, which have no connection to the largest component in 2008, if the most important source journals are considered (figure 2.7).

The most important authority within the journal test set is Appl Phys Let due to its high number of inlinks, i.e. references from the other 44 journals. This emphasizes, that although the journal citation identity indicators introduced by Bonnevie-Nebelong (2006) indicate a certain self-isolation of Appl Phys Let in terms of knowledge import, it can be regarded as a central information source for the other journals.

In contrast, Rev Mod Phys can be regarded as a hub, because it has a high number of outgoing arcs, i.e. references to other sources, and no inlinks, which is typical of a small review journal. At 1.1%, the self-reference rate is very low as well (figure 2.6). The definition of hubs and authorities is based on the famous link analysis approach by Kleinberg (1999).

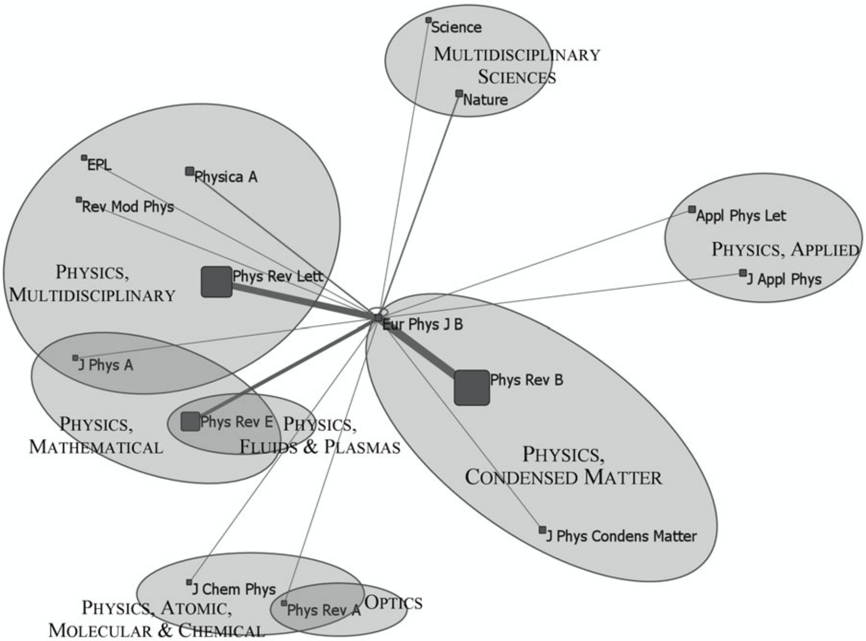

Figure 2.8 Ego network of Eur Phys J B with most frequently cited journals and respective WoS subject categories in 2008. Includes journals that were cited at least 145 times (1% of all Eur Phys J B references in 2008).

Figure 2.8 focuses on the reference environment of Eur Phys J B and takes all journals into account that were cited at least 145 times, which accounts for 1% of all documents cited by Eur Phys J B in 2008. This ego network shows the 14 most important source journals clustered by WoS subject categories and reveals the frequent import of knowledge from multidisciplinary physics journals by Eur Phys J B. Five of the 14 most important sources of information are assigned to that category, while Eur Phys J B's category 'Physics, Condensed Matter' is only represented by itself and two other journals. The network also reveals the importance of Nature and Science as frequently cited multidisciplinary journals.

2.1.6 Publishing Language

English has become the de facto language or modern lingua franca of science (Garfield, 1967, 1989; Reguant & Casadella, 1994). Developments after World War II lead to an internationalization of science:

> Progressive specialization played an important role in these changes. For one thing, it meant that it was no longer possible for all fields to be equally well represented in any one country. Scientific collaboration now took place on a worldwide basis. Thus, from a "scientific-geographical" point of view, scientific publishing was no longer feasible within national borders. (Götze, 1997, p. 52)

English has developed into a lingua franca similar to Latin as the language of scholars in the Middle Ages and French as diplomatic language from the beginning of the 17th century (Reguant & Casadella, 1994). This poses a problem for non-native speakers of English in science (Hwang, 2005; Ferguson, Perez-Llantada, & Plo, 2011), who are confronted with a language barrier and struggle between publishing in a foreign language or their mother tongue, which is generally a trade-off between visibility and expression of research results:

> Scientists look for international visibility by publishing in English either in national journals or in high-profile international journals; conversely, they hope to attract a larger regional audience by publishing in their mother tongue or they choose a national journal because they are not sufficiently fluent in English. (Meneghini & Packer, 2007, p. 113)

The extent to which such language barriers are responsible for the bias towards Anglo-American authors as producers of output in scientific journals is unclear. Meneghini and Packer (2007) propose that authors should provide an English and national language version of their journal article to close the communication gap. Although the Public Library of Science (PLoS) journals grant this option, it is questionable if authors would make the effort to do so. Another possibility of guaranteeing multilingual access to published results would be for the journals to provide a professional language service. Since this option is regarded as too expensive, scientists have no other choice than to use English (Meneghini & Packer, 2007).

Table 2.8 Share of English and non-English documents in the WoS citation databases (all documents published between 1981 and 2010).

Database	English	Non-English
SCI	93.8%	6.2%
SSCI	93.5%	6.5%
A&HCI	71.1%	28.9%
CPCI-S	98.5%	1.5%

Table 2.9 Percentage ($P_{\%}$) of languages of all documents in SCI published between 1981 and 2010.

Language	$P_{\%}$	Language	$P_{\%}$	Language	$P_{\%}$
English	93.84	Chinese	0.31	Dutch	0.03
German	1.77	Portugese	0.14	Ukrainian	0.03
Russian	1.50	Italian	0.08	Rumanian	0.02
French	1.30	Polish	0.07	Swedish	0.02
Spanish	0.40	Czech	0.06	Turkish	0.02
Japanese	0.32	Hungarian	0.04	Korean	0.02
				Other	0.05

Table 2.8 shows the percentages of English and non-English publications in the four WoS citation databases. While in arts and humanities national language publications are relevant (28.9%), in the natural sciences research is hardly published in a language other than English. Rather surprisingly, the percentage of foreign languages is almost as low in the social sciences (6.5%) than it is in the sciences (6.2%). Due to the international character of scientific conferences, it was to be expected that proceedings are in general published in English.

In table 2.9 the distribution of languages is listed for all documents in SCI published between 1981 and 2010. The position of English is striking. German, Russian and French publications are of some significance but, as figure 2.9 shows, they become irrelevant over the years. Japanese has lost importance as well, while the share of Spanish publications stayed almost constant at 0.4%. The only language that increased its share was Chinese, which in 2010 was on the same level with French and Spanish articles. After a peak of 97.4% from 2004 to 2006, English output showed a minimal decrease in favor of other languages, but it increased again to 97.3% in 2010.

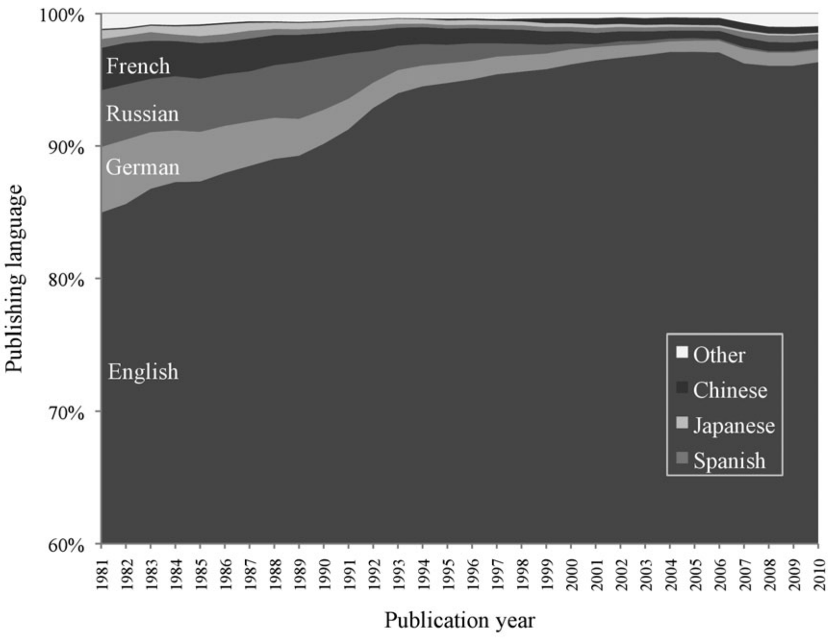

Figure 2.9 Share of languages in SCI from 1981 to 2010 by language.

The dominance of English is clearly reflected in the publishing language of the 45 analyzed journals: all journals publish their articles in English. Studying the linguistic distribution as stated in the WoS data (Van Leeuwen, Moed, Tijssen, Visser, & Van Raan, 2001), one discovers that out of the 168,109 documents, 7 are registered by WoS as written in a language other than English, namely German (2 publications), Romanian (2), Welsh (2) and Serbian (1). If one takes a look at the original documents, it becomes apparent that the articles supposedly written in Romanian, Welsh and Serbian are in English as well. The documents stated to be German are actually published in German. One is an article by Hubert Goenner published in Ann Phys in 2006, which is entitled “Zur Geschichte der einheitlichen Feldtheorie: Einsteins Jahre erfolgloser Forschung” (“On the history of the integrative field theory: Einstein’s years of unsuccessful research”). The other is a reprint of an obituary for Paul Drude, who was the editor of Ann Phys before he committed suicide in July 1906, written by Max Planck in the same year.

In disciplines where languages others than English are relevant, language distributions can be examined. For example refer to Van Leeuwen et al. (2001), who evaluated language biases for the medical faculty of a German university, Arvanitis and Chatelin (1988), who analyzed language distributions in soil science research, or Larsen and Leta (2009), who compared English to national language output in the social sciences and humanities for Argentina, Belgium, Brazil, Finland, France, Germany, Spain and Sweden.

2.2 Producers of Output

Journal output is produced by authors of scientific articles. Authors and their affiliation with scientific institutions make it possible to analyze journal output by its origin (Wormell, 1998). It can be examined which and how many researchers contribute to the published content of a scientific periodical. Author addresses listed in the publication can be used to accumulate producers of output on different levels (De Lange & Glänzel, 1997).

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In-situ study of operating SOFC LSM/YSZ cathodes under polarization by photoelectron microscopy

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Figure 2.10 Author names and institutional addresses of an article published in 2008 in Solid State Ion.

The author himself represents the smallest, i.e. micro level of aggregation, while a country (or a community of states like the European Union) represents the largest unit of output. Between these two, different kinds of meso evaluations are possible: scientific output can be evaluated for groups of authors, departments or complete scientific institutes like universities, research centers or companies involved in R&D, or it can be aggregated for cities or geographic regions.

Figure 2.10 depicts authors and institutional addresses of an article published in Solid State Ion. For an output evaluation one can extract six contributing authors affiliated with three different institutions. Evaluating scholarly output on the author level, the contribution can be counted as one publication for each of the six authors or fractionally, i.e. one sixth per author. Further analysis reveals that the publication shown in figure 2.10 identifies a collaboration between corporate R&D workers and a researcher at a university. At the same time, this publication indicates an international collaboration between the USA, Germany and Italy. Analyzing the journal output on the macro level, it can be recorded that in this particular case three countries contributed to Solid State Ion. The following sections will describe these possibilities of journal evaluation, apply them to the test set of 45 journals, and address the limitations and problems with data acquisition.

2.2.1 Authors

The number of worldwide R&D workers is estimated to be approximately 5.7 million (Mabe & Amin, 2002; Cope & Kalantzis, 2009). A large proportion of them appear as authors of scientific articles in order to publish their results, often in cooperation with colleagues, who then appear as co-authors (Georghiou, 1997; Tenopir & King, 2000). The number of authors per document is highly dependent on the scientific discipline. An increase in the number of authors can, however, be perceived in all areas of research.

From his findings based on publications in Chemical Abstracts since 1900, Price (1963) predicted the extinction of single-authored papers by 1980. Although publications with one author still exist and probably always will, the share of multi-authored documents has further increased (Abt, 2007). Especially in experimental physics, where research is carried out at large international facilities, the number of co-authors, involved institutions and countries is rather high (Abt, 1992; De Lange & Glänzel, 1997). Abt (1992) reports the highest median values for the number of co-authors in the medical area. The values[5] for condensed matter physics represent middle ranks. The mean number of authors per publication increased over time from 2.0 in 1970 to 3.1 in 1990 (Abt, 1992). Glänzel and De Lange (1997) find similar results regarding international collaboration. The highest values are reported for nuclear science and medicine, while the share of internationally co-authored papers is lower in solid state physics, mathematics, engineering and chemistry. However, all disciplines experienced tendencies towards greater collaboration and internationalization (Abt, 1992; Glänzel & De Lange, 1997).

5 It should be noted that Abt (1992) seems to confuse mean and median values. He lists the *median* number of authors in Physical Review B as 2.38. A *median* value of an integer can, however, never equal 2.38 because it represents the value that divides a sample into two halves. Since the number of authors per paper is always measured by a whole number, the median cannot be a decimal either. An exception occurs when the number of samples, i.e. publications, is even and there are two middle values instead of one. However, the median is then defined as the mean of these two numbers, which in the case of authors per paper can at most result in a median of 0.5.

If one takes a look at the total level of scientific output and the number of active researchers, productivity per author has remained almost constant. To a very large extent, the increase in research output is caused by the increase in the number of active scientists (Tenopir & King, 2000). The growth in the average number of authors per publication is due to increase in co-authorship.

One phenomenon related to an increase in authors per publication, which emerged due to output evaluation, is honorary authorship. Researchers are added as authors although their contribution to the publication is only marginal or non-existent (Cope & Kalantzis, 2009). Determining the actual contribution of authors is almost impossible. Sometimes the order of author names or a special labeling indicates the importance of the researchers for the particular publication. Other than distinguishing between first (or primary) author and secondary authors it is, however, not possible to document the amount of work per author. This information can only be gathered by questioning the authors directly and even then it is hard to determine the value of the contribution (Diodato, 1994).

Table 2.10 Distribution of number of authors per publication for all documents published in the 45 journals between 2004 and 2008.

Number of authors	P	$P_{\%}$	$\sum P_{\%}$
1	16592	9.9	9.9
2	31511	18.7	28.6
3	32359	19.2	47.9
4	26556	15.8	63.7
5	19904	11.8	75.5
6	14424	8.6	84.1
7	9647	5.7	89.8
8	6000	3.6	93.4
9	3791	2.3	95.6
10	2389	1.4	97.1
>10	4936	2.9	100.0

For the 45 journals under analysis, the number of authors per document is computed from the WoS dataset. For example, the publication displayed in figure 2.10 would count for six authors. Coleman (2007) refers to the mean number of authors per document per journal as journal associativity. Overall, the average article is produced by four authors (median = 4, arithmetic mean / journal associativity = 4.4) with a high deviation from the standard of 8.21. The large deviation is caused by very few publications with a great number of co-authors (table 2.10). Most publications are produced by three authors. 97.1% of the 168,109 documents had no more than 10 authors. Single-authored papers account for 9.9% of all documents. This value is lower than that discovered by Abt (2007).

Table 2.11 Statistics for number of authors per publication: mean (= journal associativity (Coleman, 2007)), median, maximum and standard deviation for the number of authors per publication-

Journal	**Mean**	**Median**	**Max**	**Std. Dev.**
J Stat Phys	2.1	2	6	0.97
J Stat Mech	2.5	2	7	1.15
Eur Phys J E	3.3	3	10	1.64
Act Cryst A	2.6	2	11	1.74
Phys Today	1.3	1	11	0.74
J Rheol	3.1	3	12	1.32
IEEE Nanotechnol	4.3	4	14	2.47
Phys Solid State	3.9	3	14	2.23
Rev Mod Phys	2.8	2	14	2.11
Soft Matter	3.8	3	14	2.10
Ann Phys	2.4	2	15	2.09
Solid State Ion	4.2	4	15	1.91
Comput Mater Sci	3.2	3	16	1.56
Eur Phys J B	3.2	3	16	1.90
J Phys A	2.2	2	17	1.19
J Vac Sci Technol A	4.4	4	17	2.19
J Phys Condens Matter	4.0	3	18	2.35
Nanotechnol	4.8	4	19	2.30
Phys Stat Sol A	5.0	5	19	2.54
Appl Phys A	4.8	4	21	2.33
Phys Stat Sol B	4.4	4	21	2.67
Phys Fluids	2.6	2	22	1.23
EPL	3.4	3	23	2.12
J Appl Phys	4.7	4	23	2.39
J Phys D	4.2	4	23	2.32
Physica B	4.5	4	23	2.59
Appl Phys Let	5.2	5	26	2.49
Physica C	5.0	4	26	2.85
Act Cryst B	3.9	4	27	2.16
J Magn Magn Mater	4.7	4	28	2.30
Phys Lett A	2.8	2	29	1.68
Rep Prog Phys	2.2	2	31	2.32
Phys Rev E	3.0	3	37	1.76
Supercond Sci Technol	5.2	5	39	2.88
Int J Thermophys	3.6	3	40	2.53
Pramana	2.8	2	42	2.73
Phys Rev A	3.4	3	45	2.19
Hyperfine Interact	5.3	4	50	4.44
J Low Temp Phys	4.4	3	55	3.86
Phys Scr	3.7	3	75	3.63
JETP Lett	3.8	3	82	4.10
New J Phys	4.3	3	220	5.71
Nucl Instrum Meth B	5.4	5	226	4.97

continued on next page

Journal	Mean	Median	Max	Std. Dev.
Nucl Instrum Meth A	9.2	5	816	21.20
Phys Rep	12.5	2	2,512	138.22
Total	4.4	4	2,512	8.21

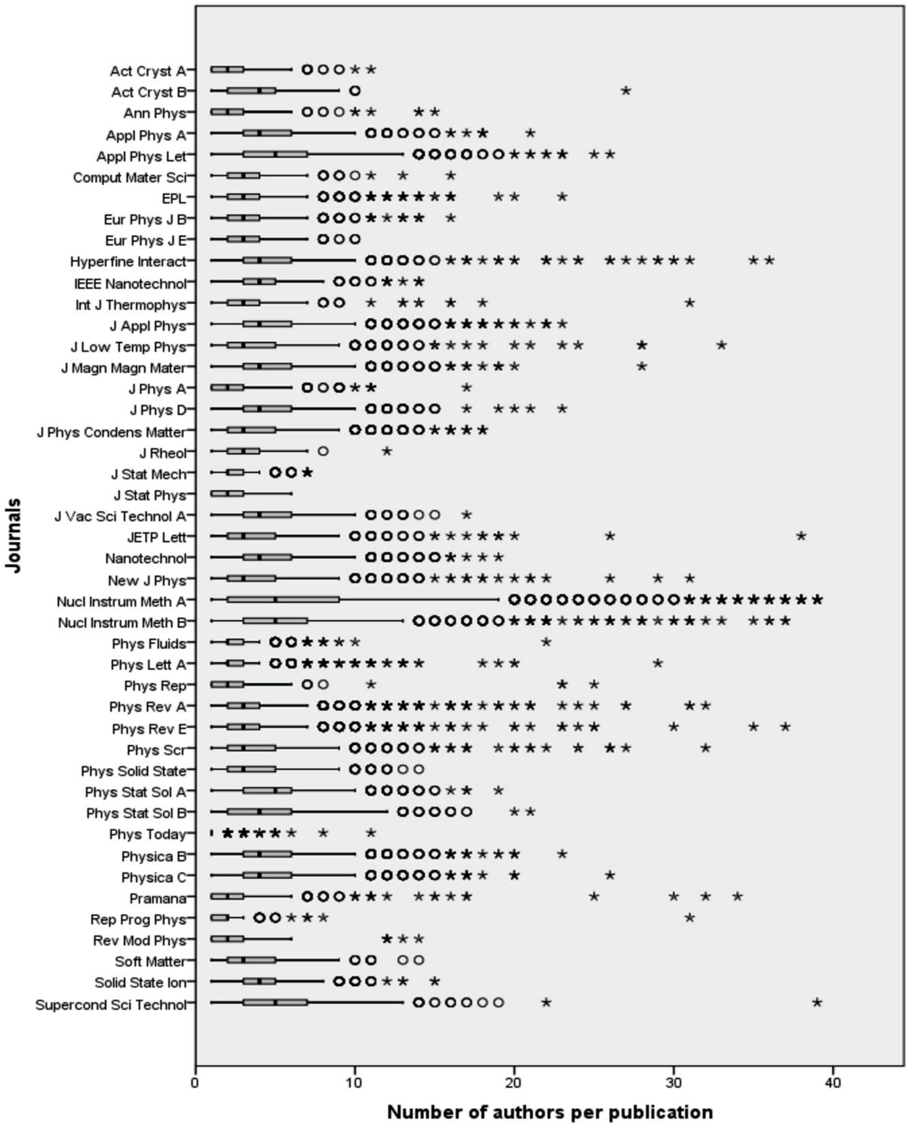

Figure 2.11 Box plots showing the number of authors per journal. The diagram includes all documents with less than 40 authors per publication.

Descriptive statistics of the number of authors per publication for each of the 45 journals are shown in table 2.11 and reveal skewed distributions and differences between the periodicals. Figure 2.11 displays box-and-whisker plots of these distributions. Since 99.8% of all 168,109 publications have no more than 39 contributors, the diagram disregards the remaining 0.2% with 40 or more authors. Even without these outliers, the frequency distributions remain highly skewed for the majority or periodicals. J Stat Phys represents the journal with the lowest maximum value of 6 authors[6] and is thus the journal without any outliers. Except for Eur Phys J E and Phys Solid State, all other journals show extreme outliers regarding the number of authors per document. Four journals stand out with publications co-authored by over 200 researchers, namely Phys Rep with one article authored by 2,512 persons, Nucl Instrum Meth A (maximum authors = 816), Nucl Instrum Meth B (226) and New J Phys (220). The publication with 2,512 authors was produced by nine collaborations. 14 of the 197 pages are taken up by lists of authors and affiliations. Due to its large number of references (499) it is defined as a review paper by WoS, although title and abstract suggest that it contains original research results. Phys Today, on the other hand, publishes a majority of single-authored documents, which can be explained by the type of published content: as shown in section 2.1.4, Phys Today publishes primarily letters and documents that are in general authored by one person, i.e. editorial material, news and biographical items.

Apart from the average number of co-authors, the number of unique contributors can be investigated because it reflects the diversity of researchers a journal attracts. On the one hand, the number of different contributors depends on the degree of thematic specialization of the periodical. The larger the subject area the journal aims to cover, the greater the number of possible contributors. If, on the contrary, a periodical focuses on a sub-speciality of a research field, the number of unique authors is limited because there are only a small number of researchers working in the field. A small number of contributing authors is thus not per se a negative indicator regarding a periodical's prestige.

In the 1920s, Alfred J. Lotka found a regularity of the distribution of the number of publications per author in chemistry and physics. Lotka's law, which (together with Bradford's law of scattering (Bradford, 1934) and Zipf's law (Zipf, 1949)) is one of the central laws in bibliometrics, is defined as:

$$x^n y = c \tag{2.2}$$

where x denotes the number of papers per author, y is the percentage of authors who published x papers and n and c represent constant parameters depending on the particular scientific field. Lotka found $c = 0.5669$ and $n = 1.888$ for chemistry and $c = 0.6079$ and $n = 2.020$ for physics (Lotka, 1926). The law suggests that most of the output of a scientific field is generated by a few very productive authors and that many researchers publish only once or twice. It proves an inverse relationship between the number of documents and the number of researchers authoring them (Lotka, 1926; Diodato, 1994; Tenopir & King, 2000). Schauder (1994) noticed that Lotka's Law applies rather to 'little science' but does not hold for 'big science' such as high energy physics, where scientists work in large teams.

6 An assumed limitation of the number of authors per publication by J Stat Mech could not be confirmed.

Due to author name ambiguities it is, however, not easy to compute the true number of unique authors let alone compile a ranking of authors by the number of publications. Although "it would seem a simple process" (Smalheiser & Torvik, 2009, p. 1), author disambiguation, i.e. assigning a publication not to an author name but the individual person behind it, "represents a major, unsolved problem" (Smalheiser & Torvik, 2009, p. 1).

Underlying problems of author allocation can be classified into four different categories: authors publish under different names or spellings of names (synonymy), different authors publish under the same name (homonymy), incomplete or lacking metadata and publications authored by a large number of authors from multiple institutions and disciplines (Smalheiser & Torvik, 2009). Synonymy in author names can be caused by

> a) orthographic and spelling variants, (b) spelling errors, (c) name changes over time as may occur with marriage, religious conversion, or gender reassignment, and (d) the use of pen names. (Smalheiser & Torvik, 2009, p. 1)

In order to allocate all publications to an individual affected by name synonymy all spelling variants, including database-induced spelling mistakes, have to be identified (Tunger, Haustein, Ruppert, Luca, & Unterhalt, 2010). Figure 2.12 shows all known spelling variants for Albert Einstein[7] in the authority file of the German National Library (Personennamendatei).

Disambiguating various individuals that publish under the same name is a difficult task, which gains complexity with common names and database size. It can either be approached by some form of manual authority control or rule-based algorithm that computes probability values based on similarities of publication metadata (Torvik, Weeber, Swanson, & Smalheiser, 2005; Smalheiser & Torvik, 2009; Gurney, Horlings, & Van den Besselaar, 2011).

Both approaches solve author disambiguation for manageable amount of bibliographic data of limited research communities (e.g. institutional repositories), but come up against computational limits when it comes to large international multidisciplinary bibliographic databases such as WoS and Scopus. Establishing and maintaining a registry file that assigns unique IDs to individual authors works, for example, for book collections in libraries (e.g. Library of Congress Name Authority File[8] or Personennamendatei[9] by the German National Library, for example see figure 2.12), but is problematic for journal articles. Extending library authority files to journal publications would not be possible due to the sheer amount of documents. Moreover, the metadata often do not provide enough information for the librarian to identify the individual behind the name.

7 http://d-nb.info/gnd/118529579
8 http://authorities.loc.gov
9 http://www.d-nb.de/standardisierung/normdateien/pnd_info.htm

Person	Einstein, Albert (männlich)
Andere Namen	Einstein, Albert Einstein, A. Einstein, ... Aiyinsitan Ai-yin-ssu-t'an, A-po-t'e Ai-yin-ssu-t'an Ajnštajn, Albert Ajnštajn, A. Aynishtayn Aynštayn, Ălbirt Einshtein, Al'bert Einsteina, Alberta Einšteinas, A. Ainshtain, Albert Ėjnštejn, Al'bert Ėjnštejn, A. Eynshṭeyn, Alberṭ Inshtin Ainshutain, A. Ainshutain, ... Ainštain, ... Á[illegible]nstá[illegible]n, Albertos Á[illegible]nstá[illegible]n, Almpert Ainstaina, Albarta Ainsyut'ain, Alberŭt'ŭ
Akademischer Grad	Prof.
Quelle	M; B 1996; LCAuth; Biogr. H Emigr.; IPI 8/2004 MGG 2
Lebensdaten	1879-1955
Beruf(e)	Physiker
Funktion(en)	Textverfasser (Text)
Land	Deutschland (XA-DE); Schweiz (XA-CH); USA (XD-US)
Weitere Angaben	Amerikan. Physiker dt. Herkunft, Nobelpreisträger 1921; 1901 Schweizer Staatsbürger, ab 1940 amerikan. Staatsbürger; lebte 1894-1913 überwiegend in der Schweiz, 1914-1933 in Deutschland, emigrierte 1933 in die USA
Beziehungen zu anderen Personen	Einstein, Alfred (Cousin)
Organisation(en)	Universität<Prag, - 1882> Universität<Zürich> Preußische Akademie der Wissenschaften<Berlin> Princeton University
Sachgebiet(e)	21.5p Personen zur Physik
Autor von / Beteiligt an	570 Publikationen

Figure 2.12 Authority entry for Albert Einstein in the Personennamendatei of the German National Library. Source: http://d-nb.info/gnd/118529579.

It should be assumed that the individual author would be able to identify his or her own publications. However, this is not necessarily the case. Above all, a system where researchers list their publications would depend on the participation of all authors. This approach is unrealistic for a number of reasons (Smalheiser & Torvik, 2009). Automatic approaches rely on rules to disambiguate publications with the same author last name and first initial to different individuals. For example, they evaluate institutional addresses, co-authors, title words, publication venues, citation relations and other bibliographic metadata (Gurney et al., 2011). For large datasets their success rate is around 90% (Onodera et al., 2011), which might be sufficient for retrieval purposes.

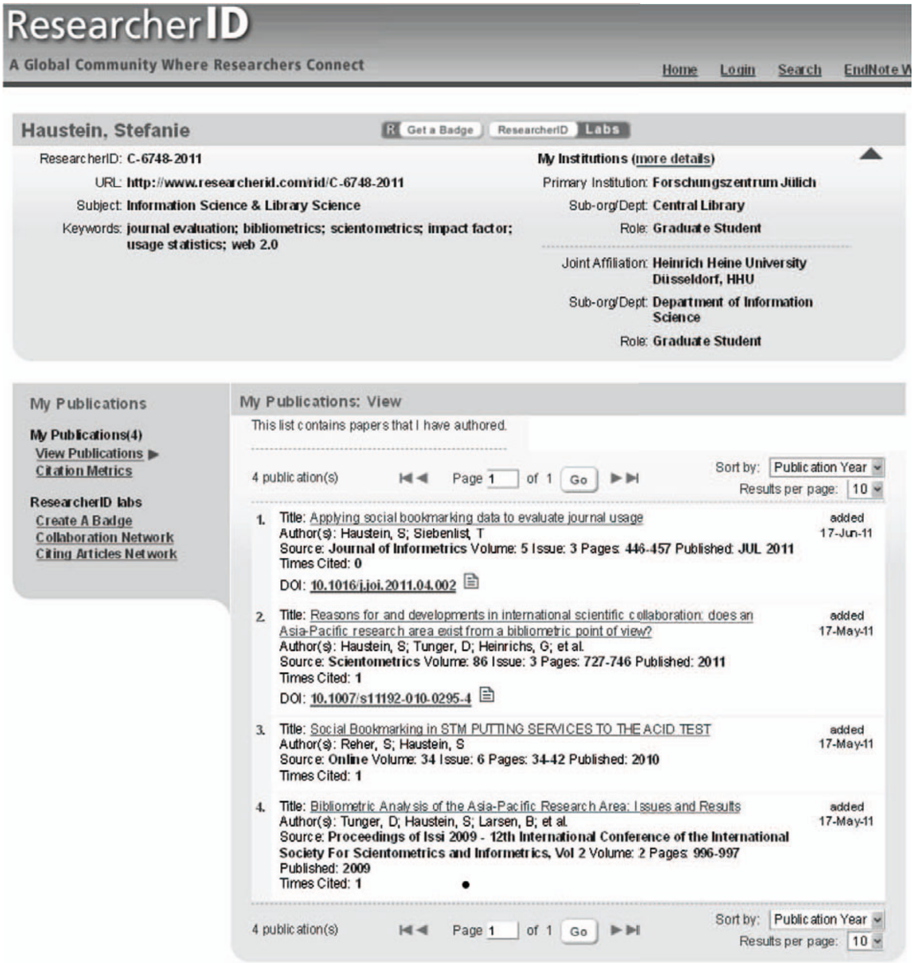

Figure 2.13 ResearcherID profile for Stefanie Haustein. Source: http://www.researcherid.com/rid/C-6748-2011.

When generating rankings and collaboration networks it is, however, necessary to assign all papers correctly, because missing single publications can cause huge differences in the results. Scopus and WoS (ResearcherID[10]) have tried both disambiguation of author (and institution) names by algorithms and attribution of papers through participation of individual authors. Figure 2.13 shows a ResearcherID profile. All information, i.e. publications, institutions and area of research, needed to be provided by the authors themselves. If this information is not provided, the only way to identify an individual behind synonymous and homonymous author names is to examine the data in detail:

> Consequently, it is necessary to analyze the metadata, and sometimes the text, of a work of literature in order to make an educated guess as to the identity of its authors. (Smalheiser & Torvik, 2009, p. 1)

For the evaluation of frequent contributors to particular journals this represents a time and cost-intensive analysis, because to be exact, every author name has to be examined. Even then this can lead to inconsistent results.

Table 2.12 Ranking of authors contributing most frequently to Soft Matter

Author name	*P*
MOHWALD, H	9
SCHUBERT, US	9
STEINER, U	7
FERY, A	5
HAMLEY, IW	5
STUART, MAC	5
TSUJII, K	5
BALAZS, AC	4
BOKER, A	4
CASTELLETTO, V	4
CLARKE, N	4
CROSBY, AJ	4
JAKLI, A	4
JIANG, L	4
MANN, S	4
RYAN, AJ	4
SCHAAF, P	4
SPATZ, JP	4
TAKAHARA, A	4
ULIJN, RV	4
VOEGEL, JC	4
WOOLEY, KL	4
XU, J	4

10 http://wokinfo.com/researcherid/

Table 2.13 Ranking of authors contributing most frequently to J Appl Phys

Author name	*P*
WANG, J	63
WANG, Y	61
ZHANG, Y	53
LI, J	52
ZHANG, J	52
LIU, Y	51
YAO, YD	47
ZHU, JG	47
WANG, XL	45
KIM, JH	44
WANG, H	44
SELLMYER, DJ	40
WANG, L	40
LIU, W	39
SUZUKI, T	39

In table 2.12, the most frequent contributors to Soft Matter based on WoS data are listed. For the 654 documents published in Soft Matter, WoS extracts 2,059 unique author names, of which 1,771 (86.0%) contributed one article only. If common spelling variations of these authors are sought, misassigned publications can be found. For example, besides ‘Mohwald, H.’, who authored 8 papers, there is another publication authored by ‘Moehwald, H.’, and both refer to Helmuth Möhwald, who is the most frequent contributor to Soft Matter. Spelling variants are generally visible in the long tail of the frequency distribution. That is, however, where they have the greatest effect, because if the publication counts of different name variants are combined, changes in the ranking can be crucial. Ambiguities seem not to be serious for Soft Matter since it is a specialized journal with a rather small community, where homonymy is limited. Except for Helmuth Möhwald no obvious cases of synonymy could be observed. Judging by the institution, ‘Zhang, J’ and ‘Zhang, JM’ seem to be correctly listed as two individuals, as are ‘Yang, S’ and ‘Yang, SG’. It appears to be different for J Appl Phys (table 2.13). There are 59 authors with the last name Wang who published in J Appl Phys between 2004 and 2008, and together they account for 1,247 articles. It is not possible to determine the number of individual authors for certain without extraordinary expense that could not be justified by the value of the resulting author ranking. If name variants are corrected, as was done for the author names appearing in Soft Matter, co-authorship networks can depict the central contributors of a journal. The most central author is not necessarily the one who publishes the greatest amount of articles, but the one who frequently collaborates with his colleagues. If variants were not adjusted, the whole network structure would be flawed.

Figure 2.14 displays the co-authorship network of all 654 publications that appeared in Soft Matter between 2005[11] and 2008. The co-author matrix was extracted with

11 In contrast to the other journals under evaluation, publications from 2004 are not included because Soft Matter was only founded in 2005.

Network Workbench. Visualization was processed with the 'Physics' layout algorithm in GUESS. Nodes represent authors, edges represent co-authored documents in Soft Matter. In the periphery of the network, contributors are displayed who either published alone or in small groups of authors who did not collaborate with other authors in Soft Matter. In figure 2.14, node size depicts the number of publications, while in figure 2.15 it displays citation counts.

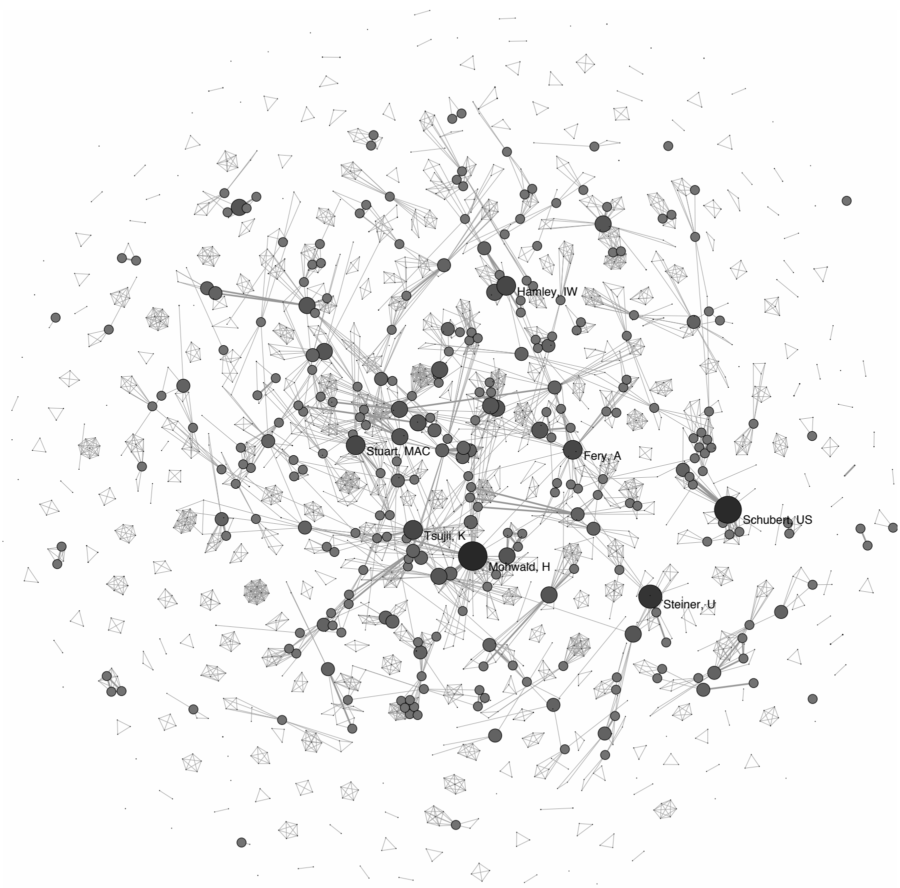

Figure 2.14 Co-author network for 654 documents published in Soft Matter between 2005 and 2008. Node size represents number of publications.

The network structure reveals that Möhwald does not only contribute the most publications but is also central to the author network: due to his many connections with other researchers, he is positioned at the center of the network graph. He is also among the most highly cited authors of Soft Matter although the highest citation counts were achieved by two reviews by authors that have only a peripheral functions in Soft Matter, namely Mathilde Callies and David Quéré ("On water repellency", 2004) and Paul Roach, Neil J. Shirtcliffe and Michael I. Newton ("Progress in superhydrophobic surface development", 2008).

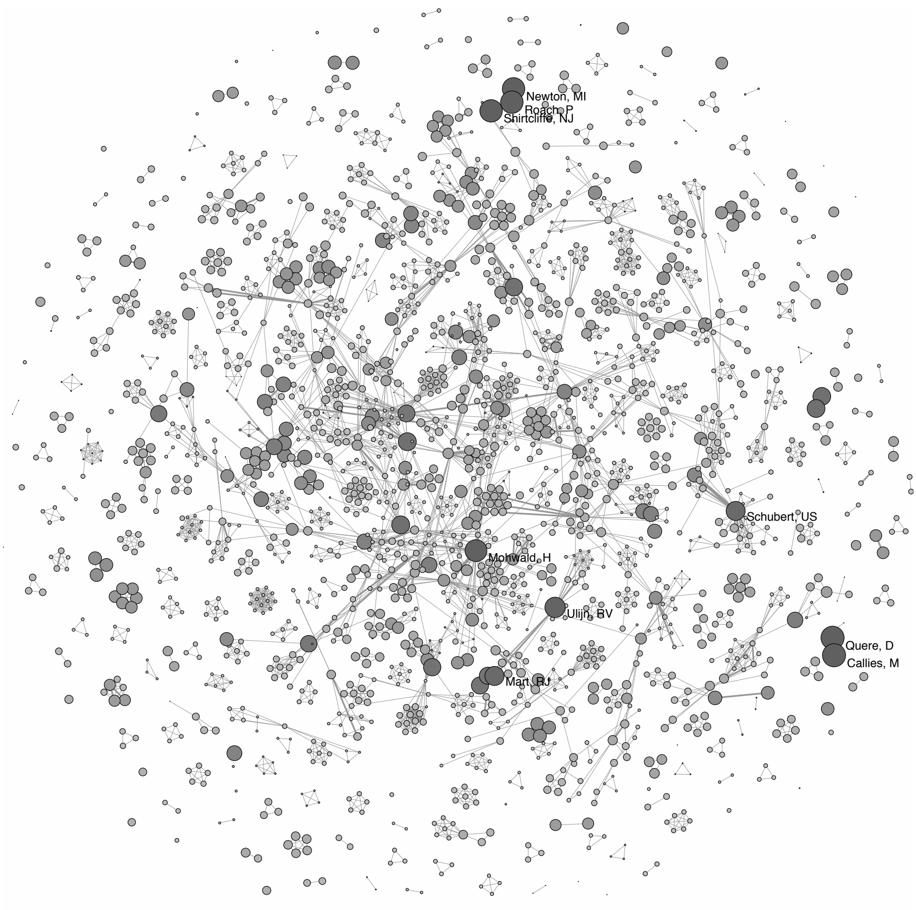

Figure 2.15 Co-author network for 654 documents published in Soft Matter between 2005 and 2008. Node size represents number of citations.

Another approach to analyze contributing authors on the micro level is an evaluation from the gender perspective. Aggregating scholarly output based on gender, which is usually done by matching authors' first names to the particular sex, a scientific discipline can be evaluated in terms of its share of male and female researchers, often focusing on the under-representation of women in the natural sciences and engineering. Bordons, Morillo, Fernandez, and Gomez (2006) compared demographic data of Spanish researchers in chemistry and natural resources to research output between 1994 and 1999 and found that women were under-represented in both fields and that they were slightly less productive than their male colleagues, although differences were not significant and mostly caused by the fact that women work in lower professional ranks compared to men. Jagsi et al. (2006) examined the gender of first and last US authors of original articles published in six medical journals over a period of 35 years and showed that the percentage of female first and senior authors increased significantly over time and that in 2004 49% of medical students were women. A percentage of 29.3% of female first authors and 19.3% female senior authors shows that in medical research, women are, however, still under-represented.

2.2.2 Institutions

Scientific institutions are producers of journal output on the meso level. They provide the infrastructure that is needed to do research. Names and addresses of the institutions an author is affiliated with are listed in their publications. Thus it is possible to assign journal articles to institutions in the same ways as it is possible to assign them to authors. To evaluate the most prominent contributor of journal output on an institutional level, publications have to be accumulated per institution in analogy to author analysis. However, synonymy is a much greater problem for institutional addresses than it is for author names.

Results from the automatically generated "Analyze Results" section in WoS should by no means be used for a ranking of institutions. Such institutional rankings are highly erroneous, because they evaluate affiliation names as stated in the publication. This leads to numerous variants of institutional names including acronyms and abbreviations of the top level and names of various departments and sub-departments. Institutional data from WoS should thus not be used without extensive cleaning, which involves looking at addresses and authors in original documents and a detailed examination of institutional structures.

In Scopus the different spellings that derive from author affiliation stated in the publications are merged under the top level name of the institution. Instead of 530 in WoS, Scopus lists 160 institutions whose authors published in Soft Matter within the time span under analysis. The difference can be seen in figure 2.16, which lists the most frequently contributing institutions based on Scopus and particular differences in comparison to the ranking produced by WoS. While changes in the first ranks are minimal, huge differences can be observed for the medium positions already: Forschungszentrum Jülich is ranked 22nd most frequently contributing institution in Soft Matter between 2005 and 2008 in Scopus, but only achieves 43rd place according to WoS. This is mainly due to the synonyms of the institutions which are not at all controlled in WoS.

For seven publications in Soft Matter, WoS lists seven different institutional addresses referring to Forschungszentrum Jülich:

- Forschungszentrum Julich, IFF, Inst Weiche Mat, D-52425 Julich, Germany
- Forschungszentrum Julich, Inst Festkorperforsch, D-52425 Julich, Germany
- FZ Julich, Inst Festkorperforsch, D-52425 Julich, Germany
- Helmholtz Zentrum Julich, Inst Festkorperforsch, D-52425 Julich, Germany
- Forschungszentrum Julich, Julich Ctr Neutron Sci, D-85747 Garching, Germany
- Forschungszentrum Julich, D-52425 Julich, Germany
- Forschungszentrum Julich, Inst Bio & Nanosyst, D-52425 Julich, Germany

Institution name	*Scopus rank*		*Web of Science rank*
Max Planck Institut fur Kolloid Und Grenzflachenforschung Potsdam	1		1
University of Massachusetts Amherst	2		2
University of Bristol	2	1	3
University of Manchester	4		4
Universität Bayreuth	4	3	7
University of Cambridge	6	2	4
CNRS Centre National de la Recherche Scientifique	7	5	12
University of Leeds	7	3	10
University of Sheffield	9	1	8
Technische Universiteit Eindhoven	9	1	10
Hokkaido University	11	1	12
Imperial College London	11	1	12
Massachusetts Institute of Technology	11	1	12
Université de Strasbourg	11	3	8
University of Durham	15	4	19
University of Tokyo	15	1	16
University of Oxford	15	4	19
Max Planck Institute for Polymer Research	15	1	16
University of Pennsylvania	19		19
Northwestern University	19		19
Martin-Universität Halle-Wittenberg	19	6	25
Institut Laue-Langevin	22	9	31
Forschungszentrum Jülich in der Helmholtz Gemeinschaft	22	21	43
Japan Science and Technology Agency	22	61	83
National Institute of Standards and Technology	22	36	58
Jozef Stefan Institute	22	3	25
Friedrich Schiller Universität Jena	22	9	31
Debye Institute	22	--	--
Universität Freiburg im Breisgau	29	29	58
University of Melbourne	29	2	31
Institute of Chemistry Chinese Academy of Sciences	29	25	4
University of California, Los Angeles	29	4	25
University of Hull	29	2	31
University of Wisconsin Madison	29	2	31
Chalmers Tekniska Högskola	29	14	43
Universite Pierre et Marie Curie	29	193	222
Uppsala Universitet	29	14	43
North Carolina State University	29	2	31
Universite Paris 7- Denis Diderot	29	54	83
Cornell University	29	2	31
Kyushu University	29	2	31
CEA Saclay	29	10	19
Universite Montpellier 2 Sciences et Techniques	29	2	31
Technion - Israel Institute of Technology	29	2	31

Figure 2.16 Differences in rankings of institutions contributing most frequently to Soft Matter based on Scopus and WoS data. Institution names are taken from Scopus and are not corrected, e.g. 'Martin-Universität Halle-Wittenberg' should be 'Martin-Luther-Universität Halle-Wittenberg'.

While the first four can be linked to the Institute of Solid State Research (IFF) directly and the last one to the Institute of Bio- and Nanosystems (IBN), the other two can only be identified after further investigation: Jülich Centre for Neutron Science in Garching is an outpost, where IFF is involved. The address, which does not further specify an institute, can only be linked to IFF through the author of the publication.

Since WoS tries to limit the institutional addresses to the top level name, these seven variants are subsumed under three different institutions under "Analyze Results", namely 'Forschungszentrum Julich' (5 publications), 'FZ Julich' (1 publication) and 'Helmholtz Zentrum Julich' (1 publication). Scopus on the other hand is able to affiliate all seven publications to the top level name 'Forschungszentrum Jülich in der Helmholtz Gemeinschaft'. These differences, although they seem small, lead to a difference in the ranking of the most productive institutions in Soft Matter by 21 ranks. The example of the address variants of Forschungszentrum Jülich show that an analysis below the top level of an institution, i.e. a particular department, is only possible by means of a detailed analysis including author names.

2.2.3 Countries

Examining journal contributors on the macro, i.e. country, level is fairly unproblematic since country names are controlled terms in the databases. Like institution names, countries can be extracted from the author addresses stated in the publications (see figure 2.10). An analysis of contributing countries can answer the question whether the particular journal is a national, continental, intercontinental or truly international publication venue (Wormell, 1998).

Countries have been the subject of numerous bibliometric studies, e.g. see Kim (2005); Guan and Ma (2007); Glänzel, Debackere, and Meyer (2008) or Haustein, Tunger, Heinrichs, and Baelz (2011). Wormell (1998), Bonnevie (2003), Bonnevie-Nebelong (2006) and Coleman (2007) applied country-level studies to evaluate the internationality of journal contributions. Diodato (1994) gives a rather general definition of journal internationality, which he calls 'attraction power of a journal':

> The portion of articles that the journal publishes by authors outside the country, language, or organization usually associated with the journal. [...] For example, if a journal is published in France and if there is no restriction on the language of publication, a 100 percent attraction rate for the journal means that all articles are in languages other than French. (Diodato, 1994, p. 4)

Definition and example seem to oversimplify the relation between a country and a journal. In today's processes of scholarly communication it is often hard to determine the nation it is "usually associated" with. The country of origin is usually determined by the publisher. Thus, all Elsevier journals would be defined as Dutch and labeled as international, if they published a high percentage of articles by authors from outside the Netherlands.

While Bonnevie (2003) examines journal internationalization simply as the contribution of major geographic regions, Arvanitis and Chatelin (1988) and Coleman (2007) measure a periodical's internationality by calculating the share of foreign publications or authors in comparison to all publications or authors, respectively.

Since in the sciences journals represent the main channel of communicating research results author addresses listed in articles provide access to evaluate the formal way of international scientific collaboration. A document is referred to as internationally co-authored, if the author addresses include more than one country (Luukkonen, Tijssen, Persson, & Sivertsen, 1993; Moed, 2002; Haustein et al., 2011).

Reasons for international collaboration in R&D can be attributed to different causes. Motives can be subdivided into direct and indirect advantages. Direct benefits involve access to complementary knowledge and research facilities available through the cooperation and also sharing expenses and risks (Kim, 2005; Birnholtz, 2007). Indirect benefits of scientific collaboration occur when academic bonds can be the first step towards economic or political cooperation (Georghiou, 1997). Cognitive, social and cultural factors can influence cooperation between researchers of different nationalities. Language, location, economics and politics can all play a decisive role (Price, 1963; Inonu, 2003; Kim, 2005; Luukkonen et al., 1993; Wagner, Brahmakulam, Jackson, Wong, & Yoda, 2001).

To a large extent, developments in the information and communication infrastructure have enhanced the exchange of information and thus collaboration between scientists. Among other factors, these improvements have lead to a global increase in transnational research and internationally co-authored publications, which can be described as the internationalization of science (Glänzel & De Lange, 1997; Haustein et al., 2011). Average geographical distances between collaborating researchers have increased from 334 km in 1980 to 1,553 in 2009 (Tijssen, Waltman, & Van Eck, 2011). Glänzel and De Lange (1997) report, that in solid state physics international collaboration is governed by bi- and trilateral cooperation.

Analyzing national contributors for periodicals reveals the international scope of the journals. It demonstrates, whether contributions are mainly submitted by authors from one particular country or region or if the journal is truly international and publishes articles from various countries. By comparing author internationality to origin of readership and citations, one can discover interesting discrepancies between output and visibility. For example, if a journal to a large extent publishes documents from authors affiliated with Russian institutions, but if these are frequently cited by authors worldwide, the journal can be attested an international reach despite the nationally oriented contributions.

Coleman (2007) defines journal affinity as

$$\text{journal affinity} = \frac{\sum_{k=1}^{m} F_k}{\sum_{k=1}^{m} N_k} \tag{2.3}$$

where F_k is the number of foreign authors in article k and N_k represents the total number of authors in k. It is not possible to extract information about the connections between all authors and addresses from the 2004 to 2008 WoS data[12]. If there is more than one address and more than one author, it is not possible to match the number of authors to a country. It is thus not possible to determine the exact number of foreign authors. Coleman (2007) limited her study to first authors, because if identified by the journal

12 Since 2008 the address field of the WoS data includes information about the affiliated authors, which makes it possible to determine the exact number of authors per institution and country.

the reprint author is listed together with his or her address. However, limiting the analysis to the first author shows only part of the picture and makes an examination of international collaboration impossible. Thus, internationality is measured by the share of publications which were co-authored by at least one author from the particular country (Christensen & Ingwersen, 1996). Table 2.14 lists the publishing country as registered by Ulrich's Periodicals Directory, number of different contributing countries and percentages of publications for the three strongest contributors[13]. If the country of the publisher is written in italics, it is identical with the strongest contributor. According to Diodato (1994) the attraction power or internationality would be low for these countries. This might be true for J Rheol and Phys Solid State but Phys Stat Sol A is clearly not a German journal but has frequently attracted contributions from 93 different nations (Marx & Hoffmann, 2011). The absolute number of different countries and the distribution of contributors thus seems a better measure to determine the degree of internationality than comparing the journal based on the geographic location of the publisher.

Table 2.14 Internationality of 45 journals including the number of contributing countries (N), the country of publication and the percentage of articles ($P_{\%}$) contributed by the three strongest countries. Italics indicate that the publishing country and the strongest contributor are identical.

Journal	N	Country of publisher	Contributing countries ($P_{\%}$)		
J Rheol	32	*USA*	USA (53.0)	FRA (11.5)	ENG (6.9)
Rep Prog Phys	36	GBR	USA (38.2)	DEU (19.1)	FRA (9.3)
Rev Mod Phys	36	*USA*	USA (28.4)	ENG (20.5)	DEU (17.4)
IEEE Nanotechnol	38	*USA*	USA (48.4)	KOR (11.6)	JAP (7.5)
Act Cryst A	41	DNK	USA (26.4)	DEU (14.7)	FRA (11.4)
Soft Matter	43	NLD	JAP (26.7)	USA (11.9)	CHN (11.2)
Ann Phys	44	*DEU*	DEU (39.9)	USA (17.9)	ENG (5.4)
Phys Solid State	45	*RUS*	RUS (83.4)	UKR (11.5)	DEU (4.9)
Phys Today	46	*USA*	USA (44.3)	ENG (2.6)	CAN (1.4)
JETP Lett	48	*RUS*	RUS (89.2)	DEU (10.7)	FRA (6.5)
J Low Temp Phys	51	*USA*	USA (29.0)	JAP (22.2)	DEU (10.7)
Act Cryst B	52	DNK	ENG (15.2)	DEU (14.4)	USA (14.4)
Eur Phys J E	55	DEU	FRA (32.4)	DEU (24.5)	USA (13.2)
Phys Rep	55	NLD	USA (32.6)	DEU (23.2)	FRA (14.7)
J Vac Sci Technol A	56	*USA*	USA (37.5)	JAP (14.2)	KOR (10.3)
J Stat Mech	58	GBR	FRA (23.8)	USA (18.1)	DEU (17.9)
Phys Fluids	60	*USA*	USA (42.0)	FRA (14.1)	ENG (9.6)
J Stat Phys	61	*USA*	USA (31.3)	FRA (21.5)	ITA (13.1)
Solid State Ion	61	NLD	JAP (23.2)	USA (15.9)	CHN (13.3)
Pramana	64	*IND*	IND (62.2)	USA (11.1)	DEU (6.4)
Supercond Sci Technol	64	GBR	JAP (23.2)	USA (15.9)	CHN (13.3)

continued on next page

13 Internationally co-authored publications count as a whole publication for each of the contributing countries, thus the sum of all percentages is greater than 100%.

Journal	N	Country of publisher	Contributing countries ($P_{\%}$)		
Hyperfine Interact	65	NLD	DEU (19.0)	JAP (13.0)	USA (12.4)
Int J Thermophys	68	*USA*	USA (19.3)	DEU (13.5)	JAP (13.3)
New J Phys	69	GBR	DEU (30.5)	USA (22.9)	ENG (16.3)
Comput Mater Sci	71	NLD	CHN (18.0)	DEU (13.9)	USA (11.7)
Nanotechnol	75	GBR	USA (24.8)	CHN (24.3)	KOR (7.3)
Appl Phys A	76	*DEU*	DEU (19.7)	CHN (18.7)	USA (14.3)
EPL	77	FRA	DEU (22.1)	USA (18.8)	FRA (18.4)
Physica C	81	NLD	JAP (41.6)	USA (11.5)	CHN (9.8)
Eur Phys J B	85	DEU	FRA (16.8)	DEU (16.8)	CHN (14.8)
Appl Phys Let	86	*USA*	USA (34.2)	CHN (14.6)	JAP (13.5)
Phys Stat Sol B	86	*DEU*	DEU (22.4)	USA (14.8)	JAP (11.3)
Nucl Instrum Meth A	87	NLD	USA (25.9)	ITA (17.6)	DEU (15.8)
J Magn Magn Mater	90	NLD	JAP (23.1)	DEU (11.8)	USA (10.6)
J Phys A	90	GBR	USA (15.2)	ENG (10.8)	DEU (9.9)
Phys Lett A	90	NLD	CHN (35.8)	USA (11.9)	RUS (7.9)
Phys Scr	90	SWE	USA (16.3)	DEU (14.4)	CHN (9.9)
Physica B	90	NLD	JAP (20.7)	CHN (13.6)	USA (13.4)
Phys Rev A	91	*USA*	USA (30.1)	DEU (13.7)	CHN (10.8)
J Phys Condens Matter	93	GBR	USA (16.9)	DEU (16.1)	FRA (12.3)
Nucl Instrum Meth B	93	NLD	USA (18.4)	JAP (13.8)	DEU (12.8)
Phys Stat Sol A	93	*DEU*	DEU (18.9)	JAP (12.7)	FRA (11.6)
J Phys D	95	GBR	CHN (23.0)	USA (13.5)	DEU (8.7)
J Appl Phys	96	*USA*	USA (33.0)	JAP (12.6)	CHN (12.5)
Phys Rev E	101	*USA*	USA (29.0)	DEU (14.5)	FRA (10.1)

A 2-mode network of journals and contributing countries is able to display national and international focuses. Figure 2.17 depicts all 45 journals linked through their most frequently occurring countries according to author addresses. For each of the journals those nations were included that together contributed at least 50% of all publications. On the one hand, the network reveals the central positions of US American and German contributions in solid state physics. The USA were the most frequently contributing country for 23 of the 45 journals. In total, only eight different nations ranked as the most important producers of output among the 45 journals. Germany was the strongest contributor to seven and Japan to five periodicals. The others were China and France (strongest in 3 journals), Russia (2 journals), England and India, which were central contributors of Act Cryst B and Pramana respectively. The network structure is able to identify these regional focuses, e.g. of JETP Lett and Phys Solid State towards Russia and that of Pramana towards India (Haustein, 2011). The national scopes of these journals are confirmed by the composition of the editorial boards examined in section 6.2.

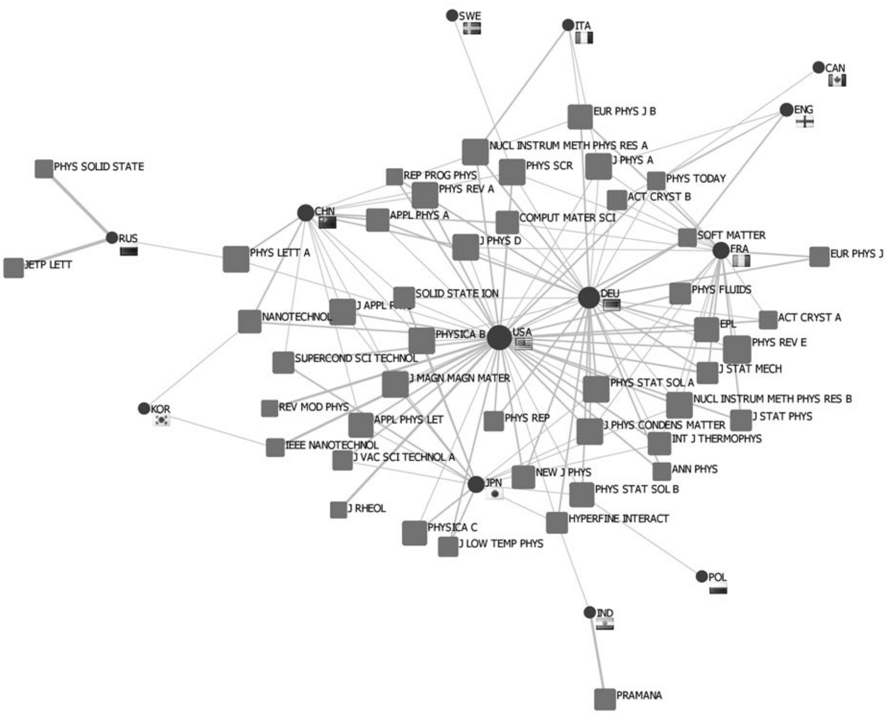

Figure 2.17 2-mode network of 45 journals and their strongest contributing nations. Node size represents absolute number of contributing countries per journal and number of journals involved per country, respectively.

The skewness of the distribution of contributing countries does not, however, necessarily inform about the absolute number of countries involved. Although 62.2% of all documents published in Pramana involved authors affiliated with Indian institutions, authors from 63 other countries published in Pramana as well. With 64 different nations, Pramana thus scores an average value (table 2.14). The number of unique countries per journal ranges from 32 (J Rheol) to 101 (Phys Rev E) with a median of 68 (Int J Thermophys). The number of nations involved per periodical reflects the internationality and is almost normally distributed around 68 countries present. A Pearson's r of 0.613 shows that it correlates positively with the total documents published. Journals with a large output therefore display higher values of internationality. If one normalizes by publication output, Rev Mod Phys shows the highest international involvement.

Summary

This chapter described possibilities of evaluating scholarly journals in terms of their publication output. Although Price (1975)'s prediction of one million scholarly journals has not been reached, the number of periodicals is constantly growing accompanied by an increasing number of documents per journal per year and pages per document.

The most common unit for analyzing journal as well as researcher, institutional and national scholarly output is the single document. Quantity-based research evaluation has led researchers to manipulate statistics by artificially increasing countable output and publishing their results in several instead of in a single article. A number of journal output indicators were introduced in section 2.1. An analysis of the annual number of publications revealed significant differences between journals. Periodicals publish anything between a few to several thousand articles per year integrated in issues appearing at varying intervals between weekly and once a year. While the periodicity of publication used to have an impact on the up-to-dateness of contents and cause publication delay, possibly influencing authors' submission choices, single issues have become less important in electronic publishing, where documents can be accessed online before actual publication.

Each type of document published in a journal serves a different purposes. Research articles and proceedings papers contribute to the advancement of scientific knowledge by describing results of new research. Letters and short communications put special emphasis on the rapidity and the up-to-dateness of published contents. Review articles summarize previous publications in order to provide an overview of the research field and put single results into context. Other than that there are publications which do not contribute to the advancement of scholarly knowledge directly, but rather round off the journal's contents. An analysis of the distribution of document types distinguishes the journal's focus in terms of scope and aim, which can help readers and librarians to choose the most suitable sources to fulfill their information needs and authors to pick an adequate publication venue.

Examining the length of articles reveals significant differences between the document types so that the number of pages seems a better unit to normalize research output rather than the number of documents. The level of scholarliness is hence better expressed by the median number of references per page than per document, since biases caused by article length are balanced. Periodicals publishing a large number of letters can thus be as scholarly in terms of average number of references as review journals. While the average number of references represents an indicator for determining the overall scholarliness of a journal, the percentage of documents without any references identifies the share of unscholarly papers published.

Citing half-life and the Price index examine the age structure of cited references and thus indicate the up-to-dateness of the knowledge import of the periodical, i.e. the literature used. The diversity of the imported knowledge can be determined through an analysis of the cited sources, which represent the journal citation identity. A low citations/citee-ratio and low self-reference rate indicate a high citing diversity and a wide horizon, which means that these journals frequently import knowledge from various sources. A high self-reference rate and high citations/citee-ratio, on the other hand, reveals a certain degree of isolation.

A network graph of the reference network provides additional information about the structure of the knowledge import process. Central nodes with a high number of inlinks represent authorities that function as the main sources of information in the entire network, while nodes with many outgoing links stand for hubs that review the literature of the field. Isolated nodes reveal peripheral journals that are not well connected to the rest of the network.

The content of scholarly journals is shaped by the contributing authors. The producers of journal output were analyzed on the micro, meso and macro level, i.e. contributing authors, institutions and countries, in section 2.2.

Statistics concerning the number of authors per document reveal differences in the size of author groups between disciplines and journals. The number of unique authors reflects the diversity of contributors that shape journal output. The indicator shows whether the journal is able to persuade a large and diverse group of authors to submit their research results to it. However, homonymy and synonymy problems related to authors' names make it difficult to identify unique persons. Author disambiguation can be approached by the manual construction and maintenance of authority files or rule-based algorithms but has not been entirely solved for large multidisciplinary databases.

Synonyms are even a greater problem in the analysis of contributing research institutions, which represent the medium aggregation level of journal contributors. They provide the infrastructure needed to produce research results published in scholarly journals. Only after intensive data cleaning is it possible to determine the institutions that contribute most frequently to a periodical. A comparison of contributing universities and research organizations among journals reveals which periodical is able to attract the most prestigious departments in the particular field.

On the macro-level an analysis of contributing countries reveals whether the journal has a national or continental focus or is a truly international serial able to attract researchers from all over the world. The absolute number of contributing countries, the number of countries per document and the distribution of documents per country provide insight into the level of internationality of a particular periodical. In a network of journals and contributing countries, the international structures and connections can be visualized.

This chapter showed that the dimension of journal output involves various aspects of the publication output of scholarly journals which cannot be reduced to a single lists that ranks periodicals according to the annual number of documents published. The set of indicators introduced in this chapter can be used to determine a broader picture of journals in terms of output including the levels of scholarliness and internationality, the distribution of document types and contributors and the structure of the knowledge import.

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Chapter 3
Journal Content

When evaluating scientific journals, the thematic content cannot be disregarded. It is crucial to analyze and compare published topics in order to find relevant information. Journals can be ranked by relevance regarding a particular topic. However, it is not possible to make a general judgement as to whether content in one journal is better than in another, since the importance of a topic changes with the perspective of the individual user. Thematic relevance is in the eye of the beholder. When analyzing content it is thus even more important to provide a multidimensional approach and depict published content from various angles. Journal mapping and clustering techniques are able to provide such perspectives.

The academic world has to deal with the problem of massive information overload. Researchers are confronted with the almost impossible task of keeping up with the amount of information available (Garfield, 1984; Wouters, 1999b; Moens, 2000; Kipp, 2005; Bawden & Robinson, 2009). With the emergence of electronic publishing, the amount of documents available has further increased. Researchers are confronted with masses of scientific publications. The challenge is to manage this information overload.

Subject indexing, abstracting and classification schemes organize literature by content and help to create order out of chaos. Classifying is natural to humans. It provides orientation by helping to compare new information with known concepts in our knowledge base, which makes it easier to understand (Cleveland & Cleveland, 2001; Bertram, 2005). Subject indexes and classification systems help researchers to find publications relevant to their area of research in order to fulfill their specific information needs (Stock & Stock, 2008).

The present chapter will describe different indexing methods and existing tools which can be used to analyze and depict journal content. Periodicals can either cover a broad field and more general topics or focus on a specific area of research. Content analysis can reveal the specific topics dealt with in the journal.

> Identified thematic trends and conceptual structures can improve our understanding of what topics are hot, how long a particular thematic trend is expected to grow, and how a variety of topics fit on a global intellectual picture. (Chen, Song, Yuan, & Zhang, 2008)

Comparing published content over time allows insight into the development of hot topics, shifts in emphasis or even the development of new research areas.

Content description is defined by ISO 5127 (2001) as a

> description based on data taken from the document and resulting from the assignment of index terms or notations from an indexing language. NOTE Content description may also be achieved through textual representation and the assignment of index terms may be derived intellectually or by mean of programmes.

Three actors can be identified when it comes to providing information about content of scientific publications: the author, who provides content in the form of the fulltext, summarizes it in an abstract, sometimes indexes it with keywords or provides access to relevant literature by citations. The professional indexer, who functions as an intermediary between author and reader, indexes documents for retrieval in order to manage the huge amount of scientific output. Recently a third perspective has been added by the user's, i.e. reader's, point of view (Kipp, 2005; Peters & Stock, 2007). Readers index content themselves by assigning freely chosen uncontrolled terms, so-called tags, to documents (Peters & Stock, 2007; Peters, 2009).

Since all of these perspectives provide access to journal content and may reflect different access points, they are examined in this chapter. While section 3.1 gives an overview of different indexing methods from a theoretical perspective, section 3.2, section 3.3 and section 3.4 are concerned with journal content analysis in practice. Section 3.2 differentiates between indexing on the journal level (section 3.2.1) and article level (section 3.2.2). Various methods are applied to the set of 45 journals. Different approaches for representing content are considered: the authors' perspective (p. 106) is described as well as the approach by professional indexers (p. 114) and the analysis of social tagging is introduced to represent a reader-specific view of journal content (see p. 121). Section 3.3 describes thematical changes over time. Section 3.4 focuses on similarities and differences between periodicals and combines clustering methods with content description from the authors', indexers' and readers' perspectives.

3.1 Digression: Indexing Methods

Knowledge representation and organization aims to manage the information overload by summarizing and structuring documents to improve the retrieval of relevant content (Stock & Stock, 2008). Besides serving information retrieval, subject indexing provides orientation about the subjects (Bertram, 2005). Content is summarized by the application of controlled vocabulary to avoid ambiguities derived from "the complexity, variability, and richness of natural language" (Cleveland & Cleveland, 2001, p. 35), which manifest themselves in phenomena like polysemy, homonomy and related terms (Bertram, 2005; Kipp, 2005).

ISO 5127 (2001) defines indexing as

> denotation of the content or form of a document by means of words, phrases or notations according to the rules of an indexing language.

Indexing comprises all methods and approaches which aim to provide metadata for documents to represent their content and improve their retrieval (Nohr, 2005). In subject indexing, terms are assigned to represent document text. Index terms can be natural language terms drawn from the document text or controlled terms, or they may be represented by artificial terms, called notation (Moens, 2000). Of course, an index is not able to fully represent a document's concepts. Subject indexing thus compromises in the sense that not all information included in the document can be conserved. Index terms do, however, represent basic concepts of the document allowing the user to grasp the essential thematic content. He should then be able to decide if it is relevant to him and hence worth reading (Moens, 2000; Cleveland & Cleveland, 2001).

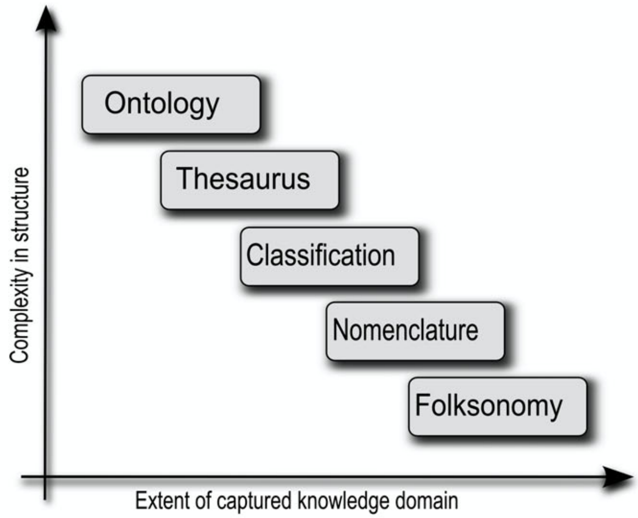

Figure 3.1 Five types of knowledge organization systems arranged according to complexity and extent of knowledge domain. Source: Weller (2010, p. 21).

There are different kinds of knowledge organization systems, which vary in terms of complexity and extent of the knowledge they cover. Weller (2010) describes the trade-off between the two:

> The more a knowledge organization system makes use of semantic relations, the more complex it is in semantic structure. But the more complex the structure, the smaller the captured knowledge domain will have to be, due to reasons of feasibility [. . .]. (Weller, 2010, p. 21)

Nomenclatures, thesauri and classifications represent the well-established types of knowledge organization systems. These three have recently been complemented by ontologies at the one and folksonomies at the other end of the spectrum (Stock, 2009, 2010). Ontologies represent the most complex form of these five systems because they are able to depict semantic and syntactic relations between different terms in great detail (Nohr, 2005; Stock, 2010; Weller, 2010). Ontologies represent the vocabulary of a specific domain and describe concepts, instances and relations in machine-readable formal language. Due to their complexity they have to compromise in the extent of the knowledge domain they can capture (Weller, 2010). Folksonomies complement the traditional knowledge organization systems at the other end of the knowledge organization spectrum. They have little structure but represent knowledge from the users' perspective in an uncontrolled manner (Peters, 2009). Since ontologies are not applied in journal indexing, they are not discussed here. For a detailed overview refer to Weller (2010). Nomenclatures are omitted for the same reason: they are not used for indexing physics journals, but are, for example, applied for to indexing in chemistry.

The following sections focus on those indexing methods and knowledge organization systems that are applied to represent journal content. Social tagging, i.e. folksonomies, is introduced as a new, user-generated approach to content evaluation.

3.1.1 Classification Systems and Thesauri

While most literature on indexing and abstracting differentiates strictly between classification schemes and thesauri, differences are merely operational. When it comes to describing journals and their content, there is no general difference between the two. Both methods aim to represent the content of indexed entities using controlled vocabulary (Cleveland & Cleveland, 2001).

> Classification and indexing via a hierarchical classification system or thesaurus are common methods of attempting to resolve [the] problem [of locating relevant documents] by using controlled vocabularies to rationalise natural languages by removing ambiguities and consolidating similar items. (Kipp, 2005, p. 419)

Classification schemes assign documents to precoordinate classes, which are represented by an artificial language called notation. Thesauri represent a postcoordinate polydimensional approach which developed through the need for a more flexible method to combine different natural language descriptors (Cleveland & Cleveland, 2001; Broughton, 2004; Batley, 2005; Bertram, 2005). When analyzing journal content this difference becomes negligible. The level on which different methods of indexing are applied is more significant. Subject indexing can apply either to the whole periodical or on the level of single documents. While this section describes the theoretical backgrounds of classification schemes and thesauri, section 3.2 focuses on the practical application of subject indexing to scientific periodicals in general and the 45 physical journals in particular.

ISO 5127 (2001) defines classification as an

> arrangement of symbols indicating concepts into classes and their subdivisions to express generic relations or other types of relation between them.

Cleveland and Cleveland (2001) describe the difference between classification schemes and thesauri as marginal. They represent two methods of subject indexing which aim to represent a document's content adequately by applying one or more index terms. The latter consist of controlled vocabulary terms, which are either represented by natural language terms (in the case of thesauri) or by an artificially constructed language, in which the terms are called notations, that organize items in classification systems. Although indexing based on thesauri usually applies more terms implying more details, the underlying principle of the two methods of subject indexing is however the same:

> The process of deciding what some item is about and of giving it a label to represent this decision is conceptually the same whether the label assigned is drawn from a classification scheme, a thesaurus, or a list of subject headings, whether the item is a complete bibliographic entity or a portion of it, whether the label is subsequently filed alphabetically or in some other sequence [...]. (Lancaster, 2003, p. 17)

Cleveland and Cleveland (2001) state:

> Some people become confused in that in general in numerate classification systems the categories pre-exist and items are dropped into the proper category. With indexing, many terms are assigned to the information item. Some see this as a different activity. Procedurally it is; theoretically it is not. The term is a classification category and when the indexer selects a term she drops the item into that category. The difference is that in indexing the item goes into many more categories than it generally does in a classification system. (Cleveland & Cleveland, 2001, p. 30)

In the following the two approaches, that of classification systems and thesauri, will be described in more detail listing specific advantages and disadvantages with reference to indexing journal content. Since we use subject indexing as a means to depict a summary of the thematic orientation of scientific periodicals, the focus lies on the use of existing indexes and classification systems and not on the process of subject indexing as applied by librarians and information professionals. Procedural methods of indexing such as conceptual content analysis, generalization and translation or detailed operations such as notation building, citation and filing order are thus omitted (Moens, 2000; Lancaster, 2003). For a detailed description of these processes refer to Broughton (2004), Batley (2005) or Bertram (2005).

Classification

There is some confusion when it come to the term ‘classification’, which can refer to the activity of assigning documents to defined classes of a classification system and thus is a specific method of the general subject indexing. At other times the subordinate term of classification is also used as an equivalent of the broader term of subject indexing, which causes confusion (Lancaster, 2003). Following Weller (2010) ‘classification’ is used synonymously for ‘classification scheme’ and ‘classification system’.

Classification schemes are more strict and controlled than subject indexing which assigns terms from a thesaurus. Documents are put into the fixed niches of a system, which is constructed in order to group similar items. Pigeon-holing is explicitly encouraged. Classification is thus a precoordinate approach, because it puts a document into one class of a pre-established system. In physical systems such as library shelves, inter- and multidisciplinary topics raise problems because they deal with topics which would be assigned to more than one prefixed class (Broughton, 2004). This problem applies to journal classification in particular. A journal unites publications on different topics and even if its schematic scope is limited to a specialized area of research, it is difficult to assign a journal to one fixed niche unless these niches represent very broad subject areas. In digital systems, multiple assignment is possible.

Classification schemes are constructed systematically and try to map knowledge universally (e.g. DDC or WoS subject categories, p. 94 and ERA, p. 101) or depict specific disciplines in detail (compare Inspec classification on page 114). Elements are grouped by thematic similarities. While a thesauri provides both, an alphabetic and systematical entry to index terms, a classification scheme is always built systematically. It is always constructed hierarchically, which allows for a distinction between broader and narrower subjects (Bertram, 2005). Specificity increases with the level of a subclass

(Broughton, 2004). Enumerative classification schedules list top-down all possible classes and subclasses. Precoordinated compound classes try to factor in all topics, they want to cover. If new subjects emerge, it is necessary to create new classes. In general it is unproblematic to add lower levels of hierarchy. Including entirely new branches of knowledge can however be problematic, when the structure of the classification scheme is limited. For example, a decimal classification system like DDC[1] only allows for ten coordinate classes on the same level of hierarchy. DDC is thus known to suffer from an inadequate representation of new areas of science and technology like computer science and engineering. The integrity of numbers makes it hard for the system to keep up with new developments in knowledge (Sweeney, 1983). More flexible systems allow for on the fly combination of different basic classes to create the required compound class and are called faceted or analytico-synthetic classifications (Stock & Stock, 2008). Since differences between precoordinate and faceted classification primarily concerns classifiers during the indexing process, details of different approaches are not further thematized. For a detailed description of these processes, see Cleveland and Cleveland (2001) and Broughton (2004).

Classes and subclasses of classification schemes are described by natural language headings that summarize the group's subject. To improve clarity of the structure of the system, headings are represented by an artificial language. These so called notations can be alpha-numerical, are language independent and unique (Stock & Stock, 2008). Documents are assigned one or more notations indicating their affiliation to a particular class within the classification system. When it comes to scientific periodicals, classification can be applied on journal or on article level. Journal classifications are rather broad because the whole periodical has to be represented by a few notations, whereas classification systems indexing single documents represents a more detailed approach. In journal evaluation the classification of single documents facilitates an analysis of assigned notations regarding frequency. Thematic focus areas can thus be discovered.

Thesauri

While a classification scheme provides an usually rather broad overview of thematic content of documents, thesauri offer the possibility to describe entities in greater detail (Moens, 2000). In contrast to a classification system, a thesaurus adapts to natural language terms. Instead of artificially constructed notations, index terms are taken from natural language. The advantage of natural language terms is their expressiveness. A thesaurus is the most common form of a predefined set of controlled vocabulary terms and contains a list of index terms including some basic semantic structure (Salton, 1968; Moens, 2000; Stock & Stock, 2008). ISO 5127 (2001) defines a thesaurus as

> controlled vocabulary including equivalent terms, interrelations and rules of application.

Thesauri try to solve problems of synonymy and semantic ambiguity by controlling the use of index terms (Kipp, 2005). They contain descriptors as preferred terms to be used

1 http://www.oclc.org/dewey

for indexing, as well as non-descriptors, which function as entry points that refer to the descriptors. Furthermore, thesauri contain relations of equivalence, hierarchy or associativity. A non-descriptor points to its synonymous descriptor as USE. Thesauri indicate hierarchical relations to a broader or narrower term by BT and NT or refer to a similar index term as RT for related term. Rules of application are stated in the Scope Note (SN) (Moens, 2000; Nohr, 2005; Stock & Stock, 2008).

The advantage of thesauri in contrast to subject indexing by classification is their flexibility: a document's content can be represented by a variety of index terms and does not have to fit into pre-established classes. Thus, new concepts can be easily integrated (Moens, 2000; Cleveland & Cleveland, 2001; Broughton, 2004).

3.1.2 Human vs. Automatic Indexing

Subject indexing is originally a manual process, consisting of two basic steps, i.e. conceptual analysis and translation into indexing language (Cleveland & Cleveland, 2001). The huge disadvantages of human indexing are evident in the time and effort involved, which lead to enormous costs. An intellectual indexer has to analyze the aboutness of a document in order to assign suitable index terms. The aboutness or topicality of a document describes the subjects and topics discussed (Stock & Stock, 2008). Due the complexity of cognitive processes involved in the creation and understanding of natural language text, methods in intellectual indexing are not yet fully understood and cannot be reproduced automatically (Moens, 2000).

> Such a process would require complete knowledge of the lexical, syntactic and semantic and discourse properties of the texts beside domain world and contextual knowledge. The challenge is to find better text analysis methods that identify the main topics of a text as well as its subtopics with a minimum of reliance upon external knowledge. (Moens, 2000, p. 228)

Although research on the automation of subject indexing has come a long way, automatic methods are still far from capable of replacing human indexing because they are not able to understand document text. Automatic indexing has not managed to replace intellectual methods due to the complexity of human language (Luhn, 1958; Moens, 2000; Lancaster, 2003; Bertram, 2005; Weller, 2010).

> Historically, and still to a large extent today, text indexing or abstracting is done manually - one should say intellectually - by experts. Automatic indexing and abstracting could learn from the human cognitive processes. (Moens, 2000, p. 55)

However, computer-aided and automatic procedures exist, which extract natural language terms from text and assign descriptors from controlled vocabulary. Automated indexing can be subdivided into different levels, which execute intellectually defined rules and algorithms that aim to replace the process of understanding a document's aboutness in order to integrate it into the knowledge organization system, which again has to be pre-established intellectually to some extent. A rule-based approach consists of three steps, where the first one is applied on the word level and eliminates stop words without meaning, unifies morphological variants (stemming) and synonyms and disambiguates homonyms. A second step tries to reduce the extracted words to a few central terms reflecting the document's aboutness, while these are matched to the respective terms or notations in the knowledge organization system in the third step. In the following, theoretical background is provided for the most common approaches, which are also applied in analyzing journal content (Nohr, 2005).

Luhn (1957) was the first to propose to directly extract index terms from the document automatically. His approach is based on the assumption that term frequency represents its importance and can be employed to extract the central concepts of a text:

> It is here proposed that the frequency of word occurrence in an article furnishes a useful measurement of word significance. (Luhn, 1958, p. 160)

This method is called statistical or probabilistic indexing as opposed to methods from computational linguistics based on linguistic rules or lexicons (Bertram, 2005; Nohr, 2005; Stock, 2007; Stock & Stock, 2008). In practice, both approaches are combined to enhance the results of automatic indexing (Stock & Stock, 2008). Moens (2000) describes common methods and processes behind automatic indexing as follows:

> The majority of existing automatic indexing methods select natural language index terms from the document text. The index terms selected concern single words and multi-word phrases and are assumed to reflect the content of the text. They can be directly extracted from the title, abstract, and full-text of a document. (Moens, 2000, p.77)

She further sums up:

> A frequently used process first identifies the individual words of text (lexical analysis) and removes words that do not bear upon content (stop words). It then might conflate the words to their stem (stemming) and possibly recognizes phrases in the text. Finally, it weights words and phrases according to their importance in the text. (Moens, 2000, p. 229 f.)

Technically the direct extraction of individual words from document text, called lexical analysis, is not problematic. Not every word makes a good index term, however. Functional and grammatical words are not suitable as index terms nor are common terms appearing in many other documents of the database as well (Moens, 2000). Useless terms can be excluded by applying a list of stop words, which are not to be used as index terms (Salton, 1968). Generic stop lists contain functional words and can be applied to any document written in that particular language. Generic lists can be supplemented by lists that contain domain-specific stop words (Moens, 2000). Some automatic methods also exclude short terms, because function words tend to consist of a small number of characters. This process is, however, problematic for abbreviations of terms that represent important concepts.

Additionally the process of automatic indexing usually applies stemming. Stemming algorithms try to reduce the morphological variants of extracted words. Stemmers either only conflate singular and plural forms of words into a standardized form or reduce words to their stem or root. The latter is based on the assumption that different words with the same stem are semantically related and different variants should be summarized under one index term, which helps to reduce the number of terms (Moens, 2000). There are different methods of reducing words to their stem. One approach is based on a table that lists stems together with all possible variants and applies stemming by a simple look up. Although the process is guaranteed to find the correct stem, the maintenance of a comprehensive dictionary is costly (Moens, 2000). A more common approach is to apply a set of general language-dependent rules to remove affixes and transform morphological variants into their stem. The Lovins and the Porter algorithm represent the most common rule-based approaches (Lovins, 1968; Porter, 1980; Willett, 2006). The Porter stemmer consists of five basic steps to conflate groups of words with a common stem, which are believed to have similar meanings, into one term (Porter, 1980). Even though this rather simple method conflates some terms incorrectly, i.e. overstemming (e.g. 'relate' and 'relativity') and understemming, it performs at least as well as other more elaborate or complex methods (Porter, 1980). Other stemming approaches are based on the frequencies of letter sequences to detect morphemes (Hafer & Weiss, 1974) and clustering of similar words by comparing character sequences by the n-gram method (Damashek, 1995).

After preprocessing, i.e. lexical analysis, stop word removal and stemming, term frequency can be calculated. Term weighting can be applied to chose the most suitable terms for indexing by applying Zipf's law or TF-IDF (Moens, 2000). In order to further conflate and standardize terms and to check for synonyms and semantic ambiguities, terms can be matched to a pre-established thesaurus. While automatic methods manage to extract natural language terms or assign the matching descriptor from a thesaurus, building a thesaurus automatically remains problematic (Moens, 2000).

3.1.3 Author Keywords

Author keywords are index terms chosen by the author to best reflect the topics discussed in the particular publication (Diodato, 1981). Literature on this method of indexing is, however, very rare. Kipp (2006a) supposes that this might be due to difficulties in data aggregation (Kipp, 2005, 2006a). Author indexing is a method applied to relocate the process of intellectual indexing to the person who is supposed to know a document's content best: its creator. Although the author's perspective and language to describe the subject matter of the particular publication are already represented by title and abstract terms, author keywords help to reduce the content to a few significant and central terms, which can help potential readers to decide upon the relevance of the document (Diodato, 1981; Moens, 2000; Peters & Stock, 2007; Peters, 2009). In contrast to title and abstracts, which are reduced representations of a document's content, author keywords carry meaning and are of central importance to the article's topic. There is no need to extract the most suitable terms for indexing from the text, because this step has already been carried out by the author, who is supposed to be able to choose terms that reflect content best (Moens, 2000; Booth, 2001). Although author indexing has the advantage of being free of charge, it also suffers from indexing inconsistencies arising through a vast number of different indexers. It suffers from problems based on synonymy and homonymy, if natural language terms can be applied without any vocabulary control. Also index terms applied by authors may differ from those assigned by professional indexers. The author aboutness may represent the intended content but is also subjective. While the indexer aboutness is more objective, it also depends on the interpretation of content by the indexer and always serves a purpose (Stock & Stock, 2008). Author keywords are examined in section 3.2.2.

3.1.4 Citation Indexing

Another but entirely different approach to subject indexing is the indexing method based on citations. Garfield (1979) reduces the concept of citation indexing to its essentials:

> Citations are the formal, explicit linkages between papers that have particular points in common. A citation index is build around these linkages. It lists publications that have been cited and identifies the sources of the citations. Anyone conducting a literature search can find from one to dozens of additional papers on a subject just by knowing one that has been cited. (Garfield, 1979, p. 1)

Based on the assumption that a citation reflects transfer of information from the cited to the citing document and thus a contextual connection, citation indexing can be regarded as an indirect method of subject indexing. Citation indexing can be used to cluster documents which are thematically related (Cleveland & Cleveland, 2001). Citation indexing was first applied in the legal profession by Shepard's Citation, a citator service established in 1873 to keep track of the future influence and application of legal decisions (Garfield, 1979; Young, 1998; Wouters, 1999a; Stock & Stock, 2008). The underlying idea was taken up by Eugene Garfield at the Institute for Scientific Information and applied to scientific literature. Wouters (1999a, 1999b) gives a very detailed overview including a personal communication of how this idea was developed and by whom Garfield was influenced. The basic idea behind establishing a citation index for scientific literature was to allow researchers to access all documents that refer to earlier publications in order to keep track of developments and have an overview of where results and published information are used. He compared it to an "individual clipping service" (Garfield, 1955, p. 109) that would help researchers to become systematically aware of where earlier publications are perceived and if results and method are adopted, criticized or further developed:

> It is too much to expect a research worker to spend an inordinate amount of time searching for the bibliographic descendants of antecedent papers. It would not be excessive to demand that the thorough scholar check all papers that have cited or criticized such papers, if they could be located quickly. The citation index makes this check practicable. (Garfield, 1955, p. 108)

Garfield felt confident that citation indexing would solve the limitations of traditional subject indexing:

> [...] it is impossible for any one person (the indexer) to anticipate all the thought processes of a user. Conventional subject indexes are thereby limited in their attempt to provide an ideal key to the literature. The same may be said of classification schemes. In tracking down the origins of an idea, the citation index can be of real help. (Garfield, 1955, p.110)

Since citation indexing is based on the direct contextual connection between publications and reflects the placement of a document in relation to the previous literature by the author, it is independent of intellectual interpretation of meaning by an intermediary. Its independence from natural language index terms and artificial notations avoids semantic problems and all the problems involved with conventional subject indexing such as time consumption and cost intensity or natural language ambiguities. Citation indexing thus forms a direct channel between author and reader (Garfield, 1979; Cleveland & Cleveland, 2001).

One year after the publication of the Genetics Citation Index, which was a citation index containing 146,000 publications and 246,000 references from genetics research in 1961, the first SCI was published in 1964. With its annual compilation and steady increase in coverage, the SCI laid the foundation for a new area of information science focusing on the evaluation of scientific output and visibility, namely scientometrics (Garfield, 1979; Wouters, 1999a, 1999b).

Besides all its advantages over intellectual subject indexing, the citation-based method also has some shortcomings. While Shepard's includes an intellectual judgement on the nature of the issued citation with respect to its source, i.e. if it referred to the cited publication in a positive or negative manner, citation indexing does not supply such information. The SCI cannot supply such judgements due to sheer mass of documents and the fundamental difficulty of evaluating whether a citation is of a positive, negative or neutral nature (Stock & Stock, 2008). The only one capable, if any, of rendering such a judgement would be the author.

The descriptive-intertextual approach by Rauter (2007) requires authors to include their motives in citing a particular source by including superscript letters (*p* for a positive, *n* for a neutral and *a* for a negative reference) in the text's footnotes (Rauter, 2006, 2007). The practicability of this approach, which would require the whole process of scientific communication and publishing to adapt to it, remains, however, highly questionable.

It is therefore at present impossible to know whether a citing author regarded the document's content favorably, whether he criticized the results or if the reference was made from a neutral perspective. While the missing information about the positive or negative nature of the citation does not affect the basic assumption of contextual relations between the citing and the cited document, there are other problems involved in citing publications that do. There are many reasons, besides direct thematic relations, for citing a document as there are reasons not to cite it. Brooks (1986) lists seven motives for citing. Camacho-Minano and Núnez-Nickel (2009) review all the literature discussing and analyzing researchers' citing motivations. They differentiate between normative and social constructivist theories. While the former refers to creating and validating scientific knowledge, the latter comprises the social and economic processes involved in the production of science. They come to the conclusion that, although intensively explored for over 30 years, questions regarding citers' motivations cannot yet be fully answered (MacRoberts & MacRoberts, 1984; Brooks, 1986; Vinkler, 1987; Stock, 2001; Bornmann & Daniel, 2008; Camacho-Minano & Núnez-Nickel, 2009; MacRoberts & MacRoberts, 2010).

What can be acknowledged is that citation indexing can be used to find topically related literature, but that it cannot fully replace other indexing methods as Garfield had predicted in the early years (Garfield, 1955, 1979). Due to its dependence on differing motivations for citing or not citing, citation indexing is neither able to index all the relevant literature, nor can an immediate contextual relation between the citing and the cited document be guaranteed to the full extent. Bearing these shortcomings in mind (as all citation analyses do), citation indexing can be applied in order to cluster similar documents.

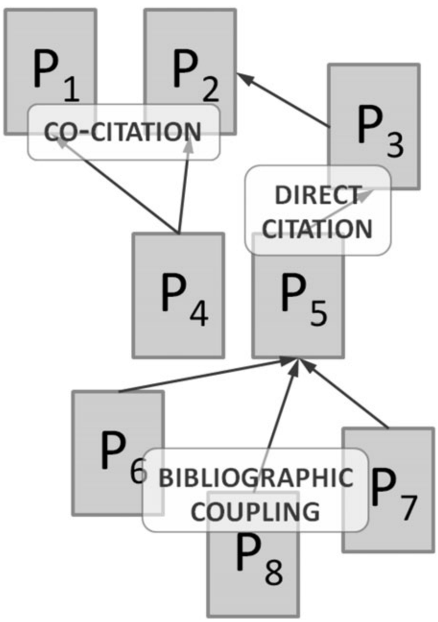

Figure 3.2 Schematic representation of citation-based similarity measures: direct citation, bibliographic coupling and co-citation patterns; arrows represent references from the citing to the cited document.

Content similarity cannot only be indicated by direct citations between documents, but is also assumed to exist between two documents that either cite the same or were cited by the same publication. The first concept is referred to as ‘bibliographic coupling’ and was developed by Kessler (1963a). Kessler (1963a) argues that two documents are similar if they list the same documents in their reference lists (compare documents P_6, P_7 and P_8 in figure 3.2, which all cite document P_5). The more cited publications they have in common, the more related these documents are supposed to be (Kessler, 1963b, 1963c, 1965; Ahlgren & Jarneving, 2008).

In addition to direct citations and bibliographic coupling both Small (1973) and Marshakova (1973) independently add a third measure to discover contextual relations between documents. Small (1973) defines co-citations as a link between two documents by a third citing both (compare documents P_1 and P_2 in figure 3.2, which are co-cited by P_4). The difference between bibliographic coupling and co-citations is described as follows:

> In measuring co-citation strength, we measure the degree of relationship or association between papers as perceived by the population of citing authors. Furthermore, because of this dependence on the citing authors, these patterns can change over time, just as vocabulary co-occurrences can change as subject fields evolve. Bibliographic coupling, on the other hand, is a fixed and permanent relationship because it depends on references contained in the coupled documents. Co-citation patterns change as the interests and intellectual patterns of the field change. (Small, 1973, p. 265)

Direct citations, bibliographic coupling and co-citations can measure the degree of similarity between two documents either by the absolute number of citations, shared references or co-citations, usually through the application of a certain threshold. A more suitable form of measurement, however, is to apply some form of normalization to make up for differences in the length of reference lists or the number of received citations. For example, two documents are assumed to be more alike if they were both cited by a research article listing 15 references than by a review paper citing 150 source articles. The same applies to co-citations. Normalization is thus based on the total number of listed references or citations received and can be calculated by different measures of similarity, e.g. cosine, Dice or Jaccard similarity indexes (Qin, 2000; Stock & Stock, 2008; Peters, 2009; Sasaki, Miyata, Sakai, Inazumi, & Kobayashi, 2009).

Direct citations, bibliographic coupling and co-citation data have been used for information retrieval purposes (Bichteler & Eaton, 1980) and predominantly for clustering similar documents (or if aggregating data, authors, journals, scientific disciplines and institutions) for science mapping (Small, 1994; Persson, 1994; Tsay, Xu, & Wu, 2003; Boyack, Klavans, & Börner, 2005; Jarneving, 2007; Ahlgren & Jarneving, 2008; Ahlgren & Colliander, 2009; Shibata, Kajikawa, Takeda, & Matsushima, 2009; Sternitzke & Bergmann, 2009; Boyack & Klavans, 2010). Boyack and Klavans (2010) state a preference in science mapping for co-citation analysis over the other two similarity clustering techniques. Direct citations between documents are hardly applied due to the need for a long time window. Also, Boyack and Klavans (2010), who applied different clustering techniques to a set of more than 2 million documents from biomedical science, showed that direct citations produced the most heterogeneous results. Co-citation and bibliographic coupling clusters usually differ to some extent, with co-citation clusters being closer to calculations based on direct citations (Small, 1973). Bichteler and Eaton (1980) applied bibliographic coupling and co-citation analysis to information retrieval and showed that a combination of the two worked best. Boyack and Klavans (2010) obtained the best clustering results through a combination of bibliographic coupling data and similarity values based on title and abstract words. For the detection of new emerging research fronts, direct citations proved to be the best and co-citation analysis the worst method due to the time lag of the latter (Shibata et al., 2009). Hence, the choice of underlying data for the clustering of similar documents depends primarily on the particular research question which it intended to help to answer. A clear definition of the data set which includes a strict differentiation of references and citations is thus indispensable, as Price (1986) pointed out earlier.

When analyzing similarities between journals based on the structure of their communication processes, three types of citation relations can be evaluated: direct journal citations, journal co-citations and bibliographic coupling of journals. Following McCain (1991), citation linkages between journals are computed by counting the number of articles from one journal which cited another. Journal co-citations hence "count all articles co-citing at least one article from each of two journals" (McCain, 1991, p. 22). An article co-citing two periodicals is thus always counted as one journal co-citation regardless of how many publications from the two periodicals it listed in its reference list. Co-citation strength between two journals thus increases with the number of different documents citing articles from both journals and not necessarily with the absolute citation count (McCain, 1991). The same applies to bibliographic coupling and direct citations on the journal level: journal citation strength is based on the number of citing articles and does not depend on the number of cited articles (McCain, 1991; Tsay et al., 2003).

After generating a matrix that contains the raw data for the particular type of citation relations (direct citations, bibliographic coupling or co-citations), similarity values are computed in order to normalize the matrix by size (Van Eck & Waltman, 2009). Usually thresholds are defined to depict only strong similarities before applying clustering and mapping techniques to visualize journal relatedness (Börner, Chen, & Boyack, 2003; Tsay et al., 2003). In order to depict similarities that reflect the structure of the entire communication process of scholarly journals, i.e. knowledge import and export as represented by references and citations, bibliographic coupling and co-citation matrices can be combined to give a more robust picture of contextual relationships. This method is applied to the 45 journals in section 3.4.1.

3.1.5 KeyWords Plus

KeyWords Plus are automatically generated index terms included the bibliographic records in WoS based on "frequently occurring words in the titles of an article's cited references"[2]. Thus, this automatic approach is built on the basic assumption of citation indexing that a citation reflects thematic similarity (compare section 3.1.4). It involves indexing a document indirectly through its cited references and is thus derivative (Garfield & Sher, 1993). Qin (2000) describes the approach as 'citation-semantic':

> By selecting the original key words or phrases used by authors in the cited document titles, the KeyWords Plus preserves the cognitive, methodological, and theoretical links between the new (source) document and the old (cited) works. In this sense, the KeyWords Plus can be considered as citation-semantic, or cognitive, indexing compared to the analytic indexing where terms are assigned by human indexers according to their perception and understanding of the document content. (Qin, 2000, p. 166)

Algorithms extract the most suitable phrases from the titles of all cited references included in the WoS citation indices. The most frequent terms or phrases are assigned to the source document as KeyWords Plus. A more detailed description of the generation

2 http://images.isiknowledge.com/WOK46/help/WOS/h_fullrec.html

process can be found in Garfield (1990) and Garfield and Sher (1993). Examples of analyses based on KeyWords Plus can be found in Buter, Noyons, and Van Raan (2010), Li, Zhang, Wang, and Ho (2009) or Qin (2000). In section 3.2.2, KeyWords Plus represent the automatic indexing method and are compared to reader-generated tags together with professional indexing and title and abstract terms.

3.1.6 Social Tagging

Chapter 4 describes how informetric studies focus on the user of scientific publications by analyzing the click and download data of electronic articles to generate statistics about journals and articles in a quantitative manner (Gorraiz & Gumpenberger, 2010; Rowlands & Nicholas, 2007; Bollen, Van de Sompel, Smith, & Luce, 2005; Darmoni, Roussel, & Benichou, 2002). While electronic publishing laid the groundwork for these kinds of statistics, new developments in Web 2.0 grant access to an additional layer of metadata, which reflects the user, i.e. reader-specific, view on content (Peters & Stock, 2007).

With the emergence of Web 2.0, online services have been developed which concentrate on user-generated content and collective intelligence. The idea behind this concept is that

> in a community large enough there will always be at least one expert on any given topic, and that bundled knowledge will help to correct for mistakes and eliminate spam. (Weller, 2010, p. 68)

Following the prosumer concept of Toffler (1980), the former consumer of knowledge additionally becomes a producer as well. Peters (2009) differentiates between two kinds of collaborative information services, namely sharing services (such as YouTube[3] and Flickr[4]) and social bookmarking services such as Delicious[5]. The latter have found their way into academia as online reference management services. Enabling researchers to store, search and share interesting resources, these platforms are designed on the model of Delicious, but accommodate the special requirements of academic users, i.e. managing bibliographic metadata of scientific literature (Hammond, Hannay, Lund, & Scott, 2005; Hotho, Jäschke, Schmitz, & Stumme, 2006; Kipp, 2006b; Farooq, Song, Carroll, & Giles, 2007; Hannay, 2007; Capocci & Caldarelli, 2008; Csora, Van der Heyden, & Kersten, 2009; Good, Tennis, & Wilkinson, 2009; Reher & Haustein, 2010). CiteULike was the first service to cater these specific needs. In an interview, CiteULike's Richard Cameron described the motivation behind the development of a bookmarking tool that allowed scientific literature to be stored:

> The reason I wrote the site was, after recently coming back to academia, I was slightly shocked by the quality of some of the tools available to help academics do their job. [. . .] Collecting material for a bibliography is something which appeared to require an amazing amount of drudgery. All the existing options seemed to require more effort than strictly necessary to transfer the citation details for the

3 http://www.youtube.com
4 http://www.flickr.com
5 http://www.delicious.com

> article currently open in my web browser into some sort of permanent storage. [. . .] So, the obvious idea was that if I use a web browser to read articles, the most convenient way of storing them is by using a web browser too. (*Why write CiteULike? Interview with Richard Cameron*, n.d.)

Like other Web 2.0 platforms, social bookmarking services enable their users to annotate electronic documents with freely chosen keywords. These so-called tags can be chosen on the fly without adhering to indexing rules. Thus the barrier for user participation is fairly low (Pierce, Fox, Rosen, Maini, & Choi, 2008). By tagging articles, academic prosumers generate new information about resources (Tenopir & King, 2009). While all the tags occurring on a platform are called a 'folksonomy", the totality of all the tags assigned to one particular document is called a 'docsonomy' (Vander Wal, 2005; Peters, 2009; Terliesner & Peters, 2011). Tags can help both the user who picked them to organize his documents and other users to find new content (Mathes, 2004; Peters, 2009; Strohmaier, Körner, & Kern, 2010).

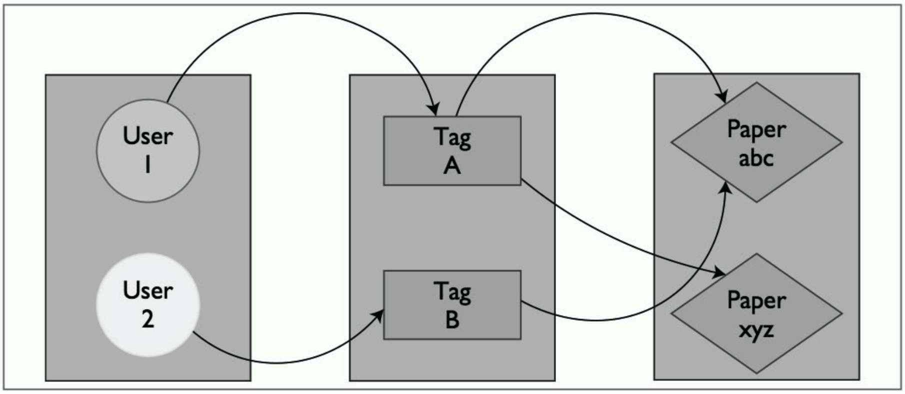

Figure 3.3 Anatomy of a tag application. Source: Farooq et al. (2007, p. 30).

The anatomy of a tag application is based on a tripartite graph of the user-tag-resource triple (Farooq et al., 2007; Cattuto, Benz, Hotho, & Stumme, 2008; Peters, 2009). Entities are connected in any way possible via their threefold relationships. Users and resources are connected through common tags (compare figure 3.3). Also corresponding bipartite relationships of user-tag, user-resource and resource-tag can be extracted (Van Damme, Hepp, & Siorpaes, 2007). With respect to the application of social tagging to subject indexing of scientific publications, the latter connection is of particular interest.

With social tagging a new dimension of indexing evolves, which represents the users', i.e. readers', point of view on content. Social tagging offers additional metadata and adds a new user-specific dimension of indexing to the traditional perspectives of author and intermediary indexing (Kipp, 2006a, 2006b; Peters & Stock, 2007; Stock, 2007; Peters, 2009). Readers take a different approach for indexing documents. In contrast to the indexer, who aims to cover all the topics discussed in the document, users are likely to highlight a few specific topics, in which they are particularly interested (Lin, Beaudoin, Bul, & Desai, 2006; Haustein, Peters, & Terliesner, 2011).

Precisely due to their flexibility, folksonomies, however, share all the problems of uncontrolled vocabulary: synonyms and homonyms are not recognized; there is no control for any semantic relations. What is more, social tagging introduces new particular problems: tags can be assigned in any language and do not only include contextual meaning but may be judgemental or performative (Kipp, 2007). For example, the user can refer to an article as 'important' or tag it with 'to_read'. The latter example introduces another tag-specific problem: since single tags are separated by blanks, phrases and compound words need to be compiled (Weller, 2010). Since social tagging is not regulated, different methods of coping with these kinds of tags have been established: words are either separated by special characters like underscores or hyphens or simply written together without blanks. The term 'social tagging' can thus appear in the form of 'social_tagging', 'social-tagging' or 'socialtagging' etc. This presents an entirely new, tag-specific form of synonymy. Current research in Web 2.0 deals with these tag-specific problems. Simple automatic methods have been introduced to clean and adjust these problems – for example the tag gardening approach by Peters and Weller (2008) – but current methods are not yet able to fully account for these problems.

However, there are also advantages in extending methods of subject indexing to social tagging. Folksonomies authentically represent the users' language. Tags and tag frequencies can offer direct channels to the readers opinions. While indexers focus on reflecting the whole aboutness or topicality of a document's content, tags reflect the content as perceived by the readers. Although this conveys a rather subjective perspective, meaning reveals actual comprehension, which can differ from what was intended by the author:

> A text has an intrinsic subject, an aboutness, but has a variable number of meanings in accordance with the particular use that the person can make of the aboutness at a given time. (Moens, 2000, p. 12)

While the author-aboutness is permanent, the user-aboutness, i.e. meaning and informativeness, which is the new information a reader gains by reading a document, can change over time (Moens, 2000; Stock & Stock, 2008). Due to the dynamic nature of social bookmarking and tagging, content descriptions evolve in real time. Topical trends and changes in the language of a specific discipline can be depicted, whereas this information is lost when content is translated to controlled vocabulary by the indexer (Peters, 2009; Haustein et al., 2011).

Keeping these specific limitations in mind, social tagging can be applied as one method to index scientific articles from a distinct point of view. Tags add another layer of metadata to documents and provide a reader- (as opposed to author- or indexer-specific) perspective on the description of journal content. Multiple interpretations of content become possible (Peters & Stock, 2007; Peters, 2009; Haustein et al., 2011). These new possibilities are described in detail on page 121.

3.2 Level of Analysis

If applied to scientific periodicals, subject indexing can either be carried out by treating the whole journal as one item or accessing each document separately. While section 3.1 provided the theoretical background including advantages and disadvantages of different indexing methods, section 3.2 will apply existing solutions to the set of 45 journals. This practical approach will, on the one hand, show how scientific periodicals can be evaluated in terms of subjects covered but also identify limitations. Section 3.2.1 will introduce two classification schemes used to index journals (the WoS subject categories and ERA systems) and section 3.2.2 will describe three possibilities of accessing subject indexing on the article level, i.e. indexing by authors, information professionals and users.

3.2.1 Journal Level

Journal classification schemes assign periodicals to different scientific disciplines or subdisciplines. Classification is usually applied by experts when a journal is added to a database or library catalog. Hence, the classification schemes fulfill database-specific requirements and are far from being perfect or complete:

> Classification of science into a disciplinary structure is at least as old as science itself. After many centuries of constructive but yet inconclusive search for a perfect classification scheme, the only sensible approach to the question appears to be the pragmatic one: what is the optimal scheme for a given practical purpose? To this end, ever so many systems have been conceived and installed by general and special libraries, publishers, encyclopedias and, in ever growing number, by electronic databases, internet based information services, web crawlers, etc. (Glänzel & Schubert, 2003, p. 357)

Chen (2008) puts it in a nutshell:

> The scientific knowledge of human beings is a complex and dynamic network. Due to its complexity, finding a perfect classification scheme for scientific networks remains an unsolved problem for scientists and librarians thus far. (Chen, 2008, p. 2296)

The most commonly used journal specific classification scheme is the one developed by the ISI, where journals are assigned to one or more subject categories when added to the WoS (Rafols & Leydesdorff, 2009a; Zhang, Liu, Janssens, Liang, & Glänzel, 2010). The allocation of the categories is, however, extremely controversial. In the following, the WoS classification is described in detail and applied to the 45 journals under analysis. An alternative is represented by the hierarchical classification approach established by the Australian Bureau of Statistics (ABS) in 2008.

Web of Science Subject Categories

The subject category classification scheme was constructed manually (Boyack et al., 2005). When journals are added to the WoS database they are assigned to one or more subject categories by ISI staff based on journal title and citation characteristics (Guerrero-Bote, Zapico-Alonso, Espinosa-Calvo, Gomez-Crisostomo, & De Moya-Anegon, 2007; Rafols & Leydesdorff, 2009a). Pudovkin and Garfield (2002) specify the process as follows:

> Journals are assigned to categories by subjective, heuristic methods. [. . .] These procedures are followed by the ISI editorial group in charge of journal selection and are similar to those used for the SCI and Current Contents journal categories. This method is ÒheuristicÓ in that the categories have been developed by manual methods started over 40 years ago. Once the categories were established, new journals were assigned one at a time. Each decision was based upon a visual examination of all relevant citation data. As categories grew, subdivisions were established. Among other tools used to make individual journal assignments, the Hayne-Coulson algorithm is used. The algorithm has never been published. It treats any designated group of journals as one macrojournal and produces a combined printout of cited and citing journal data. (Pudovkin & Garfield, 2002, p. 1113)[6]

Currently[7] there are 222 different categories. 173 are included in SCI, 55 in SSCI and six categories appear in both. The classification of the WoS subject categories is non-hierarchical and levels of specialization can differ greatly (Leydesdorff & Rafols, 2009). For example, there are 53 categories concerned with medical topics and only ten for chemical journals. The two categories named “Ornithology” and “Biology” are treated equally. The number of publications in scientific disciplines composed of subject categories is highly skewed (compare figure 3.4) and so is the number of journals within a category. “Materials Science, Coatings & Films” contains only 17 periodicals, while “Engineering, Electrical & Electronic” aggregates 246 different journals (compare section 3.2.1).

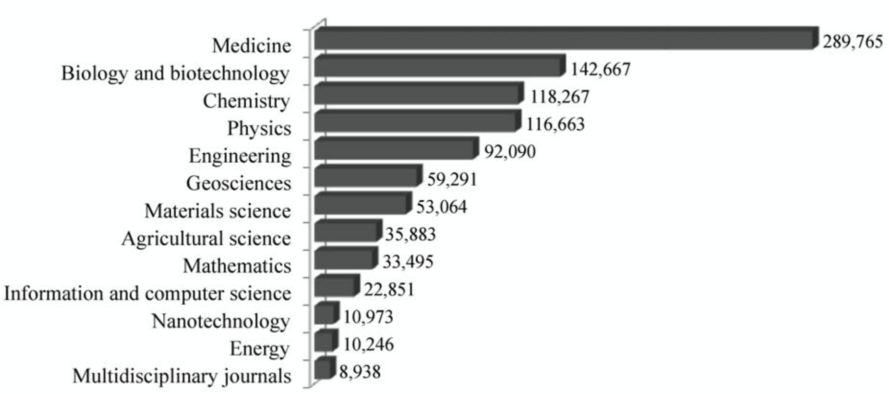

Figure 3.4 Number of articles and reviews published in 2007 assigned to twelve scientific disciplines based on WoS subject categories.

6 ‘Subdivisions’ are not to be understood in the hierarchical sense but as splitting one large category into two smaller ones: the subject category scheme does not include any hierarchical information.

7 Data is based on JCR 2009 edition accessed in 2011.

Occasionally, changes are applied to the WoS scheme (Leydesdorff & Rafols, 2009). New categories are added if the existing classes no longer suffice anymore to depict the current landscape of scientific communication (Pudovkin & Garfield, 2002). When Rafols and Leydesdorff (2009a) and Zhang et al. (2010) evaluated the 2006 edition of JCR, a total of 220 categories existed, 172 of which were in the SCI. Rafols and Leydesdorff (2009a) created a map of science based on similarities of these 220 subject categories, which can be seen in figure 3.5.

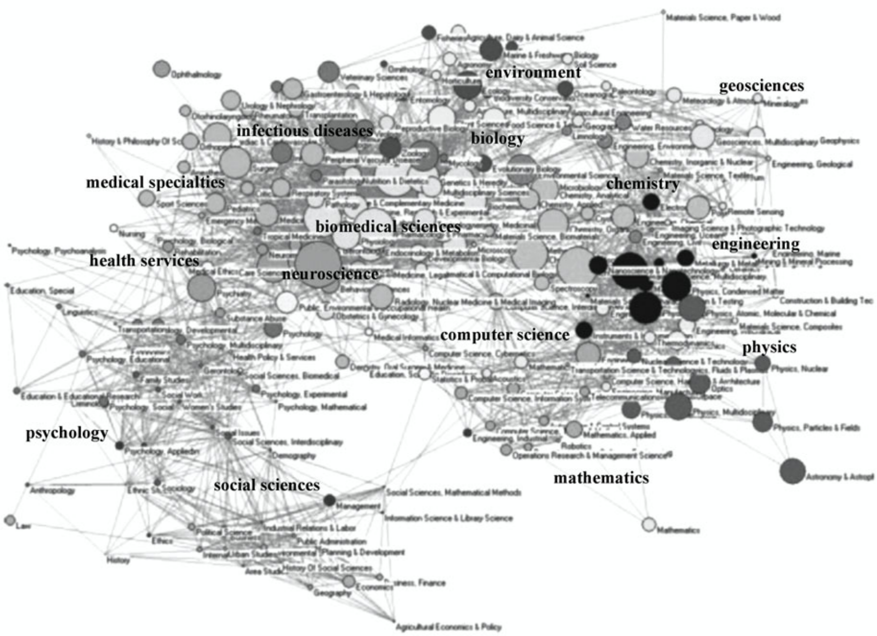

Figure 3.5 Map of science based on similarity of 220 subject categories, own labelling of disciplines. Source: (Rafols & Leydesdorff, 2009a).

Only small changes have occurred since the evaluation by Rafols and Leydesdorff (2009a) and Zhang et al. (2010). Two new subject categories were introduced in the 2009 edition of JCR. "Cell & Tissue Engineering" was added to the SCI and "Hospitality, Leisure, Sport & Tourism" was introduced into the SSCI. "Psychiatry", which was previously included in both indices, was eliminated from SSCI. Since the 1998 edition about 30 categories have undergone alterations. To a large extent, changes occured in category names. For example, "Aerospace Engineering & Technology" was renamed "Engineering, Aerospace" and "Computer Science, Software, Graphics, Programming" changed to "Computer Science, Software Engineering". One category can also be split into two as "Emergency Medicine & Critical Care" became "Critical Care Medicine" and "Emergency Medicine". Since the 1998 edition, twelve new subject categories were launched to represent newly developed research areas, including "Nanoscience & Nanotechnology", "Medical Ethics" and "Biodiversity Conservation". Notably, most of the new classes arise from the medical and life sciences. Besides the emergence of "Nanoscience & Nanotechnology" in JCR 2005, no changes applied to the classification of physics journals. The 45 journals under analysis have been assigned to a total of 22 different subject categories. The scopes of these 22 categories, as defined by Thomson Reuters, are given in section 3.2.1.

Table 3.1 Scope notes for 22 WoS Subject Categories, total number of journals (SO_{WoS}) and number of 45 analyzed journals (SO_{45}) assigned to category. Source: http://science.thomsonreuters.com/mjl/scope/scope_scie/

Subject Category	**Category description**	SO_{WoS}	SO_{45}
Physics, Applied	covers those resources dealing with the applications of condensed matter, optics, vacuum science, lasers, electronics, cryogenics, magnets and magnetism, acoustical physics, and mechanics. This category also may include resources on physics applications to other sciences, engineering, and industry.	108	13
Physics, Multidisciplinary	covers resources having a general or interdisciplinary approach to physics. This category also includes theoretical and experimental physics as well as special topics that have relevance to many areas of physics.	71	13
Physics, Condensed Matter	covers resources that deal with the study of the structure and the thermal, mechanical, electrical, magnetic, and optical properties of condensed matter. Topics covered in this category include superconductivity, surfaces, interfaces, thin films, dielectrics, ferroelectrics, and semiconductors. This category also includes resources from the former category of Solid State Physics as well as resources on condensed fluids.	66	11
Materials Science, Multidisciplinary	covers resources having a general or multidisciplinary approach to the study of the nature, behavior, and use of materials. Relevant topics include ceramics, composites, alloys, metals and metallurgy, nanotechnology, nuclear materials, and adhesion and adhesives.	214	8
Chemistry, Physical	includes resources on photochemistry, solid state chemistry, kinetics, catalysis, quantum chemistry, surface chemistry, electrochemistry, chemical thermodynamics, thermophysics, colloids, fullerenes, and zeolites.	121	4
Mechanics	includes resources that cover the study of the behavior of physical systems under the action of forces. Relevant topics in this category include fluid mechanics, solid mechanics, gas mechanics, mathematical modeling (chaos and fractals, finite element analysis), thermal engineering, fracture mechanics, heat and mass flow and transfer, phase equilibria studies, plasticity, adhesion, rheology, gravity effects, vibration effects, and wave motion analysis.	123	4
Physics, Mathematical	includes resources that focus on mathematical methods in physics. It includes resources on logic, set theory, algebra, group theory, function theory, analysis, geometry, topology, and probability theory that have applications in physics.	47	4
Physics, Atomic, Molecular & Chemical	includes resources concerned with the physics of atoms and molecules. Topics covered in this category include the structure of atoms and molecules, atomic and molecular interactions with radiation, magnetic resonances and relaxation, Mossbauer effect, and atomic and molecular collision processes and interactions.	33	3

*c*ontinued on next page

Subject Category	**Category description**	SO_{WoS}	SO_{45}
Crystallography	covers resources that report on the study of the formation, structure, and properties of crystals. This category also includes resources on X-ray crystallography, the study of the internal structure of crystals through the use of X-ray diffraction.	25	2
Instruments & Instrumentation	includes resources on the application of instruments for observation, measurement, or control of physical and/or chemical systems. This category also includes materials on the development and manufacture of instruments.	58	2
Nanoscience & Nanotechnology	includes resources that focus on basic and applied research at the micro and nano level across a variety of disciplines including chemistry, biology, bioengineering, physics, electronics, clinical and medical science, chemical engineering and materials science.	59	2
Nuclear Science & Technology	covers resources on nuclear energy (fission and fusion processes), nuclear energy and fuel, nuclear power, and nuclear electric power generation. This category also includes resources on nuclear engineering (the branch of technology that applies the nuclear fission process to power generation), nuclear safety, radiation effects, and radioactive waste management. Note: Resources on nuclear physics (low-energy physics) appear in the category Physics, Nuclear.	33	2
Physics, Fluids & Plasmas	covers resources on the kinetic and transport theory of fluids, the physical properties of gases, and the physics of plasmas and electric discharges. This category may include resources on nuclear fusion.	28	2
Physics, Nuclear	includes resources on the study of nuclear structure, decay, radioactivity, reactions, and scattering. Resources in this category focus on low-energy physics. High-energy physics is covered in the Physics, Particles & Fields category.	22	2
Polymer Science	includes all resources dealing with the study, production, and technology of natural or synthetic polymers. Resources on polymeric materials are also covered in this category.	76	2
Engineering, Eletrical & Electronic	covers resources that deal with the applications of electricity, generally those involving current flows through conductors, as in motors and generators. This category also includes resources that cover the conduction of electricity through gases or a vacuum as well as through semiconducting and superconducting materials. Other relevant topics in this category include image and signal processing, electromagnetics, electronic components and materials, microwave technology, and microelectronics.	246	1
Engineering, Multidisciplinary	covers resources having a general or interdisciplinary approach to engineering. Relevant topics include computer science and mathematics in engineering, engineering education, reliability studies, and audio engineering.	79	1
Materials Science, Coatings & Films	covers resources that concentrate on research in coatings and films applied to a base material (substrate). Metals, alloys, resin solutions, and solid/liquid suspensions are the coatings most commonly used in industry. Application methods include electrolysis, vapor deposition, vacuum, or mechanical means such as spraying, calendering, roller coating, extrusion, or thermosetting.	17	1

continued on next page

Subject Category	Category description	SO_{WoS}	SO_{45}
Optics	includes resources that deal with the genesis and propagation of light, the changes that it undergoes and produces, and other phenomena closely associated with it. Resources in this category cover subject areas such as lasers and laser technology, infrared physics and technology, microwave technology, quantum optics, lightwave technology, fiber optics, opto-electronics, and photonics. Resources on photometry and luminescence are also included in this category.	71	1
Physics, Particles & Fields	includes resources on the study of the structure and properties of elementary particles and resonances and their interactions. Resources in this category focus on high-energy physics. Low-energy physics is covered in the Physics, Nuclear category.	27	1
Spectroscopy	covers resources concerned with the production, measurement, and interpretation of electromagnetic spectra arising from either emission or absorption of radiant energy by various sources. This category includes resources that report on any of several techniques for analyzing the spectra of beams of particles or for determining mass spectra.	39	1
Thermodynamics	includes resources that focus on the areas of physics examining the transformations of matter and energy in physical and chemical processes, particularly those processes that involve the transfer of heat and changes in temperature. Relevant topics in this category include cooling and heating systems, cryogenics, refrigeration, combustion, energy conversion, and thermal stresses.	49	1
number of unique journals		*1155*	*45*

Multiple classification is another problem of the WoS scheme. Of the 45 journals analyzed, 20 journals belong to more than one category and six journals were allocated to a total of four subject categories. Thus, on average every journal is related to two categories. Boyack et al. (2005) computed 1.59 subject categories per periodical on average for all journals included in SCI and SSCI in the year 2000. Zhang et al. (2010) calculated 1.54 for the 9,487 periodicals in WoS from 2002 to 2006 and Rafols and Leydesdorff (2009a) came to the same result when they calculated 1.56 categories per journal for the 7,411 periodicals in the SCI and SSCI in 2006. Hence, for the 45 physics journals the number of categories assigned is slightly higher than for all journals in WoS. The two categories "Physics, Applied" and "Physics, Multidisciplinary" are represented most frequently with 13 journals per discipline.

Figure 3.6 shows a 2-mode network graph of the 45 journals and the 22 affiliated subject categories. The network structure reveals important information about the subject areas the journals publish in according to the classification scheme of Thomson Reuters. The larger the size of the category nodes, the more journals are attached to it. The big cluster of multidisciplinary physics is largely remote and is only connected to the rest of the network by J Phys A and Soft Matter. This suggests that the other 11 journals indeed cover the whole discipline of physics or that the category serves as a reservoir for periodicals that do not fit into any other area of research represented by th subject categories. The description given by Thomson Reuters for this discipline reveals that both may be the case: this category sums up "resources having a general or interdisciplinary approach [...] as well as special topics [...]".

The WoS scheme has been severely criticized for its arbitrary structure and misclassification of journals. Boyack et al. (2005) estimated that about half of the journals were assigned improperly (personal communication cited from (Rafols & Leydesdorff, 2009a)) and even Garfield himself admits the inaccuracy and opacity of the subject category classification:

> In many fields these categories are sufficient but in many areas of research these "classifications" are crude and do not permit the user to quickly learn which journals are most closely related. (Pudovkin & Garfield, 2002, p. 1113)

As long ago as 2002 he declared the need to modify the methodology:

> JCR has become an established world wide resource but after two or more decades it needs to reexamine its methodology for categorizing journals so as to better serve the needs of the research and library community. (Pudovkin & Garfield, 2002)

While in some parts the classification by subject categories matches other schemes quite well, in others it differs greatly. Especially interdisciplinary fields of research are not treated appropriately, which is partly caused by the essential pigeonholing procedure of classification (see section 3.1.1). While the differences have only little effect on the whole structure (e.g. mapping of the whole scientific communication landscape), they can greatly influence evaluation on the micro level (Rafols & Leydesdorff, 2009a).

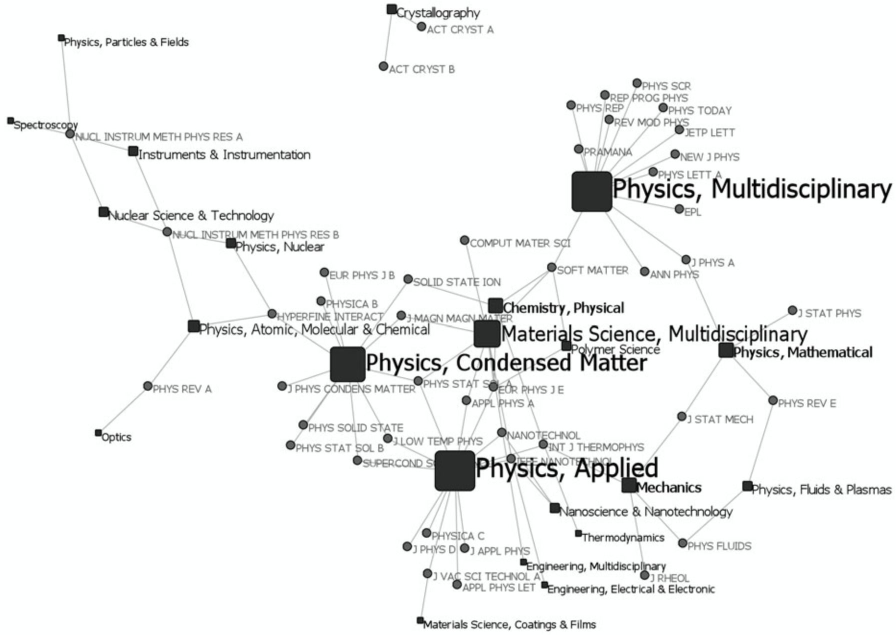

Figure 3.6 Map of 45 journals and affiliated WoS subject categories.

Quite a few studies (Glänzel & Schubert, 2003; De Moya-Anegon et al., 2004; Boyack et al., 2005; Janssens, Zhang, Moor, & Glänzel, 2009; Leydesdorff & Rafols, 2009; Rafols & Leydesdorff, 2009a, 2009b; Zhang et al., 2010) have taken up the challenge of developing new methods to classify scientific journals more accurately. Most of them are especially designed for research evaluation purposes and are based on similarities of journal citation characteristics. However, none of these classification systems are publicly available so far nor have any become generally accepted, since each research group adheres to their own slightly different classification schemes. A comprehensive alternative to the WoS classification is still needed. However, as Butler (2010) mentioned, creating "an alternative scheme is a daunting task."

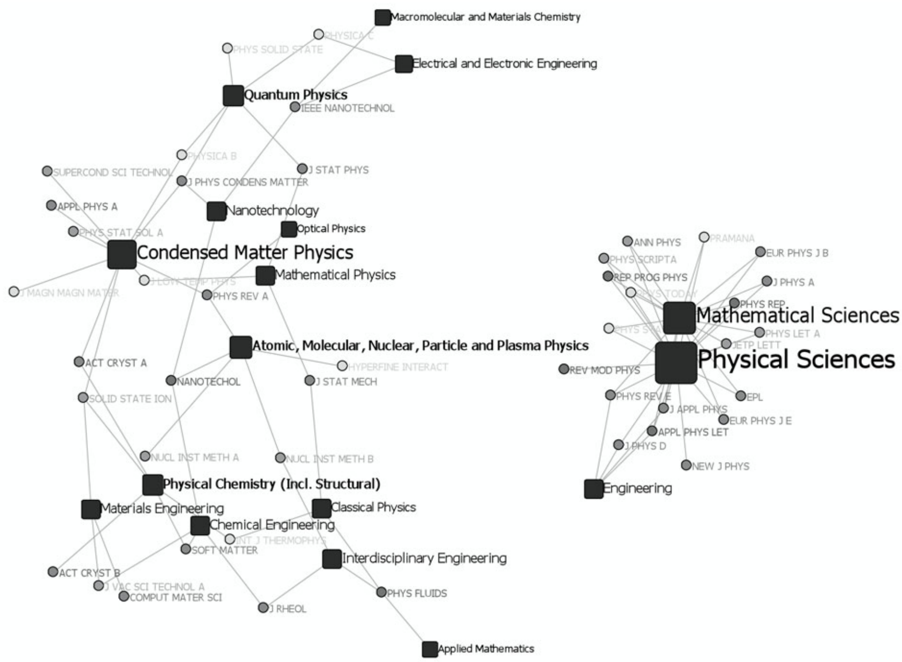

Figure 3.7 Map of 45 journals and affiliated ERA Fields of Research.

ERA classification scheme

In 2008 the Australian Bureau of Statistics (ABS) took up this daunting task to develop its own classification for research evaluation. Over 20,700 journals were selected based on the publication output of 21 Australian universities supplemented by titles from Ulrich's Periodicals Directory, WoS and Scopus. In order to create a comprehensive classification scheme suiting the evaluation of Australian research, universities were to assign publications by authors to their affiliated departments in order to create a first draft of journal sets. The preliminary classification was reviewed by a large number of experts including 700 reviewers (Butler, 2010; Haslam & Koval, 2010).

The final scheme of the ERA classification is hierarchical including three levels of specialization. The first two digits of the specific category code identify a division (e.g. 02 'Physical Sciences'), which represent a broad field of science (Pink & Bascand, 2008). There are 22 different top-level disciplines from 01 'Mathematical Sciences' to 22 'Philosophy and Religious Studies' plus an extra division MD for multidisciplinary periodicals (Pink & Bascand, 2008). Out of the 20,712 selected journals, 604 are classified as 'Multidisciplinary' (*ERA Ranked Journal List*, 2010). Table 3.2 lists the 23 divisions including the number of all and the subset of 45 journals assigned to them. Information about the sublevels is given, for those divisions that were used to classify the 45 journals. The four-digit notation consists of the division code plus two additional digits. It identifies sublevels of the division called the group (e.g. 0204 'Condensed Matter Physics'). In total, the classification lists 145 possible group codes. The most detailed classification level is called field and is indexed with a six-digit code. Another two digits are added to subdivide the group level (e.g. 020404 'Electronic and Magnetic Properties of Condensed Matter; Superconductivity') (Pink & Bascand, 2008). However, the lowest classification level is not used for the classification of journals but is only applied in the evaluation of researchers. Each journal can be assigned to at least one and a maximum of three of the first and second level of categories (*ERA Ranked Journal List*, 2010).

Figure 3.7 shows a 2-mode network of the 45 journals connected to their assigned ERA Fields of Research. In the Australian scheme, each journal can only be assigned to a maximum of three different categories. The 45 journals are allocated to 17 different categories, including the three divisions and subgroups of 'Physical Sciences', 'Mathematical Sciences' and 'Engineering' and groups sub-classified as 'Chemical Sciences' and 'Technology'.

Table 3.2 ERA classification scheme with total number of journals (SO_{ERA}) and number of 45 analyzed journals (SO_{45}) assigned to class.

Division	Group	SO_{ERA}	SO_{45}
01 Mathematical Sciences		184	16
	0101 Pure Mathematics	494	
	0102 Applied Mathematics	410	1
	0103 Numerical and Computational Mathematics	119	
	0104 Statistics	183	
	0105 Mathematical Physics	37	3
	0199 Other Mathematical Sciences	0	
02 Physical Sciences		129	19
	0201 Astronomical and Space Sciences	65	
	0202 Atomic, Molecular, Nuclear, Particle and Plasma Physics	80	5
	0203 Classical Physics	34	3
	0204 Condensed Matter Physics	44	10
	0205 Optical Physics	55	1
	0206 Quantum Physics	29	5
	0299 Other Physical Sciences	22	
03 Chemical Sciences		118	

continued on next page

Division	Group	SO_{ERA}	SO_{45}
	0301 Analytical Chemistry	83	
	0302 Inorganic Chemistry	49	
	0303 Macromolecular and Materials Chemistry	58	1
	0304 Medicinal and Biomolecular Chemistry	61	
	0305 Organic Chemistry	60	
	0306 Physical Chemistry (incl. Structural)	129	5
	0307 Theoretical and Computational Chemistry	17	
	0399 Other Chemical Sciences	26	
04 Earth Sciences		56	
05 Environmental Sciences		135	
06 Biological Sciences		285	
07 Agriculture and Veterinary Sciences		103	
08 Information and Computing Sciences		71	
09 Engineering		163	1
	0901 Aerospace Engineering	28	
	0902 Automotive Engineering	26	
	0903 Biomedical Engineering	115	
	0904 Chemical Engineering	201	4
	0905 Civil Engineering	248	
	0906 Electrical and Electronic Engineering	309	2
	0907 Environmental Engineering	40	
	0908 Food Sciences	95	
	0909 Geomatic Engineering	46	
	0910 Manufacturing Engineering	75	
	0911 Maritime Engineering	30	
	0912 Materials Engineering	225	3
	0913 Mechanical Engineering	237	
	0914 Resources Engineering and Extractive Metallurgy	158	
	0915 Interdisciplinary Engineering	77	3
	0999 Other Engineering	7	
10 Technology		78	
	1001 Agricultural Biotechnology	18	
	1002 Environmental Biotechnology	10	
	1003 Industrial Biotechnology	15	
	1004 Medical Biotechnology	17	
	1005 Communications Technologies	61	
	1006 Computer Hardware	5	
	1007 Nanotechnology	35	3
	1099 Other Technology	6	
11 Medical and Health Sciences		264	
12 Built Environment and Design		11	
13 Education		131	
14 Economics		191	
15 Commerce, Management, Tourism and Services		39	
16 Studies in Human Society		40	
17 Psychology and Cognitive Sciences		22	
18 Law and Legal Studies		6	
19 Studies in Creative Arts and Writing		120	

continued on next page

Division	**Group**	SO_{ERA}	SO_{45}
20 Language, Communication and Culture		40	
21 History and Archaeology		25	
22 Philosophy and Religious Studies		10	
MD Multidisciplinary		604	
number of unique journals		*20712*	*45*

In contrast to the WoS classification, the ERA scheme divides the network of the 45 journals into two separate components. The component on the right contains 19 periodicals, of which all are classified under 'Physical Sciences', the field represented most strongly among the journals under analysis, 'Mathematical Sciences' and 'Engineering'. Those three classes represent a top-level division of the ERA classification scheme. In contrast, the cluster on the left contains only journals allocated to groups of the lower hierarchy of the ERA classification scheme. This indicates, that the component on the right containing 19 journals forms a cluster of more general journals, while the component on the left seems to group more specialized periodicals (figure 3.7).

3.2.2 Article Level

While in section 3.2.1 whole periodicals are classified, classification can also be applied on the level of single documents. Needless to say, this method is much more elaborate and costly than classification on the journal level. Every publication has to be analyzed and indexed separately.

Intellectual subject indexing is not comprehensively available but usually limited to a specific area of research by commercial database producers. The decision which publications to cover and which to exclude depends primarily on the thematic focus of the particular database and on formal criteria such as document type or language. Databases which index journal articles often include all the documents published in a source journal (Lancaster, 2003).

The advantage of indexing journals based on article content is that in contrast to classification on journal level all facets of the published content are taken into account. While journal classification schemes have to fit all the topics published in a periodical into a few broad categories, if individual documents are classified the content is assessed anew and in detail. Categories like 'Multidisciplinary Sciences' functioning as a reservoir for journals which do not fit into any other class because they explore different areas of research can thus be avoided. Journal content evaluation through the accumulation of article attributed index terms is based on Zipf's law, which states that the frequency of a word is inversely proportional to its rank order and implies that a few frequently applied index terms are able to represent journal content to a large extent (Zipf, 1949).

There are several methods of how to analyze content on the document level, three of which are described and applied to the journal set under analysis. Index terms assigned by authors are examined (p. 106) as is subject indexing applied by information professionals at Inspec (p. 114). New methods of applying tags generated by users of social bookmarking platforms to journal content evaluation are introduced on page 121.

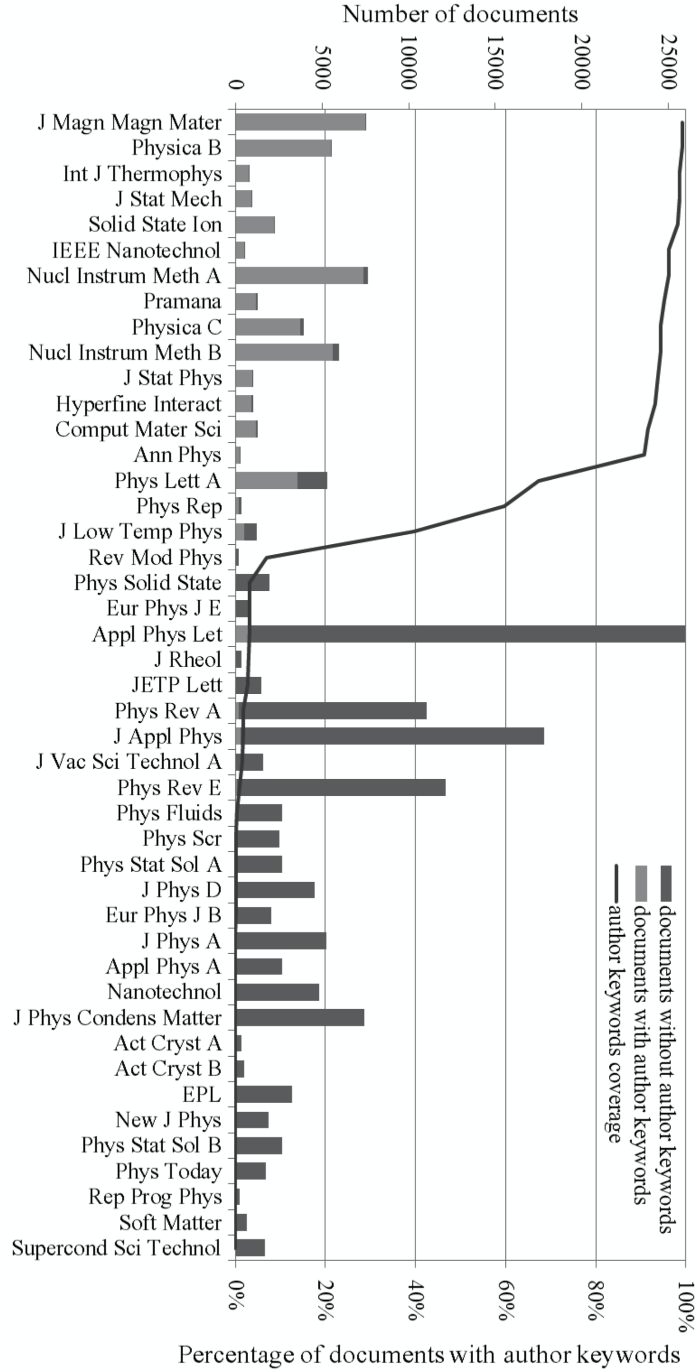

Figure 3.8 Percentage of documents per journal with and without author keywords.

Indexing by Authors

As described in section 3.1.3, author indexing provides a cost-free method fo describing a document's content by a few central significant keywords. The availability of author-provided keywords depends on the publication venue. Usually the journal asks the author to provide these index terms when submitting a manuscript, in order to provide an additional entry point for retrieval besides article title or abstract terms (Kipp, 2005). If author keywords are intended by the periodical, they are included in the WoS data, filed under the field tag 'DE'. 26.6% of the 168.109 documents were indexed by the author. 36 of the 45 journal under examination did to some extent provide author indexing, although for only 14 periodicals was the percentage of documents including author keywords above 90%. It seems reasonable to assume that the availabilty of author index terms does not only depend on the journal but is influenced by some other factor like the type of publication. The analysis of availability of author keywords regarding document types does not reveal a clear interrelation, however. Except for the document type 'News Item', all types contain documents with and without author keywords. This particular document type is, however, only present in Phys Today (compare section 2.1.4), which belongs to the nine journals that do not provide any author indexing. No causal correlation can be discovered between document types and availability of author keywords.

Table 3.3 Statistics for number of author keywords per journal.

Journal	N	Mean	Median	Min	Max	Std. Dev.
Ann Phys	269	3.6	3	1	12	1.18
Comput Mater Sci	1190	4.8	5	2	14	1.33
Hyperfine Interact	937	4.1	4	1	13	1.33
IEEE Nanotechnol	500	4.9	5	2	16	1.82
Int J Thermophys	747	5.3	5	2	11	1.55
J Magn Magn Mater	7495	4.0	4	1	19	1.24
J Stat Mech	945	3.0	3	1	6	1.10
J Stat Phys	985	4.4	4	1	12	1.66
Nucl Instrum Meth A	7377	4.2	4	1	24	1.47
Nucl Instrum Meth B	5635	4.4	4	1	19	1.54
Physica B	5514	3.8	4	1	15	1.12
Physica C	3729	3.8	4	1	11	1.13
Pramana	1203	3.8	3	1	13	1.39
Solid State Ion	2229	4.7	5	2	24	1.30
Total	38755	4.1	4	1	24	1.40

Another assumption is that journals which only provide author keywords for some of their publications only applied author indexing for a limited time. Either author-provided index terms were introduced after 2004 or this particular method was abandoned before 2008. Hence, a clear correlation between availability of author keywords and year of publication should be visible. Comparing the share of documents with author keywords by publication year revealed only a small deviation from the mean. Since no clear factor can be discovered influencing author keyword availability and which would make it possible to define a subset of publications influenced by this factor, it was decided to analyze only those journals with more than 90% of documents including author keywords. Figure 3.8 shows a clear inverse logistic distribution (see p. 114) and thus defines the 90% mark as a valid cut-off value. The percentage of documents including author index terms decreases considerably after Ann Phys. Phys Lett A, Phys Rep and J Low Temp Phys list author keywords for 67.3%, 59.8% and 39.7% of their documents. All other journals provide these only sporadically and can be disregarded with respect to analyses of author-generated index terms. Since Phys Lett A, Phys Rep and J Low Temp Phys cannot be clearly identified as journals with or without author indexing, possible causal correlations are again examined in detail for these three journals. However, no striking influence of document type or publication year on keyword availability can be discovered. Hence, the detailed analysis of author keywords is limited to Ann Phys, Comput Mater Sci, Hyperfine Interact, IEEE Nanotechnol, Int J Thermophys, J Magn Magn Mater, J Stat Mech, J Stat Phys, Nucl Instrum Meth A, Nucl Instrum Meth B, Physica B, Physica C, Pramana and Solid State Ion. All these journals supply author keywords for more than 90% of their publications, so that content descriptions can be regarded as representative of the whole journal.

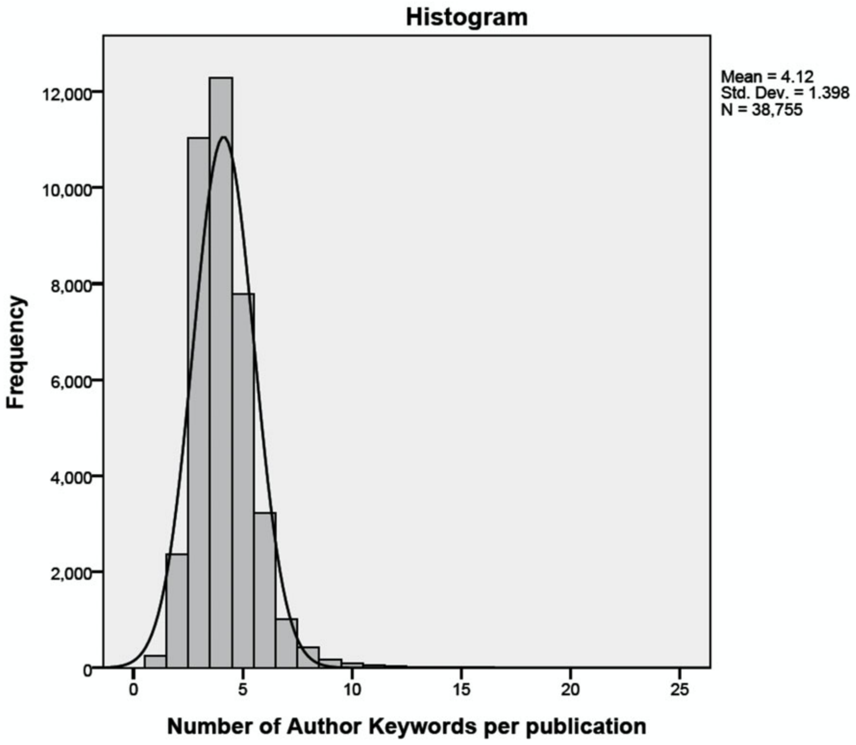

Figure 3.9 Histogram for number of author keywords per publication for 38,755 documents published in 14 journals.

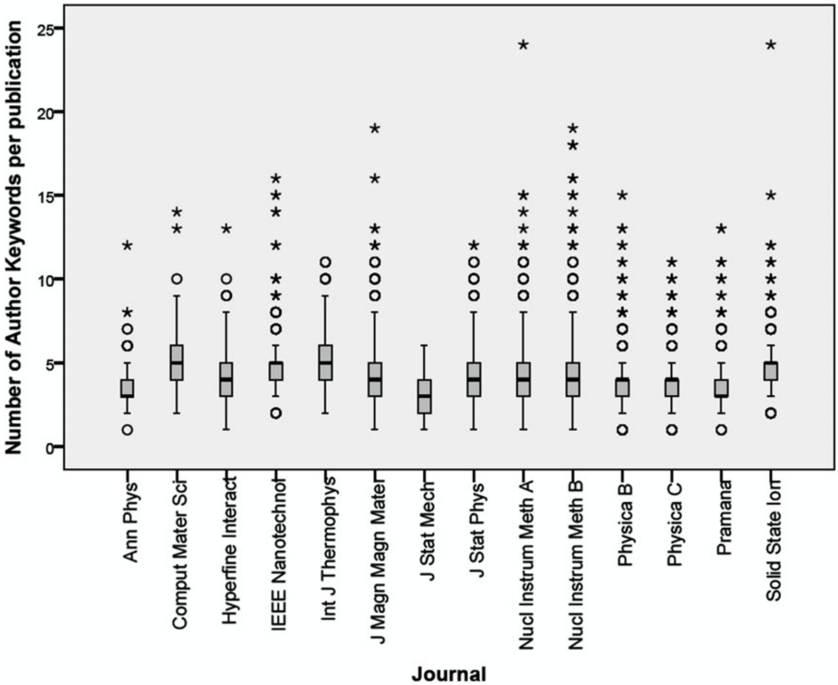

Figure 3.10 Boxplots showing the number of author keywords per publications for 14 journals.

In total, 38,755 documents published in these 14 journals were indexed with a total of 159,864 terms. The average number of keywords is 4.1 per document and varies between 1 and 24. However, only 1% of all documents contain eight or more index terms. As can be seen in figure 3.9, the number of terms assigned per article is approximately normally distributed around a median of 4 and a standard deviation of 1.40. Table 3.3 and the boxplots in figure 3.10 reveal minor differences between journals. For example, articles published in J Stat Mech contain a maximum of six terms per document, which suggests that the number of assignable author keywords is limited. This influences the mean number of terms as well. At 3.0 keywords per document, J Stat Mech has the lowest average and the lowest standard deviation. Comput Mater Sci, IEEE Nanotechnol and Int J Thermophys seem to require a minimum of two keywords. At 5.29, the latter provides the highest number of author-generated index terms per document: authors indexed 747 articles with 3,948 keywords. Over the years, frequency distributions remained constant: there is no significant difference in the average number of terms per document among the five years under analysis.

Table 3.4 Number of unique author keywords assigned to 14 journals

Journal	K^{unique}	K^{all}	$\frac{K^{\text{unique}}}{K^{\text{all}}}$	P_k	$\frac{P_k}{K^{\text{unique}}}$
Ann Phys	783	963	1.23	269	0.34
Comput Mater Sci	3645	5681	1.56	1190	0.33

continued on next page

Journal	K^{unique}	K^{all}	$\frac{K^{unique}}{K^{all}}$	P_k	$\frac{P_k}{K^{unique}}$
Hyperfine Interact	2320	3851	1.66	937	0.40
IEEE Nanotechnol	1704	2425	1.42	500	0.29
Int J Thermophys	2229	3948	1.77	747	0.34
J Magn Magn Mater	12398	30142	2.43	7495	0.60
J Stat Mech	378	2830	7.49	945	2.50
J Stat Phys	2962	4305	1.45	985	0.33
Nucl Instrum Meth A	13961	30614	2.19	7377	0.53
Nucl Instrum Meth B	11658	25025	2.15	5635	0.48
Physica B	9777	20796	2.13	5514	0.56
Physica C	6329	7879	1.24	3729	0.59
Pramana	3393	3393	1.00	1203	0.35
Solid State Ion	5035	5035	1.00	2229	0.44

Term frequency can be analyzed, in order to be able to limit the thematical focus of a journal to a small number of important terms. This implies an identification of unique index terms and the number of articles to which these have been applied. Table 3.4 lists the number of unique index terms K^{unique}, the number of total term frequency K^{all}, the average amount a unique term was assigned, the number of author-indexed publications P_k, and the average number of articles indexed with the same term, i.e. how often terms were reused. Except for J Stat Mech, all journals score a value below one, indicating that most author keywords are assigned to one publication only. To a large extent this might be due to the lack of vocabulary control. In most cases, author keywords are freely chosen natural language terms which can be used without any restrictions. J Stat Mech's results indicate some form of vocabulary control: 378 unique keywords were applied 2,830 times by authors to describe the content of 945 articles, which means that each term was used 2.5 times on average. Examining J Stat Mech's author information, one discovers a specific table of keywords[8], where controlled index terms are provided for eleven different topics. Authors are obliged to choose the most appropriate keywords for their submission to help find the most suitable editor:

> When submitting a Letter or a Paper to the journal, contributors must choose from the JSTAT table of keywords those which best define the contributions' subject of research. A system assigns the preprint to an Editor by choosing the best match of the author's keywords with the areas of expertise of the available Editors. (SISSA & IOP Publishing, 2004)

Keywords are organized in eleven sections. Sections contain 12 (section 11 'Collective phenomena in economic and social systems') to 65 (section 9 'Interface biology-physics') index terms. Analyzing the articles published between 2004 and 2008 reveals, that 203 of the 400 keywords were not adopted by any authors at all. Four unique keywords appear in two sections, e.g. the keyword 'Slow relaxation and glassy dynamics' is classified in sections 5 'Fluids, instabilities, turbulence, reaction dynamics, soft and granular matter' and 7 'Disordered systems and glassy matter', which does not allow for inference in the intended section. Even though vocabulary is supposed to be controlled, section 7 lists the index terms 'Slow dynamics and ageing (Experiment)' as two separate entries, with a difference in spelling (i.e. 'aging' and 'ageing').

8 http://jstat.sissa.it/jstat/help/helpLoader.jsp?pgType=kwList

A comparison of the prescribed list of keywords as author keywords listed in the WoS data reveals some discrepancies: the WoS entries list 378 unique keywords assigned to J Stat Mech, of which only 195 could be matched to the prescribed vocabulary. Matching the remaining assignments to the controlled vocabulary, sections 1 ‘Exact results’, 4 ‘Non-equilibrium processes’ and 3 ‘Phase transitions and critical phenomena’ were chosen most frequently by authors for indexing. Whether these discrepancies between prescribed index terms and keywords appearing in WoS arise through errors during data transfer or if J Stat Mech allows authors to choose additional uncontrolled terms after the review process, cannot be distinguished. Since vocabulary control for author indexing is not applied by the other journals either, the following thematic analysis will be based on those author keywords supplied by WoS.

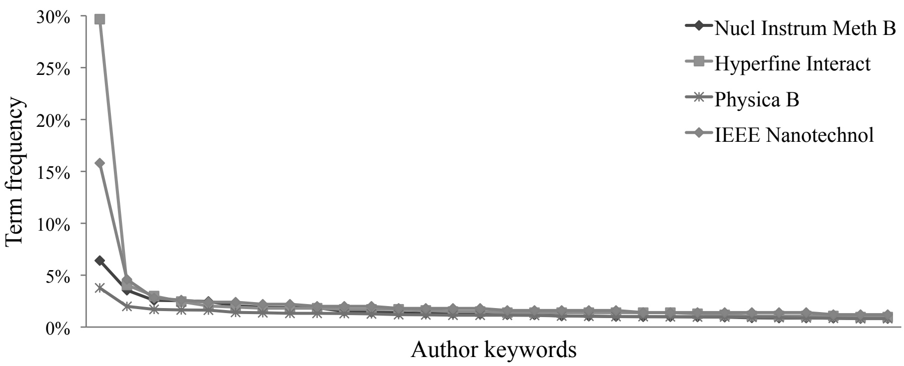

Figure 3.11 Frequency distributions of the 30 most frequently assigned unique author keywords for Hyperfine Interact, Physica B, IEEE Nanotechnol and Nucl Instrum Meth B.

Figure 3.11, figure 3.12 and figure 3.13 show differences in term frequency distributions of the 30 author keywords most frequently assigned to articles published in the 14 periodicals. What all the journals have in common is the long tail of unique keywords assigned to a small number of documents during the five years under analysis. The median percentage of author keywords applied only once to a journal is 75.9%. Except for J Stat Mech, which forms an outlier with only 38.6% non-recurring index terms due to vocabulary control, all journals are indexed with 71.2% (Physica C) to 84.9% (Ann Phys) keywords applied once only.

Differences can be observed with respect to the most frequently used keywords at the front of the distribution curve. Hyperfine Interact’s author-generated content description can clearly be limited to one power term applied 278 times, namely ‘Mossbauer spectroscopy’. 29.7% of all documents were indexed with this particular keyword (figure 3.11). The second most frequent term assigned 38 times is ‘Mossbauer’. These keywords refer to spectroscopy based on resonant emission and absorption first observed by Rudolf Mößbauer in 1957, which is especially useful for analyzing hyperfine interactions. Mößbauer received the Nobel Prize in 1961 ”for his researches concerning the resonance absorption of gamma radiation and his discovery in this connection of the effect which bears his name” (*The 1961 Nobel Prize in Physics – Presentation Speech*, 1961). The frequency with which authors indexed articles referring to Mossbauer spectroscopy reflects the significance of this particular method to research published in Hyperfine Interact. 82 keywords contained the word ‘Mossbauer’, together these were used 493 times.

None of the other author-generated content descriptions is dominated by one term in such an extreme manner. However, there are other journals where one keyword stands out from the rest: IEEE Nanotechnol is governed by ‘nanotechnology’, which accounts for 79 of 500 documents, Physica B is most often described by ‘superconductivity’ (figure 3.28) and Nucl Instrum Meth B publications are most frequently indexed with ‘ion implantation’ (361 times).

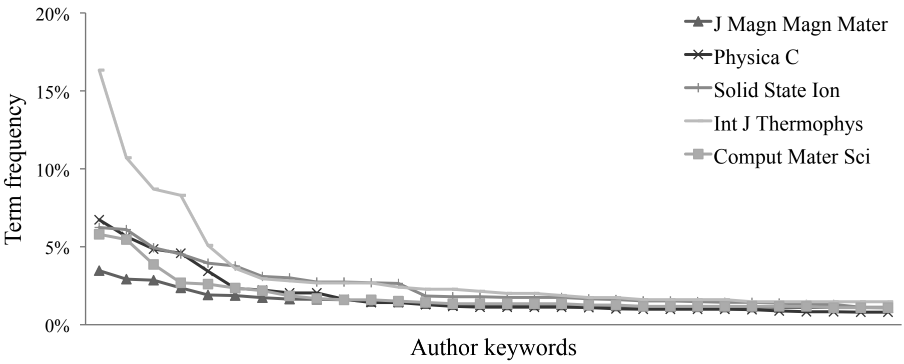

Figure 3.12 Frequency distributions of the 30 most frequently assigned unique author keywords for Comput Mater Sci, Int J Thermophys, J Magn Magn Mater, Physica C and Solid State Ion.

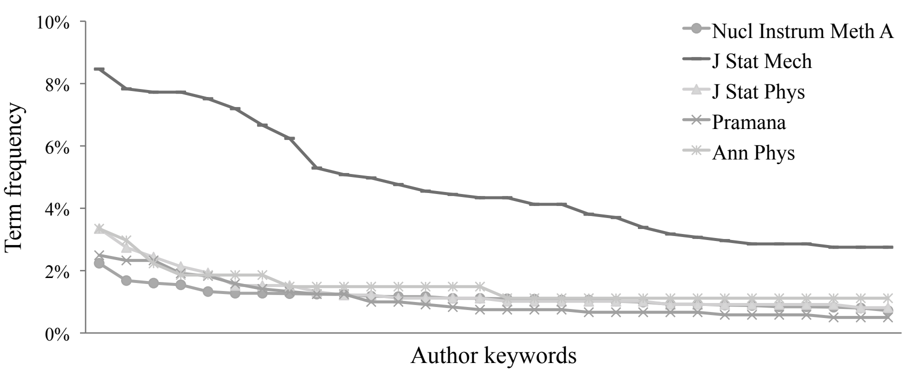

Figure 3.13 Frequency distributions of the 30 most frequently assigned unique author keywords for Ann Phys, J Stat Mech, J Stat Phys, Nucl Instrum Meth A and Pramana.

Table 3.5 Ten most frequently assigned author keywords of journals with an inverse logistic frequency distribution of author keywords, i.e. Comput Mater Sci, Int J Thermophys, J Magn Magn Mater, Physica C and Solid State Ion. Central terms are highlighted. Author keywords are taken from WoS and not corrected, e.g. 'MgB2' should be 'MgB_2'.

Author keywords	**Frequency**
Comput Mater Sci	
finite element method	69
molecular dynamics	65
electronic structure	46
density functional theory	32
finite element analysis	31
simulation	28
microstructure	26
ab initio calculations	22
DFT	20
diffusion	19
finite element	19
Int J Thermophys	
thermal conductivity	122
thermal diffusivity	80
density	65
viscosity	62
equation of state	38
surface tension	27
calibration	22
ITS-90	21
high temperature	20
high temperatures	20
thermodynamic properties	20
J Magn Magn Mater	
magnetic properties	260
magnetic anisotropy	219
magnetization	214
magnetoresistance	177
coercivity	143
nanoparticles	140
ferromagnetism	130
magnetostriction	123
magnetocaloric effect	122

continued on next page

Author keywords	**Frequency**
Mossbauer spectroscopy	120

J Magn Magn Mater	
superconductivity	251
MgB2	211
YBCO	181
critical current density	171
critical current	128
superconductor	87
flux pinning	83
coated conductor	76
thin films	76
pseudogap	61

Physica C	
superconductivity	251
MgB2	211
YBCO	181
critical current density	171
critical current	128
superconductor	87
flux pinning	83
coated conductor	76
thin films	76
pseudogap	61

Solid State Ion	
ionic conductivity	139
SOFC	136
perovskite	110
impedance spectroscopy	101
electrical conductivity	88
conductivity	84
cathode	69
solid oxide fuel cell	67
proton conductivity	61
solid electrolyte	61

These journals have in common that the second most frequent keyword has been applied about half (or less) as frequently as the first. The distribution curves of author keywords for those journals are shown in figure 3.11. While the author keyword frequencies of these journals are similar to an informetric distribution[9], these of Comput Mater Sci, Int J Thermophys, J Magn Magn Mater, Physica C and Solid State Ion can be referred

9 However, none of the actual frequency values of assigned author keywords behaves perfectly according to the informetric law of $f(x) = \frac{C}{x^a}$.

to as inverse logistic (Stock, 2006). Inverse logistic distributions of term frequency show a strong decrease in frequency after a few instead of one power term. Following Peters and Stock (2007), who apply the inverse logistic character of tag distributions for information retrieval purposes and "pick all tags of the left-hand long trunk" (Peters & Stock, 2007), author-generated content description can be limited to a few power terms. As can be seen in figure 3.12 and table 3.5, two focus terms can be picked for Comput Mater Sci, three for J Magn Magn Mater, four keywords for Int J Thermophys, five for Physica C and six central index terms are chosen to best represent content from the authors' perspective on Solid State Ion.

Another type of term frequency distribution shows a more gradual, almost linear decrease without an extreme decreasing slope, which makes it more difficult to find a cut-off value to reduce journal content description to the most important terms. As depicted in figure 3.13, such distributions can be observed for Ann Phys, J Stat Mech, J Stat Phys, Nucl Instrum Meth A, and Pramana.

Indexing by Information Professionals: Inspec

The purpose of indexing is to describe document content adequately so that it can be represented in a database, in order to be searchable by users and fulfill specific information needs. Subject indexing consists of conceptual analysis, where the indexer determines what the publication is about, and the translation of these concepts into index terms (see section 3.1).

Since professional indexing is very cost-intensive, indexing and abstracting services usually limit content coverage to a specific topic and formal criteria (Lancaster, 2003). Inspec is the leading database providing access to scientific and technical literature in the area of physics and engineering. Inspec uses both controlled and uncontrolled terms and applies different classification systems to index its contents (Lancaster, 2003). Currently Inspec indexes 3,400 journals selectively and 1,600 entirely from cover to cover[10], in addition to numerous conference proceedings, books, reports, dissertations and patents. Each of the currently eleven million bibliographic entries has been indexed by a subject specialist.

Besides the conventional bibliographic data, information regarding an article's content can be drawn from specific indexing fields. Figure 3.14 shows the detailed Inspec record of a journal article published in Appl Phys Let in 2008. 'Inspec Headings' includes one or more of 9,573 controlled index terms from the Inspec Thesaurus, which can be regarded as the standard of excellence in the field. Together with 8,826 additional cross-references (Booth, 2001), so-called lead-in terms, which direct the user to the 9,573 preferred terms, the current edition of the Thesaurus contains 18,400 terms. The first edition of the Inspec Thesaurus was released in 1973 ("Inspec Thesaurus", 2010). Figure 3.15 shows the term 'solid-state plasma' in the Inspec Thesaurus together with broader, narrower and related terms and its related classification code. 'Solid state plasma' is the preferred term for 'Alfen waves', 'electron-hole plasma' and 'plasma in solids'.

10 http://www.theiet.org/publishing/inspec/about

Atmospheric-pressure gas breakdown from 2 to 100 MHz

Authors: Walsh, J.L.[1] ; Zhang, Y.T.[1] ; Iza, F.[1] ; Kong, M.G.[1]

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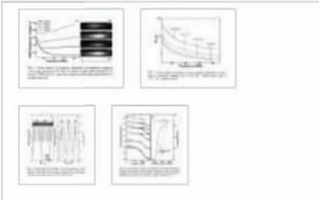
Source: Applied Physics Letters 1 Dec. 2008, vol.93, no.22, 221505 (3 pp.). *ISSN:* 0003-6951 (print), *CODEN:* APPLAB *Publisher:* American Institute of Physics *Country of Publication:* USA

Images



Language: English

Abstract: We report a detailed study of breakdown voltage of atmospheric-pressure helium gas between two parallel-plate electrodes from 2 to 100 MHz. Experimental data show that the breakdown voltage reduces initially with increasing frequency due to a diminishing contribution of drift-dominated electron wall loss and then begins to increase with increasing frequency. The latter is contrary to the current understanding that relies largely on the electron wall loss mechanism. Particle-in-cell simulation suggests that rapid oscillation of the applied voltage prevents electrons from reaching their maximum achievable kinetic energy, thus compromising the ionization efficiency and increasing the breakdown voltage.

Inspec Headings: glow discharges ; helium ; high-frequency discharges ; ionisation ; plasma oscillations ; plasma simulation ; plasma transport processes ; plasma-wall interactions

Key Phrase Headings: atmospheric-pressure gas breakdown ; parallel-plate electrodes ; drift-dominated electron wall loss ; particle-in-cell simulation ; voltage oscillation ; kinetic energy ; ionization efficiency ; breakdown voltage ; radiofrequency glow discharges ; frequency 2 MHz to 100 MHz ; pressure 1 atm ; He

Classification: A5280P High-frequency discharges
A5280H Glow and corona discharges
A5240H Solid state-plasma interactions
A5225F Plasma transport properties
A5235F Plasma electrostatic waves and oscillations
A5265 Plasma simulation

Treatment: Theoretical or Mathematical ; Experimental

Numerical Data: frequency 2.0E+06 to 1.0E+08 Hz ; pressure 1.01325E+05 Pa (help)

Chemicals: He/el

Number of References: 19

Publication Type: Journal Paper

Digital Object Identifier: 10.1063/1.3043449

Update Code: 2009002

Accession Number: 10361083

Figure 3.14 Detailed record in Inspec via EBSCO. Source: http://www.ebscohost.com/academic/inspec.

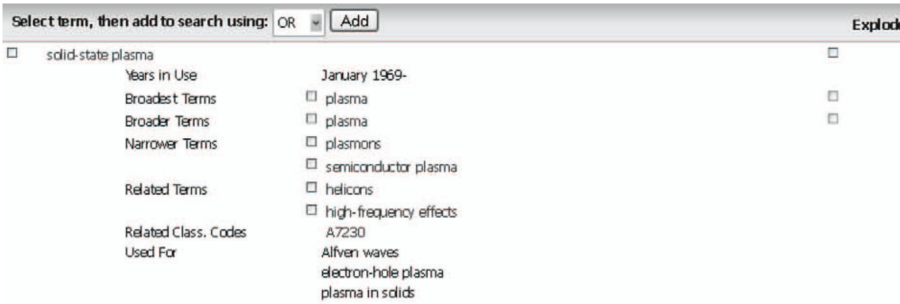


Figure 3.15 Index term 'solid-state plasma' in Inspec Thesaurus via EBSCO. Source: http://www.ebscohost.com/academic/inspec.

'Key Phrase Headings' are non-standardized terms which can complement the fixed indexing terms. In addition to the thesaurus, Inspec makes use of a specific hierarchical classification system subdivided in five broad subject areas: Physics (A), Electrical and Electronic Engineering (B), Computing and Control (C), Information Technology for Business (D) and Manufacturing and Production Engineering (E). Classification codes are alphanumeric and start with a letter indicating the broad subject, followed by four digits and one optional alphabetic letter. As can be seen in figure 3.14, the particular document published in Appl Phys Let was assigned to six classes from the Physics category.

The hierarchical structure of the classification code 'A5240 Plasma interactions' can be seen in figure 3.16. This specific terms has been in use since 1977. For each record in Inspec, the chemicals mentioned in the publication are indexed in a separate field and so are specific numerical data, such as pressure, temperature, frequency or radioactivity etc. If applicable, entries include International Patent Classification Codes. 'Treatment' indicates whether the article is, for example, of a theoretical, experimental or practical nature. Each document is assigned to one or more of eight treatment codes[11].

Out of the 45 physics journals under analysis, all but Phys Today are represented in Inspec. Coverage ranges from 19.4% to 98.1% of all documents published in a particular journal within the time frame 2004 to 2005 (compare figure 3.17). As mentioned above, Inspec covers some journals as a whole while others are covered only partly. As can be seen in figure 3.17, the percentage of documents covered does not reach 100% for any of the journals. Since the total number of documents is based on WoS data, small discrepancies may be due to minor differences between databases. If the coverage exceeds 95% the journal is hence regarded as fully covered by Inspec during the period from 2004 to 2008. Since an adequate thematic representation of journal content cannot be guaranteed if only parts of the journal are indexed, subject analysis based on intellectual indexing by Inspec is limited to those journals regarded as fully covered, namely Physica C, J Phys Condens Matter, IEEE Nanotechnol, J Phys D, J Vac Sci Technol A, J Rheol and Act Cryst A.

The terms chosen by subject specialists to index the articles published in a journal can be aggregated and ranked by number of occurrences. When downloaded via the

11 http://www.theiet.org/publishing/inspec/about/records/treatment/

EBSCO API, controlled thesaurus and uncontrolled key phrase headings are unfortunately combined and cannot be retrieved separately as displayed in the detailed record in figure 3.14. Hence, the following content analysis is based on two indexing approaches: notations from the Inspec Classification and a combination of thesaurus and uncontrolled indexer terms called Inspec Headings.

A5000 Fluids, plasmas and electric discharges
[Explode] [Previous Level]

A5200 The physics of plasmas and electric discharges
[Explode] [Previous Level]

A5240 Plasma interactions (1977-)
[Explode] [Previous Level]

A5240D Electromagnetic wave propagation in plasma

A5240F Antennas in plasma; plasma-filled wave guides (1977-)

A5240H Solid state-plasma interactions (1973-)
Scope Note:inc. wall interactions and boundary layers

A5240K Plasma sheaths

A5240M Particle beam interactions in plasma (1973-)
See:for laser beam propagation, see A5240D; for laser beam production and heating of plasma, see A5250J

Figure 3.16 Classification code ‘A5240’ in Inspec Classification via EBSCO. Source http://www.ebscohost.com/academic/inspec.

As shown in the log-log graph in figure 3.18, the number of occurrences of Inspec headings (controlled and uncontrolled indexer terms) assigned to Physica C is distributed according to a power law. 21,859 of 27,657 unique Inspec Headings were assigned only once to an article published in Physica C between 2004 and 2008, whereas 2,325 documents from the journal were indexed with the most frequent term (i.e. ‘high-temperature superconductors’).

Table 3.6 lists the 15 most frequent index terms and classification codes used to describe the thematic focus of Physica C. Both methods of content classification show a clear thematic focus of Physica C on superconductivity. The great majority of documents are assigned to Physics classes under A74* entitled ‘Superconductivity’ and a few codes from B3220 ‘Superconducting materials’ in section B ‘Electrical and Electronical Engineering’. The top terms used to index Physica C reveals the general differences of intellectual subject indexing based on classification systems or thesauri. The classification system tries to pigeonhole items in classes that best represent the whole document text. Although the structure is inflexible it permits a fast placement of the document’s content into general context. The application of thesaurus terms is, on the other hand, more flexible and allows for a more detailed description. It permits for an in-depth representation of the substances used and methods applied but coherences between the terms and hierarchical information are not supplied. Particular advantages and disadvantages of the two approaches become apparent in the example in table 3.6: Inspec Headings list various compounds which are involved in superconductivity but this relationship becomes more apparent in the Inspec Classification.

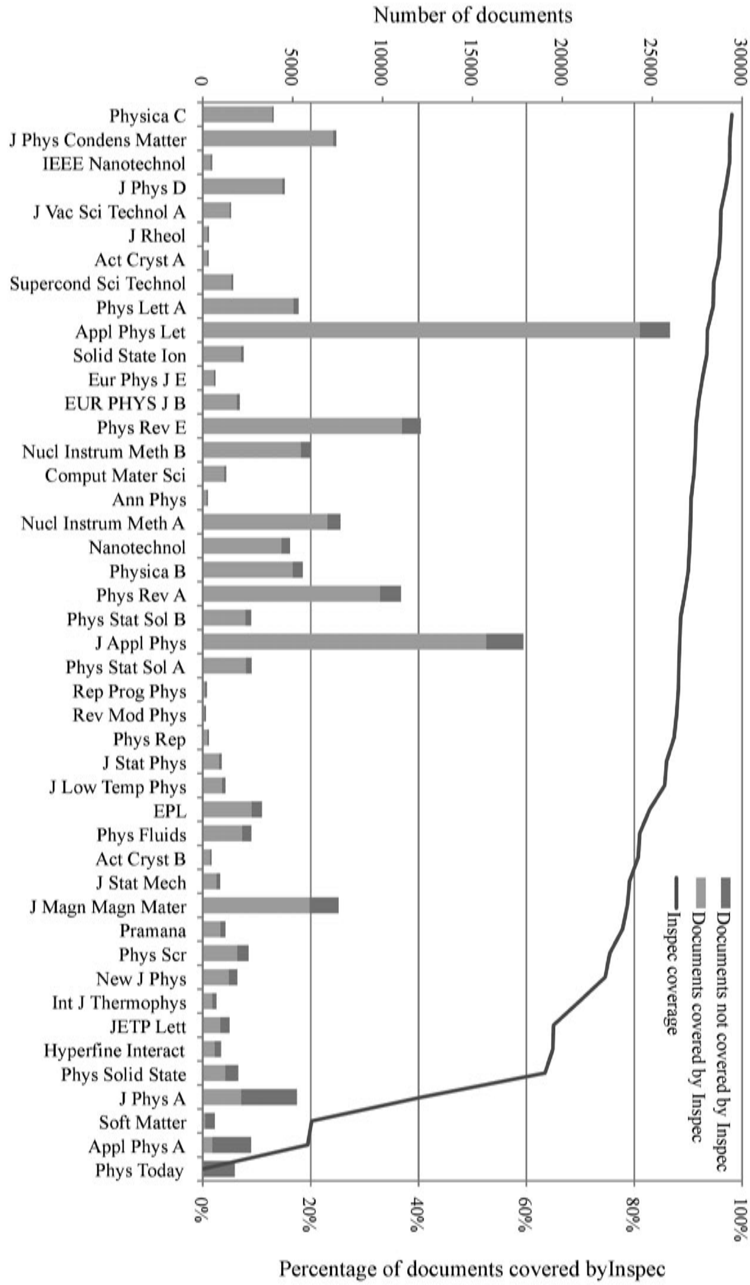


Figure 3.17 Percentage of documents covered in Inspec per journal.

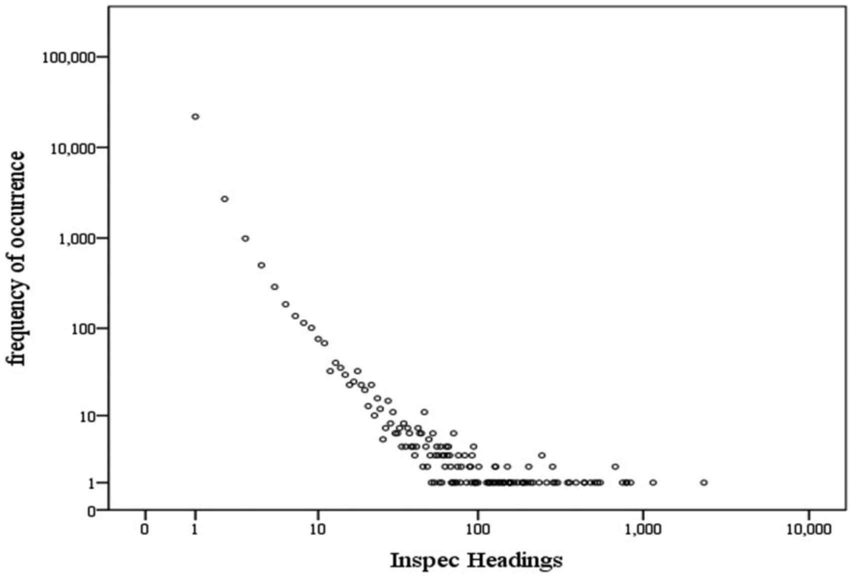


Figure 3.18 Frequency distribution of 27,657 unique Inspec Headings assigned to articles published in Physica C from 2004 to 2008.

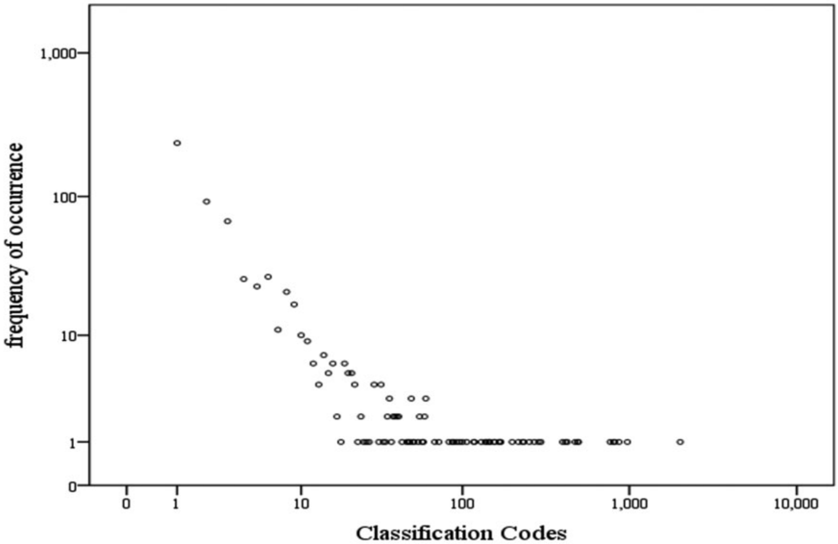


Figure 3.19 Frequency distribution of number of articles from Physica C assigned to Classification Codes.

Analyzing accumulated indexer term frequencies may not only help to investigate a single journal's content in detail but can also show similarities or differences when terms are compared across journals. A comparison regarding index terms and classification codes for Physica C, J Phys Condens Matter, IEEE Nanotechnol, J Phys D, J Vac Sci Technol A, J Rheol and Act Cryst A can be found in section 3.4.2, where a 2-mode network of the journals and most frequently assigned terms and classes from Inspec maps thematic interrelations.

Table 3.6 Fifteen most frequently assigned Inspec Headings and Classification Codes for articles published in Physica C per publication year.

Inspec Headings	**Frequency**	**Inspec Classification**		**Frequency**
high-temperature superconductors	2325	A7470V	Perovskite phase and other high-temperature superconductors	2014
barium compounds	1147	A7430C	Magnetic properties of superconductors	973
yttrium compounds	838	A7460J	Critical currents in type-II superconductors	867
strontium compounds	793	A7430F	Transport properties of superconductors	818
superconducting transition temperature	789	A7460G	Flux pinning, flux motion, fluxon-defect interactions	804
superconducting thin films	751	A7475	Superconducting films and low-dimensional structures	769
calcium compounds	678	A7430J	Electronic structure of superconductors	496
critical current density (superconductivity)	678	A7470Y	Other superconducting materials	492
bismuth compounds	549	A7460M	Material effects on Tc, K, critical currents in type-II superconductors	474
flux pinning	529	B3220H	High-temperature superconducting materials	425
X-ray diffraction	508	A7410	Superconducting critical temperature, occurrence	416
doping	480	A7450	Superconductor tunnelling phenomena, proximity effects, and Josephson effect	400
type II superconductors	441	A7420M	Other theories of superconductivity	296
critical current density	440	B3220M	Superconducting wires and tapes	287
magnesium compounds	393	B0520	Thin film growth, structure, and epitaxy	270

Indexing by Readers (Social Tagging)

As described in section 3.1.6, folksonomies provide a new, user-focused approach to content description and subject indexing. In this section, tags assigned to articles published between 2004 and 2008 in the 45 physics journals under analysis are explored. The acquisition of 13,608 bookmarks from CiteULike, Connotea andBS is explained in detail in section 4.3, where data is analyzed from a quantitative perspective to depict journal usage.

In total, 6.3% (i.e. 10,280) of all articles published in the 45 journals during the five-year time span analyzed were bookmarked by 2,441 users. Overall, these documents were bookmarked 13,608 times. 9,242 publications (89.9%) contained at least one tag. Overall, 36,429 tag applications were distributed over 9,594 unique tags. A certain amount of tag applications were, however, system-generated during import of bibliographic entries from other reference management software, i.e. 'imported' and 'jabref:noKeywordAssigned'. Together those latter appeared 625 times. In order to prevent misinterpretation of tagging behavior, these tags were deleted because they were not created by the users. Eleven such system-generated tags, which appeared 625 times, could be identified and deleted. Thus, the final folksonomy to be analyzed contained 35,804 tag applications and 9,583 unique terms, which were assigned to 8,868 unique publications. All tag applications were generated by 1,992 of 2,441 bookmarking users, meaning that 81.6% of all users indexed their references with tags.

Due to their uncontrolled nature and the information included, basic methods of tag gardening (Peters & Weller, 2008) were applied to adjust differences in spelling and check the tag-specific synonymy problems (compare section 3.1.6). Two separate approaches were chosen to clean and unify tagging data.

Table 3.7 35 tags most frequently assigned to Phys Rev E before and after manual cleaning process.

Tags uncleaned	Frequency	Tags after manual cleaning	Frequency
networks	270	network	459
network	189	simulation	127
simulation	118	community	106
pre	93	pre	93
community	86	2007	73
2007	73	dynamic	73
dynamics	72	graph	71
Theory	70	synchronization	71
modularity	62	theory	70
model	61	model	68
granular	58	modularity	62
diffusion	56	glass	60
Physics	55	granular	58
shear	55	diffusion	56
glass	54	laser	56
clustering	48	physics	56

continued on next page

Tags uncleaned	**Frequency**	**Tags after manual cleaning**	**Frequency**
complex	46	shear	55
synchronization	45	clustering	50
2008	43	colloid	47
grains	42	complex	46
structure	42	grain	45
chaos	39	structure	44
flow	38	system	44
graphs	38	2008	43
electrostatics	37	complex-network	43
noise	37	nonlinear	41
stochastic	37	flow	40
SYSTEMS	37	chaos	39
colloids	36	stochastic	39
nonlinear	34	electrostatics	37
graph	33	noise	37
laser	32	community-detection	35
evolution	28	algorithm	34
statistical	28	fluctuation	33
algorithm	26	delay	31

A first approach included basic automatic transformations such as turning all upper into lower case letters and unifying special characters to merge different variants of compound terms like 'complex-network' and 'complex_network' and extensive manual data processing. If both appeared, plural forms were changed to their singular equivalents. How these basic methods helped to unify tag-specific synonyms can be seen in table 3.7. Merging of singular and plural forms and synomyms induced by the tagging process itself improved the informative value implied in tag frequency. For example, 'network' and 'networks' could be merged to represent one tag with 459 tag applications for publications from Phys Rev E. Changes in rank order occurred for 'community', and significantly for 'graph' and 'colloid' through changing plural to singular. The latter two moved up from the 24th to 7th and 29th to 19th rank of most frequently assigned tag, respectively. 'Synchronization' appears at the 8th instead of 18th rank due to a combination of British and American spelling variants.

Tags and their frequency are visualized in form of a tag cloud.

> Tag clouds, also known as text clouds or word clouds, are layouts of raw tokens, colored and sized by their frequency [. . .]. (Ward, Grinstein, & Keim, 2010, p. 299)

Tag clouds display all tags assigned to or by an entity (Peters, 2009). The entity can either be the whole platform (folksonomy), one single document (docsonomy), one user (personomy) or any other reasonable collection of tags. Following the portmanteau approach of the above neologisms, all tags assigned to a journal could be called 'joursonomy'. Usually ordered alphabetically, tag clouds allow the user to grasp the essential subjects of the underlying resources at a glance through the information conveyed by differing font sizes. The more frequently a tag was assigned, the larger is its depiction in the tag cloud (Peters, 2009).

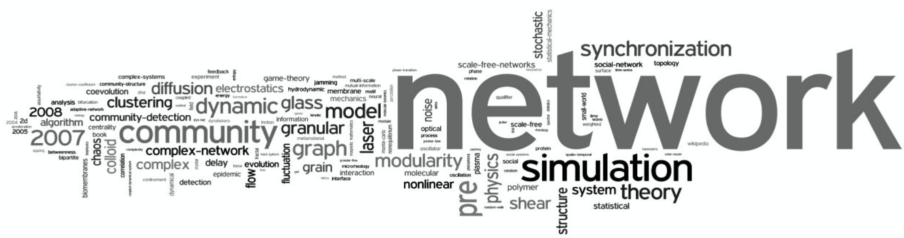


Figure 3.20 Tag cloud generated with Wordle for articles published in Phys Rev E.

Through the linkage of bookmarking entries to the respective bibliographic data via Digital Object Identifier (DOI)[12] the tags can be aggregated on the journal level, i.e. a 'joursonomy' can be generated. Figure 3.20 depicts all manually cleaned tags assigned to articles published in Phys Rev E. The importance of the 'network'-related subjects to readers of Phys Rev E becomes apparent at first glance. If tags are analyzed separately by publication year of the documents they were assigned to, thematic trends can be depicted and hot topics discovered. Figure 3.21 and figure 3.22 show all manually processed tags and their frequencies assigned to articles published in J Phys Condens Matter in 2004 and 2008, respectively. While in 2004 the most frequently used tag was 'electrostatics', 'graphene' gained importance in 2008. This reflects the growing importance of graphene, which culminated in the Nobel Prize in Physics awarded to Andre Geim and Konstantin Novoselov in 2010 "for groundbreaking experiments regarding the two-dimensional material graphene" (*The 2010 Nobel Prize in Physics – Press Release*, 2010).

However, manual tag gardening as described above is extremely elaborate and, as any other manual data processing, prone to human error and inconsistencies. Thus, an automatic process to unify synonyms induced by tagging was sought. The first automated step introduced to achieve unification of tagging-specific spelling variants of the same term was to delete all special characters applied to compound tags. This reduced the number of unique tags by 5.9% to 9,016. Language differences usually present a serious problem in social tagging (Cattuto et al., 2008). A detailed analysis revealed that this is not the case with the present set of tags. The appearance of non-English terms is marginal and can be neglected. This might be due to the fact that the tags are assigned to physics publications. These, like the great majority of scientific articles, are published in English, which is the de facto language or as Garfield (1967) put it the "international language of science". Physicists read and publish in English, and this data shows that they seem to tag in English as well. A difference can be observed between British and American English terms, however. In a tag cloud 'crystallisation' and 'crystallization' are displayed as two different terms, although they represent the exact same concept. Since the difference between British and American

12 A DOI is a unique and permanent identifier for digital objects linking them to their metadata and the location of the fulltext. The DOI system is run by the International DOI Foundation and as of April 2011 had assigned over 51 million DOI names. http://www.doi.org

English can be narrowed down to a few mainly minor spelling differences, a rule-based algorithm was applied to change British English terms into their American equivalents. After testing different approaches, the changes were limited to six conservative rules, which did not provoke any malformations but covered most of the differences between British and American English:

- -tre → -ter
- -our → -or
- -yse → -yze
- -ogue → -og
- -isation → -ization
- -isations → -izations

28 unique tags were changed and 72 tag applications affected by these rules. Although the number of unique terms was only reduced by 17 to 8,999, which equals a reduction of unique tags by only 0.2%, the effect on tag frequency caused a comparably large effect: 72 tag applications were recognized as British and changed into American spelling. 54 of these were merged with 186 American counterparts, so that 240 tag applications were unified.

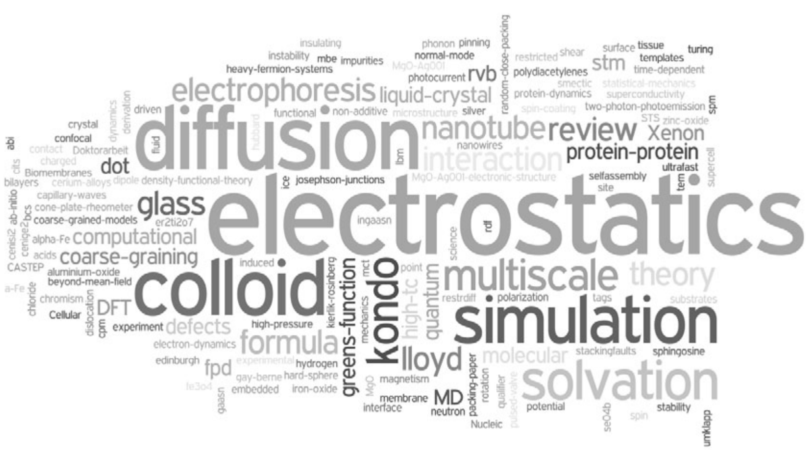


Figure 3.21 Tag cloud generated with Wordle for articles published in J Phys Condens Matter in 2004.

A common approach to find suitable index terms from uncontrolled vocabulary is to apply stemming (see section 3.1.2). Words are conflated to their stem to reduce morphological variants. Stemming is based on the assumption that an identical word stem indicates morphological relatedness (Moens, 2000). Here stemming was applied to reduce the number of tags and subsume morphologically related terms to make

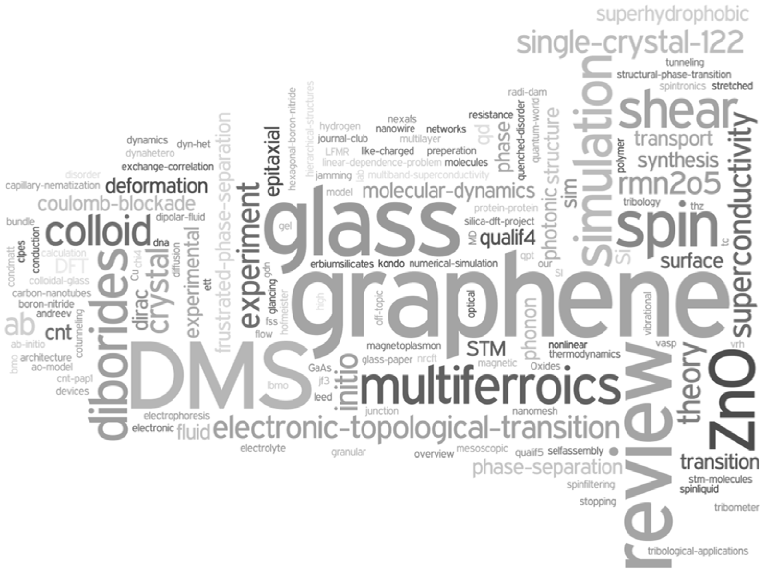


Figure 3.22 Tag cloud generated with Wordle for articles published in J Phys Condens Matter in 2008.

frequency distributions more meaningful. The Porter Stemmer is a reliable and widely-used algorithm for automatic rule-based stemming (Willett, 2006). The Porter2[13] algorithm, which is a further development of the Porter algorithm introduced in Porter (1980), was used in Python. An excerpt from the algorithm, which involves five basic steps of stemming, is shown in figure 3.23.

Stemming reduced the number of distinct terms by 909 to 8090 unique tags. This means that morphological variants could be conflated by 10.1%. All automated steps, i.e. elimination of upper cases and special characters, unification of British and American spellings and stemming, taken together caused an improvement of 15.6%. Changes of the frequency distribution caused by stemming and merging British and American English can be seen in table 3.8 for the 35 most frequently assigned tags. The tag describing complex networks gained 32 ranks after basic cleaning methods were applied, including stemming due to a combination of singular and plural. ‘Clustering’ (71 tag applications), ‘cluster’ (29), ‘clusters’ (16), ‘clusterization’ (2) and ‘clusterings’ (2) could all be gathered under the umbrella of ‘cluster’, which improved the concept’s visibility by 31 ranks from 45th (and 172nd, 365th, 2549th) to 14th. ‘Colloid’ unified ‘colloids’ (72), ‘colloid’ (33) and ‘colloidal’ (11) and ‘optic’ gained 17 ranks to be placed as 8th most frequent out of 8,090 unique tags.

Although the extensive cleaning process improved the expressiveness of the distribution of tag applications to unique tags, there are some terms where led to a loss of information. For example, ‘simul’, ‘dynam’ and ‘entangl’ are not directly comprehensive and ‘oled’ was wrongly changed into ‘ole’. Although this malformation did not merge the tags with any other unrelated terms, information is lost in case of the latter, and it cannot be reconstructed. The meaning of OLED (i.e. organic light-emitting

13 http://snowball.tartarus.org/algorithms/english/stemmer.html

diode) is irrecoverable. 'OLED' demonstrates another problem which cannot be solved: merging terms with their abbreviations. The tag 'organiclightemittingdiodes' appeared once as well and should be combined with the tag applications referring to its abbreviation. These problems can, however, only be solved through the application of extensive vocabulary control involving a comprehensive thesaurus including abbreviations and formulas from physics, engineering and chemistry (see section 3.1.1 and section 3.1.2).

```
def step_0(word):
    if word.endswith("'s'"):
        return word[:-3]
    if word.endswith("'s"):
        return word[:-2]
    if word.endswith("'"):
        return word[:-1]
    return word

def step_1a(word):
    if word.endswith('sses'):
        return word[:-4] + 'ss'
    if word.endswith('ied') or word.endswith('ies'):
        if len(word) > 4:
            return word[:-3] + 'i'
        else:
            return word[:-3] + 'ie'
    if word.endswith('us') or word.endswith('ss'):
        return word
    if word.endswith('s'):
        preceding = word[:-1]
        if s1a_exp.search(preceding):
            return preceding
        return word
    return word

doubles = ('bb', 'dd', 'ff', 'gg', 'mm', 'nn', 'pp', 'rr', 'tt')
def ends_with_double(word):
    for double in doubles:
        if word.endswith(double):
            return True
    return False
def step_1b_helper(word):
    if word.endswith('at') or word.endswith('bl') or word.endswith('iz'):
        return word + 'e'
    if ends_with_double(word):
        return word[:-1]
    if is_short_word(word):
        return word + 'e'
    return word
s1b_suffixes = ('ed', 'edly', 'ing', 'ingly')

def step_1b(word, r1):
    if word.endswith('eedly'):
        if len(word) - 5 >= r1:
```

Figure 3.23 Excerpt from the Porter2 stemming algorithm. Source: http://snowball.tartarus.org/algorithms/english/stemmer.html.

The method including automated steps to unify tag-specific synonyms and morphological variants can be achieved with minimal effort reducing the number of unique tags by 15.6%. This makes the frequency distribution more meaningful. Advantages far outweigh disadvantages. Further analysis of tags on the journal level is hence based on 8,090 unique tags obtained through the unification of 9,583 tags by automatic cleaning processes.

Table 3.8 Comparison of top 35 tag distributions with basic automatic cleaning and additional unification of British and American English and stemming.

Tags (basic cleaning)	**Frequency**	**Tags (extensive cleaning)**	**Frequency**
networks	394	network	665
theory	283	theori	284
review	271	review	278
network	269	simul	245
simulation	235	laser	230
physics	225	physic	227
laser	198	dynam	190
quantum	173	optic	176
dynamics	170	quantum	173
experiment	137	model	171
oled	134	experi	142
model	127	communiti	139
2007	119	ole	134
apl	119	cluster	120
entanglement	118	entangl	120
ofet	115	2007	119
community	112	apl	119
glass	103	colloid	116
diffusion	103	magnet	115
granular	99	glass	115
iiivsemiconductors	95	ofet	115
structure	93	diffus	106
pre	93	graph	104
nonlinear	92	complexnetwork	101
optics	91	granular	99
indiumcompounds	87	structur	99
gan	85	nonlinear	97
optical	85	nanowir	96
cavity	83	quantumdot	96
plasma	82	iiivsemiconductor	95
photoluminescence	82	pre	93
graphene	81	synchron	93
microfluidics	80	surfac	89
jap	78	indiumcompound	88
shear	78	microfluid	87

If the tags for each journal are examined more closely, differences can be observed regarding the number of tag applications. The number of times a tag was assigned to a document published in a particular journal ranges from 17 for Phys Solid State to 8,513 for Phys Rev E. Of course, the number of tag applications depends on the number of bookmarks. In order to determine the intensity with which users tag a journal, the number of tag applications has to be normalized by the number of bookmarks per journal. A journal's tagging intensity is thus defined as

$$TI_j = \frac{T_j^{\text{all}}}{B_j} \tag{3.1}$$

where B_j is the number of bookmarks on articles published in journal j and T_j^{all} represents the total number of tag applications. TI_j measures the activity with which users tag their bookmarks for a particular journal. This measure is thus independent of the absolute number of publications and bookmarks. Table 3.9 lists the TI_j values for all 45 journals. The median number of tag applications per bookmark is 2.46. Hyperfine Interact scored the highest TI_j value of 7.33, which is caused by a low number of bookmarks (9) being tagged 66 times.

Figure 3.24 Tag cloud depicting 50 most frequently assigned tags (automatically cleaned) for articles published in Hyperfine Interact between 2004 and 2008.

Table 3.9 Number of tag applications and unique tags (T_j^{all} = tag applications per journal; T_j^{unique} = unique tags per journal; TI_j = tagging intensity; TD_j = tagging diversity; TR_j = tag reuse).

Journal	T_j^{all}	T_j^{unique}	TI_j	TD_j	TR_j
Act Cryst A	43	30	1.10	1.41	1.07
Act Cryst B	32	25	3.20	3.44	1.08
Ann Phys	43	40	2.05	2.39	1.00
Appl Phys A	228	163	2.43	2.42	1.25
Appl Phys Let	6786	2133	2.62	2.94	1.77
Comput Mater Sci	123	100	2.46	2.54	1.11
EPL	948	609	2.29	2.74	1.38

continued on next page

Journal	T_j^{all}	T_j^{unique}	TI_j	TD_j	TR_j
Eur Phys J B	626	358	2.73	3.91	1.47
Eur Phys J E	280	169	2.69	3.34	1.36
Hyperfine Interact	66	53	7.33	7.33	1.00
IEEE Nanotechnol	63	44	2.25	2.89	1.14
Int J Thermophys	28	23	1.87	1.79	1.04
J Appl Phys	2644	1209	2.64	2.82	1.49
J Low Temp Phys	96	47	2.53	2.64	1.17
J Magn Magn Mater	331	223	2.59	2.86	1.17
J Phys A	758	477	2.54	3.04	1.37
J Phys Condens Matter	1231	633	2.21	2.54	1.45
J Phys D	434	324	2.18	2.38	1.13
J Rheol	25	21	5.00	6.25	1.10
J Stat Mech	603	325	2.72	3.89	1.54
J Stat Phys	155	125	1.96	2.22	1.14
J Vac Sci Technol A	71	48	2.54	2.63	1.02
JETP Lett	37	34	1.19	1.21	1.00
Nanotechnol	825	530	2.65	2.93	1.30
New J Phys	1185	677	2.72	3.58	1.32
Nucl Instrum Meth A	746	388	3.17	3.38	1.23
Nucl Instrum Meth B	303	188	2.35	2.46	1.16
Phys Fluids	616	313	2.38	2.58	1.41
Phys Lett A	352	290	2.21	2.44	1.12
Phys Rep	543	293	2.46	4.66	1.65
Phys Rev A	4334	1388	2.75	3.28	1.71
Phys Rev E	8513	2429	2.92	4.03	2.04
Phys Scr	117	96	2.05	2.06	1.02
Phys Solid State	17	17	2.83	2.83	1.00
Phys Stat Sol A	181	153	2.48	2.70	1.08
Phys Stat Sol B	223	167	2.75	2.87	1.11
Phys Today	102	84	2.37	2.83	1.11
Physica B	146	119	2.25	2.28	1.07
Physica C	127	64	1.95	1.87	1.30
Pramana	29	28	2.07	2.07	1.04
Rep Prog Phys	442	258	2.40	3.52	1.34
Rev Mod Phys	997	526	2.35	6.86	1.68
Soft Matter	281	168	2.58	2.69	1.26
Solid State Ion	22	21	1.83	1.83	1.00
Supercond Sci Technol	52	49	1.16	1.44	1.04

If one is not only interested in the number of tag applications per journal, but also in an analysis of thematic diversity, the number of unique tags per publication has to be examined. In contrast to the totality of tag applications T_j^{all}, the number of unique tags T_j^{unique} does not depend on the number of bookmarks and users but rather on the diversity of available content. Thus, the number of unique terms should be normalized by the number of unique bookmarked articles P_b.

$$TD_j = \frac{\sum T_j^{\text{unique}}}{P_b} \tag{3.2}$$

where P_b represents the number of documents published in the journal being bookmarked. $\sum T_j^{\text{unique}}$ is the sum of the number of unique tags per publication. This measurement expresses the diversity of tags assigned to articles. If the value equals 1, articles have only been tagged with one term each. Tagging diversity is 3.18 for all 10,280 bookmarked publications, meaning that on average each article was tagged by three different terms. The median tagging diversity of the 45 journals is 2.74, the arithmetic mean is 3.00. Again, Hyperfine Interact is ranked highest. What is striking is that the dominance of Mossbauer spectroscopy in the keywords assigned by authors is not at all reflected in the user tags. Figure 3.24 displays the 50 most frequent tags. While authors to a large extent agree upon one important term, user terms are most diverse. These differences may to some extent be caused by the small number of articles from Hyperfine Interact that were tagged.

TD_j does not take into account how many times an article is tagged but only how many different terms were assigned. Tag reuse TR_j indicates how many times distinct tags were reused. Tag reuse can be simply calculated by subtracting the number of unique tags from the number of all tag applications (Farooq et al., 2007). However, this measure is size-dependent: for the 45 journals under analysis it varies between 0 and 6,084 for the journals with the highest number of tag applications, Phys Rev E. Thus, normalization is needed when comparing journals with different numbers of bookmarked publications. Sen et al. (2006) introduced a more robust measure of computing tag reuse. It is based on the assumption that each tag is connected to at least one user:

$$TR_j = \frac{\sum R_t^{\text{unique}}}{T_j^{\text{unique}}} \tag{3.3}$$

where T_j^{unique} is the number of unique tags assigned to journal j and $\sum R_t^{\text{unique}}$ is the sum of the number of unique users per tag. If TR_j equals 1, tags were not taken up by other users. Tag reuse is 2.29 for the whole set of users and tags. It is higher than the value Farooq et al. (2007) computed for a set of bookmarks from CiteULike. This might be due to the preprocessing and cleaning applied, which reduced the number of unique terms, and by the limitation to physics publications, where tags are more likely to be reused than between different areas of research. As can be seen in table 3.9, TD_j is generally low and ranges from 1.00 to 2.04 (Phys Rev E). The median value of all 45 journals is 1.16. Hyperfine Interact, which scored highest for TI_j and TD_j, now has the lowest value of TR_j i.e. 1, indicating that although a high tagging activity and diversity of terms per document can be detected, no tag was assigned twice to one document. Since the number of unique tags is lower than the number of tag applications ($T_j^{\text{unique}} = 53$, $T_j^{\text{all}} = 66$), tags were assigned more than once on a journal but not on a document level.

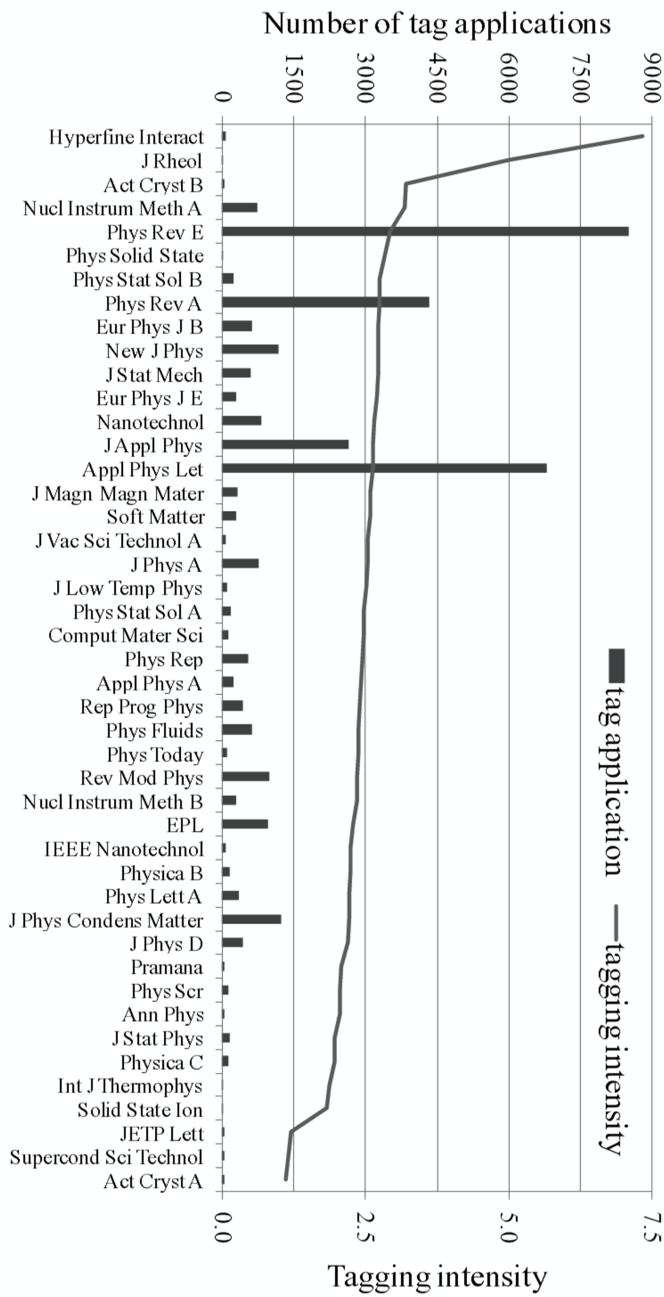


Figure 3.25 Number of bookmarks B_j and tagging intensity TI_j for 45 journals.

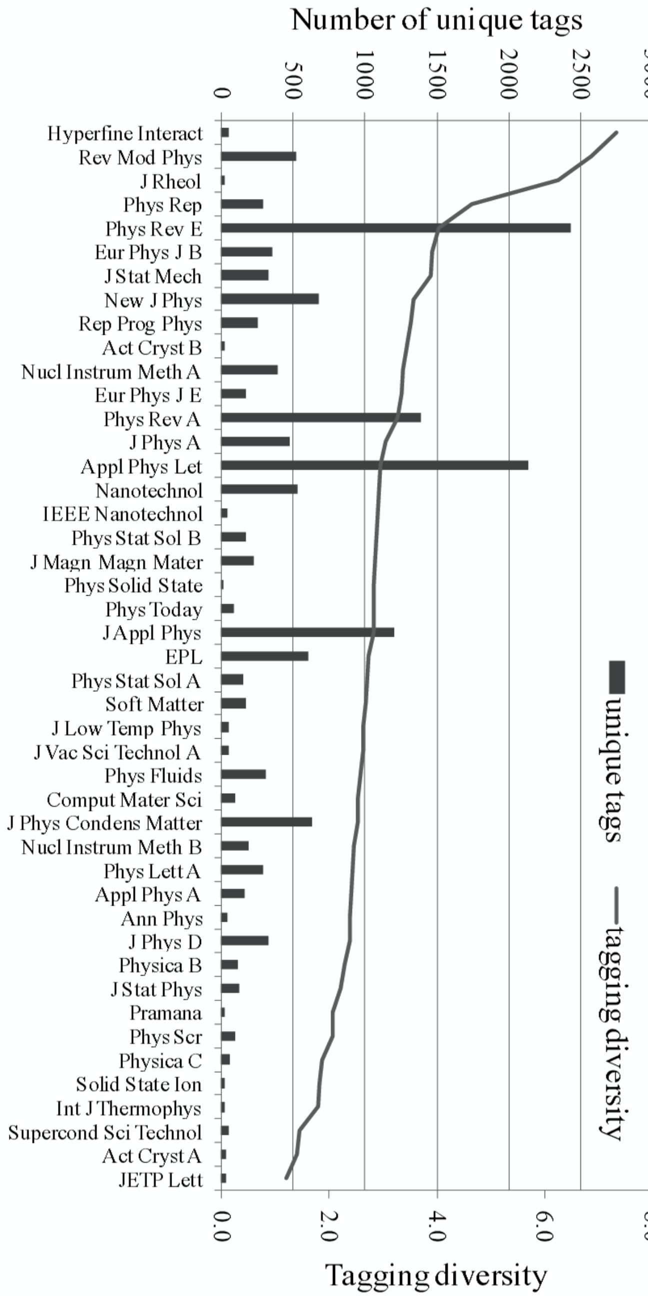


Figure 3.26 Number of bookmarked articles P_b and tagging diversity TD_j for 45 journals.

Comparison of Social Tagging and Traditional Indexing Methods

As social tagging was introduced as a new method of subject indexing, the question arises whether it provides a new perspective on journal content or if it is similar to conventional methods. To examine similarities and differences between tagging and common indexing methods, tags are compared to author-generated title and abstract terms as well as author keywords, indexer-generated Inspec subject headings and automatically generated KeyWords Plus. Previous studies (Kipp, 2005, 2006a; Lin et al., 2006; Lux, Granitzer, & Kern, 2007; Noll & Meinel, 2007a; Lu, Park, & Hu, 2010) comparing tags to author and intermediary terms have discovered low overlap between the different indexing sources: overlap was low for tags and professionally assigned index terms. The closest similarity could be discovered between tags and article titles. In the aforementioned analyses the researchers often do not differentiate between the collection of tags for all documents of a web 2.0 service, the folksonomy, and the docsonomy (except for Lu et al. (2010)). Moreover, a processing of tags and other metadata terms is regularly lacking or not explicitly reported in the papers. Calculating overlaps and matches with unprocessed terms and tags as well as simply relying on one-to-one matches on the string levels can lead to erroneous values and thus to invalid conclusions about the nature of folkonomies and metadata.

To account for the uncontrolled nature of tags and tagging-specific problems (compare section 3.1.6), the same automated cleaning procedures were applied as described above to facilitate a comparison with other indexing terms. Due to the difference between assigned index terms (Inspec headings and author keywords) and those extracted from full text (title and abstract words), tags were preprocessed in two different ways.

When compared to Inspec headings, author keywords and KeyWords Plus, tags were automatically preprocessed as described above: all upper case letters were turned into lower case, all special characters were deleted in order to unify compound terms, and British English suffixes were replaced by their American equivalents. Subsequently all terms were stemmed using Porter2. The same procedure was applied to the three kinds of indexing terms, although here compound terms were unified by deleting all blanks. Allowing for a comparison of tags and terms from titles and abstracts of the articles, following Noll and Meinel (2007b), compound tags were split at the separating character (i.e. hyphen or underscore) to allow for a matching of single-word terms of title and abstracts. This leads to a difference in the number of unique terms compared to index terms (1,596) and title and abstract terms (1,515). Additionally, stop words were removed from article titles and abstracts according to a list of 571 stop words compiled by Salton (1971) for the SMART project. All terms were also unified regarding British and American spelling differences and stemmed by the Porter2 algorithm (Peters, Haustein, & Terliesner, 2011; Haustein et al., 2011).

Table 3.10 Ten most frequent tags, title and abstract terms of all 724 articles (1,515 unique tags, split at separating characters).

Tags	Frequency	Title terms	Frequency	Abstract terms	Frequency
network	75	model	70	model	456

continued on next page

Tags	Frequency	Title terms	Frequency	Abstract terms	Frequency
quantum	44	magnet	57	right	353
theori	40	ion	51	reserv	352
review	38	quantum	42	result	349
dynam	35	effect	42	system	294
ion	35	system	40	energi	283
model	33	dynam	38	field	281
electron	30	electron	36	measur	276
magnet	30	high	34	studi	270
physic	30	properti	33	magnet	264

Table 3.11 Ten most frequent tags, author keywords, Inspec subject headings and KeyWords Plus of all 724 articles (1,596 unique tags, merged at separating characters).

Tags	Frequency	Author keywords	Frequency
network	48	network	18
review	36	randomgraph	17
theori	29	iiivsemiconductor	16
simul	26	silicon	13
2007	24	quantumopt	11
physic	24	ionimplant	11
laser	20	moleculardynam	11
model	20	stochasticprocess	10
communiti	18	polym	10
electron	16		
ion	16		

Inspec subject heading	Frequency	KeyWords Plus	Frequency
montecarlomethod	34	dynam	44
randomprocess	32	system	42
ferromagneticmateri	32	model	37
nanoparticl	28	film	26
anneal	28	simul	25
silicon	27	phasetransit	21
review	26	field	18
fluctuat	26	transit	17
molecularbiophys	25	particl	17
nonlineardynamicalsystem	25	state	17
iiivsemiconductor	25	temperatur	17

To make the analysis as exact as possible, term overlap was computed on the document level. Author keywords, title and abstract terms, indexer headings and KeyWords Plus were compiled on the article level and compared to the particular docsonomy. The prerequisite for this comparison is of course, that all of this data is available. All of the 168,109 analyzed publications have both titles and abstracts, but only 85.5% are covered in Inspec (compare figure 3.17) and only some of the journals ask authors to supply keywords (see figure 3.8). 8,868 articles were tagged by users. In total, 724 articles fulfill all necessary criteria and thus qualify for the comparison of author, indexer and reader perspectives on subject indexing. In order to compare differences and similarities of reader and author, intermediary and automatically indexed terms on the document level, each term is related to its publication via the DOI (see figure 3.27 for a schematic representation).

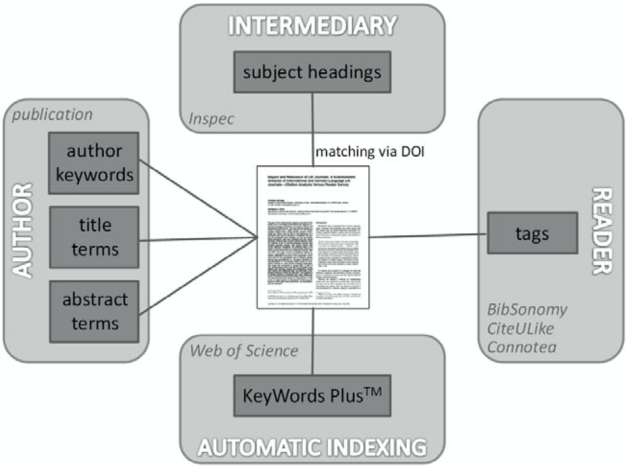


Figure 3.27 Schematic representation of a comparison of different indexing methods on the document level.

After preprocessing, the ten most frequently assigned terms for all 724 documents can be seen in table 3.10 and table 3.11. Due to the slightly different methods applied when comparing tags to abstract and title terms, the number of unique tags differs between table 3.10 and table 3.11. Counterintuitively the separation of tags leads to a reduced number of unique terms (1,515 instead of 1,596 tags). This is caused by the aggregation of parts of different terms (Peters et al., 2011; Haustein et al., 2011).

Whether terms match between the different indexing methods on a document basis is analyzed here, whereas most other approaches simply calculate the overlap of tags and metadata across the whole database. The more exact approach was applied to avoid mismatches between tags and metadata of different documents, as term overlap between docsonomy and respective metadata is more valuable than overlap between folksonomy and the entire metadata collection. The information is useless if article *a* was tagged with the same term an indexer assigned to article *b*. After all, the aim is to analyze whether the metadata is similar on the document level. Tags and terms were compared for every single document, and average overlap values were subsequently calculated. After determining the number of cleaned unique tags, author keywords, KeyWords Plus, Inspec, title and abstract terms for each of the 724 articles, the overlap between the different entities was computed. Term overlap is defined as an exact character string, appearing in the reader and author, intermediary, automatic indexing, title or abstract data, respectively. The highest share of overlap is detected between tags and abstracts: 77.6% of the 724 articles had at least one common term in tags and abstracts. For 66% at least one tag appeared in the title. This is followed by the overlap of tags and intermediary terms (33.4%) and author keywords (29.3%). Only 10.5% of all documents had at least one tag and automatically generated KeyWords Plus in common. Here, the unification of American and British English and stemming successfully increased the share of documents with at least one shared term. This shows that this comparison of term overlap is more exact. The number of at least one overlap of tags and author keywords, Inspec headings, KeyWords Plus, title and abstracts improved by 26.2%, 21%, 20.6%, 9.4% and 8.5%, respectively.

Table 3.12 lists the arithmetic mean of the similarity values of the 724 documents. First, the percentage of overlap is computed in contrast to the total number of unique tags per document on the one hand and the number of the particular meta terms on the other, in order to detect the share of common tags from both of the perspectives. The overlap-tag ratio lists the percentage of overlapping tags in contrast to all unique tags assigned to the particular document and is defined as

$$\text{overlap-tag ratio} = \frac{g}{T^{\text{unique}}} \tag{3.4}$$

where T^{unique} stands for the number of unique tags per document and g represents the overlap between tags and terms (author keywords, Inspec headings, KeyWords Plus, title or abstract terms, respectively) per document. Most tags are represented in the abstracts, which is to be expected, since the number of abstract terms is much greater than that of the other metadata. The overlap-term ratio calculates the same overlap from the other perspective:

$$\text{overlap-term ratio} = \frac{g}{K^{\text{unique}}} \tag{3.5}$$

where K^{unique} stands for the number of unique terms per document and g represents the overlap between both sets per document. On average, 24.5% of title terms are taken over by users when tagging articles. Strikingly, only 3.4% of indexer terms are adopted by users. While this might have dramatic consequences on information retrieval in Inspec, it reveals a wide difference between the reader and indexer perspectives on published contents.

To combine the two measurements, the similarity between the reader's point of view on the one hand and the author's, intermediary and automatic indexing perspective, on the other hand, is calculated by cosine:

$$\text{cosine similarity} = \frac{g}{\sqrt{T^{\text{unique}} \cdot K^{\text{unique}}}} \tag{3.6}$$

where T^{unique} stands for the number of unique tags per document, K^{unique} for the number of unique terms and g represents the overlap between tags and terms per document. If a publication is tagged by its readers with exactly the same terms the author used to describe it, the similarity of author and reader indexing is 1. It is 0, if the two sets of terms are completely different.

Similarity is computed in the same ways for tags and Inspec terms, KeyWords Plus, title and abstract terms. While there is no document, where all tags and indexer or abstract terms match exactly, there are documents with 100% matches of tags and titles, KeyWords Plus and author keywords, respectively. The highest number of documents with a cosine of 1 can be found for author keywords and tags (6 documents), followed by title (3) and KeyWords Plus and tags (2).

Table 3.12 Means of document-based similarity measures comparing tags with author keywords, Inspec subject headings, KeyWords Plus™, title and abstract terms.

	Author keywords	Inspec subject headings	KeyWords Plus™	Title terms	Abstract terms
mean overlap-tag ratio	0.118	0.133	0.029	0.365	0.503
mean overlap-term ratio	0.104	0.034	0.030	0.245	0.048
mean cosine similarity	0.103	0.062	0.026	0.279	0.143

Table 3.12 shows the arithmetic mean of the results of the similarity values computed on the document level. On average, there is hardly any overlap between reader and professional (0.062) and automatic indexing (0.026) methods. The mean cosine value is highest for title terms (0.279), abstracts (0.143) and author keywords (0.103). Overall, cosine similarities are however very low because a great proportion of documents do not have common tags and indexing terms. This implies that social tagging represents a user-generated indexing method and provides a reader-specific perspective on article content, which differs greatly from conventional indexing methods. Each approach reflects a different view on article content and can be used as third method to reflect journal content in addition to author and intermediary indexing (Peters et al., 2011; Haustein et al., 2011).

Figure 3.28 Word cloud depicting 50 most frequent of 9,777 assigned author keywords to articles published in Physica B between 2004 and 2008.

Figure 3.28 and figure 3.29 show word clouds generated with Wordle of the most frequent author keywords and tags (automatically cleaned) assigned to articles published in Physica B between 2004 and 2008. While authors most often pick ‘superconductivity’ to describe their document aboutness, users make more diverse choices. The frequent usage of content-unrelated can also be observed, tags such as the year of publication (‘2005’, ‘2006’ and ‘2008’).

Figure 3.29 Tag cloud depicting the 50 user tags out of a total of 119 most frequently assigned to articles published in Physica B between 2004 and 2008.

3.3 Content Trend Analysis

As shown in section 3.2.2, index terms applied to single documents can be aggregated on the journal level to reflect its thematic scope. Frequency distributions reveal main focuses. If index terms are analyzed year by year, i.e. accumulating all terms assigned to documents published in the same year, shifts of emphasis can be discovered or the emergence of hot topics. Computing the overlap of terms between two years indicates content stability (Stock, 1990). In the following, thematical changes and term stability are evaluated over the five years under analysis for Physica C by examining Inspec Classification Codes, Inspec Headings, author keywords, KeyWords Plus and tags year by year. Table 3.13 lists the cosine similarities of the most frequent index terms of one year in comparison to those assigned to documents published in the subsequent year. The value thus indicates the 'survival' of index terms from one year to the next (Stock, 1990):

$$\text{content stability} = \frac{g}{\sqrt{N_y \cdot N_{y+1}}} \tag{3.7}$$

where N_y represents the number of most frequent index terms assigned in the first year, N_{y+1} the number of terms in the subsequent year and g stands for the number of terms that appeared in both years. A value of 1 indicates that the same terms were most frequently assigned to the documents over time. If term stability equals 0, documents were indexed with completely different terms, indicating a thematic cesura.

Table 3.13 Cosine similarity of most frequent index terms indicating stability of content over time.

	Inspec Classification	**Inspec Headings**	**Author Keywords**	**KeyWords Plus^{TM}**	**Tags**
top n% of term assignments	50%	15%	10%	15%	100%
2004 → 2005	0.801	0.907	0.596	0.696	0.000
number of terms	$N_{2004} = 12$	$N_{2004} = 17$	$N_{2004} = 12$	$N_{2004} = 11$	$N_{2004} = 28$
	$N_{2005} = 13$	$N_{2005} = 14$	$N_{2005} = 15$	$N_{2005} = 12$	$N_{2005} = 4$

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	Inspec Classification	Inspec Headings	Author Keywords	KeyWords Plus^{TM}	Tags
2005 → 2006	0.769	0.756	0.716	0.671	0.000
number of terms	$N_{2005} = 13$	$N_{2005} = 14$	$N_{2005} = 15$	$N_{2005} = 12$	$N_{2005} = 4$
	$N_{2006} = 13$	$N_{2006} = 18$	$N_{2006} = 13$	$N_{2006} = 15$	$N_{2006} = 17$
2006 → 2007	0.881	0.819	0.641	0.653	0.000
number of terms	$N_{2006} = 13$	$N_{2006} = 18$	$N_{2006} = 13$	$N_{2006} = 15$	$N_{2006} = 17$
	$N_{2007} = 12$	$N_{2007} = 14$	$N_{2007} = 12$	$N_{2007} = 10$	$N_{2007} = 14$
2007 → 2008	0.961	0.857	0.609	0.735	0.178
number of terms	$N_{2007} = 12$	$N_{2007} = 14$	$N_{2007} = 12$	$N_{2007} = 10$	$N_{2007} = 14$
	$N_{2008} = 13$	$N_{2008} = 14$	$N_{2008} = 11$	$N_{2008} = 15$	$N_{2008} = 9$
median	0.841	0.838	0.625	0.684	0.000

In analyzing Inspec Classification Codes assigned to articles from Physica C according to year, it becomes apparent that the most frequently used classes remain similar over time. Cosine similarity values were calculated among the top classification codes accounting for 50% of annual class assignments representing term stability between the particular years. Analyzing half of all the annual class assignments of Physica C publications resulted in an average of 12.6 different codes per year. Cosine values range from 0.769 (similarity between 2005 and 2006) to 0.961 (2007 and 2008). The median of all values is 0.841 (see table 3.13).

The assignment of some classification codes, however, varies from year to year. While in 2007, 205 documents were classified under A7430J 'Electronic structure of superconductors', in the preceding year there were only 53, and 47 were assigned to this class in the subsequent year. All of the 35 articles from Physica C classified under B7410 'Particle accelerators' were published in 2006.

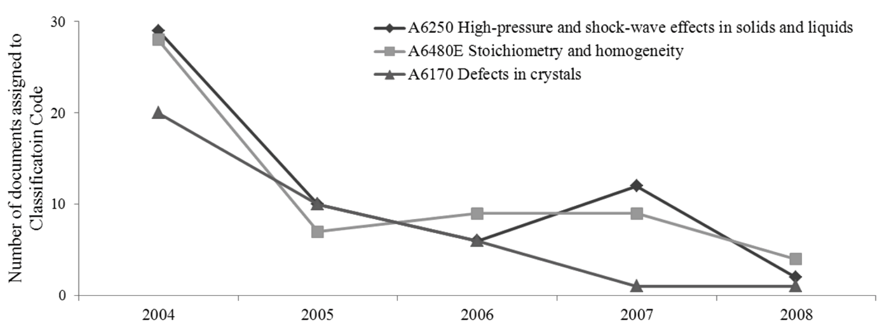

Figure 3.30 Time analysis of documents from Physica C assigned to Classification Codes A6170, A6250 and A6480E.

Figure 3.30 and figure 3.31 show three topics which lost and gained importance in the particular journal over the five years under consideration. While in 2004, 29 papers were published in Physica C dealing with 'high-pressure and shock-wave effects in solids and liquids', there were only two in 2008. Publications on 'defects in crystals' decreased gradually from 20 in 2004 to one article per year in 2007 and 2008. 'Stoichiometry and homogeneity' seemed to be a hot topic in 2004 but dropped to an average level of 7 papers per annum in succeeding years. Figure 3.31 shows the growth curves of Physica C documents classified under A6146, A7560E and B3220 of the Inspec Classification. The number of publications about 'magnetization curves, hysteresis, Barkhausen and related effects' and 'superconducting materials' increases constantly after 2005. After a mean annual output of 6.8 documents from 2004 to 2007, the number of publications on 'structure of solid clusters, nanoparticles, nanotubes and nanostructered materials' in Physica C tripled in 2008.

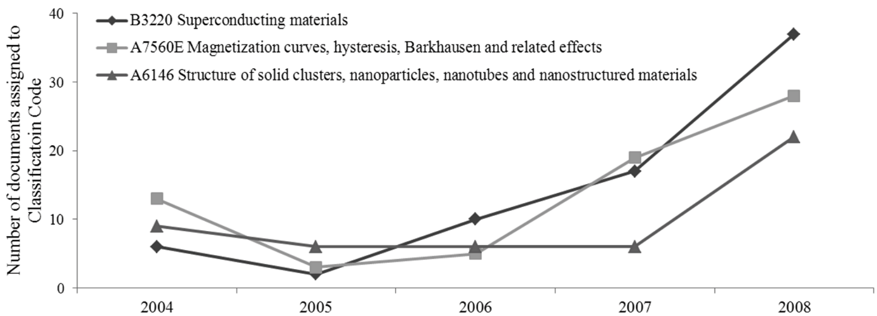

Figure 3.31 Time analysis of documents from Physica C assigned to Classification Codes A6146, A7560E and B3220.

Inspec Headings also show strong values of term stability. The most frequently applied terms accounting for 15% of annual assignments were examined, which resulted in an average of 15.4 headings per year. At 0.838, the median of the four cosine similarities is only slightly lower than that of the assigned class codes. Both methods of professional indexing show the lowest cosine values between indexer terms assigned to publications from 2005 and 2006, indicating that the thematic focuses changed most between these two years. Stability of the most frequent Inspec Headings was strong between the other years. A topic decline can be observed for the thesaurus term 'type II superconductors', which was frequently used for articles published in 2004 ($\sum_{2004} = 188$) and became less important in the following years ($\sum_{2005} = 52; \sum_{2006} = 82; \sum_{2007} = 90; \sum_{2008} = 29$).

Due to their uncontrolled nature, the frequency of assigned author keywords was more skewed than terms applied by indexers from Inspec. On average, the 12.6 most frequently used terms were examined, which accounted for 10% of all author indexing per year. As expected, author keyword stability is generally much lower than that of the terms assigned by professional indexers (median = 0.625, see table 3.13). Surprisingly, the values are not only lower but also show contradicting values. While classification codes and thesaurus headings were most diverse between 2005 and 2006, author keywords were most stable between those years. Figure 3.32 shows the most frequent terms authors assigned to publications from 2008 and their position in the frequency rankings from the four previous years. While the five most frequent terms from 2008 only interchange ranks within the top 6, a large fluctuation can be observed for ranks 6 and below. 'Vortex matter' can be identified as a hot topic since it was assigned to 218 publications in 2008 and hardly used before. In the previous years, a total of 15 articles were labeled by authors with 'vortex matter'. In 2005, this term was not applied at all.

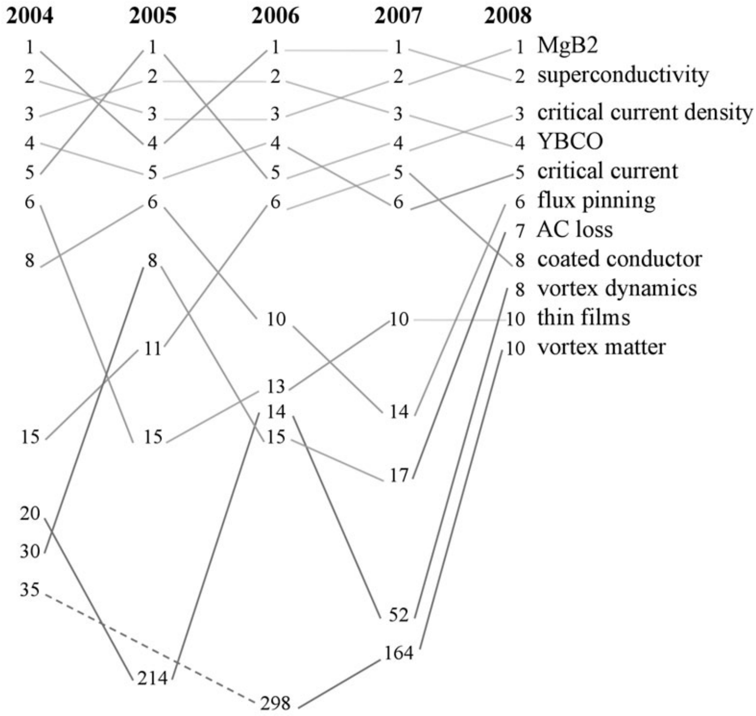

Figure 3.32 Most frequently used author keywords for Physica C from 2008 and the development of rank orders in previous years. Author keywords are taken from WoS and not corrected, e.g. ‘MgB2’ should be ‘MgB_2’.

Stability values of automatically generated KeyWords Plus is comparable to that of author keywords. 15% of all automated assignments were analyzed resulting in an average of 12.6 keywords per year. Annual similarity values of KeyWords Plus show only small standard deviations from the mean of 0.689 (median = 0.684). The strongest stability value can be observed between articles published in 2007 and 2008.

In order to analyze the term stability of user-generated index terms, all tags (extensively cleaned and stemmed, compare section 3.2.2) applied to Physica C were taken into account. Due to the small number of tags assigned to Physica C, all tags were considered for the computation of term stability. The average number of unique tags assigned to documents published per year is 14.4, but differed considerably between the particular years. Except for 2007 and 2008, no reuse of tags can be found. Although it was to be expected that term stability would be lowest for tags, the results for Physica C are not representative.

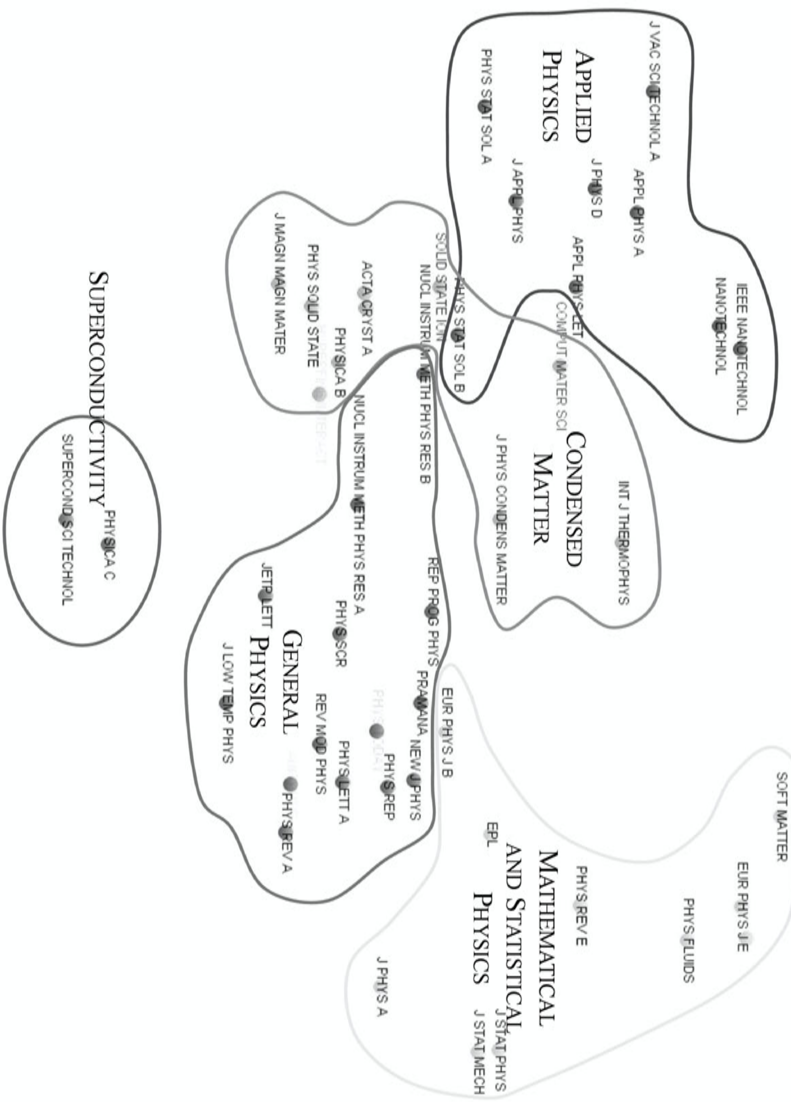

Figure 3.33 Clusters based on bibliographic coupling and co-citation data.

3.4 Content Similarity Analysis

To gain an overview of the publishing landscape, it is not only helpful to describe the content of scientific journals, but also to group similar ones. Journal similarity can be measured by calculating the overlap between terms associated with their publications. Thus, content similarity can be discovered on the grounds of different methods of subject indexing. These methods were theoretically introduced in section 3.1 and applied to the analyzed journals in section 3.2. In the following, results from the subject analysis are used to group similar periodicals. Section 3.4.1 applies bibliographic coupling and co-citations to cluster the 45 journals, while section 3.4.2 and section 3.4.3 reveal thematic similarities through common indexer terms, readers and tags. Clustering and mapping techniques are applied to visualize similarities and differences of journals regarding their content.

3.4.1 Bibliographic Coupling and Co-Citations

The most common approach to cluster similar journals is achieved through citation indexing (see section 3.1.4). On the journal level, citation matrices are highly structured as they depict dense clusters of journals that frequently exchange information and are otherwise populated very sparsely. Rafols and Leydesdorff (2009a) report a density of 2.27% for the citation matrix of 7,611 journals included in the 2006 edition of the JCR, meaning that of 57,927,321 possible citation relations only 1,315,143 were actually realized. Despite differences in methodologies, clusters based on journal-to-journal citation similarity have produced comparable maps depicting the landscape of academic journals and scientific disciplines (Leydesdorff, 1987; Boyack et al., 2005; Leydesdorff, 2007; Klavans & Boyack, 2009; Rafols & Leydesdorff, 2009a).

Bibliographic coupling and co-citation data was generated from SCI data[14] for the 45 journals under analysis. Matrices were computed separately for each publication year in order to be able to discover changes in the structure of communication over time. The time window for co-citations was limited to two years, while bibliographic coupling was analyzed over ten years. Hence to evaluate the co-citation strength between the documents published in the 45 journals in 2004 all entries from the SCI published in 2004 and 2005 were analyzed. To analyze similarity based on bibliographic coupling, the references from the 2004 publications of the 45 journals were analyzed to investigate the number of similar references from 1995 to 2004. For example J Appl Phys and Phys Stat Sol A show very high bibliographic coupling values in 2004: the two periodicals shared 1,247 references published between 1995 and 2004 in their 2004 publications.

To be able to provide a robust picture of relatedness between journals, co-citations and bibliographic coupling data can be combined to gain a journal-to-journal similarity matrix. The combined similarity values reflect the structure of the whole communication process, i.e. knowledge import and export as represented by references and citations. Thus, the combination of bibliographic couples and co-citations gives a more robust

14 This kind of data can only be generated with a local copy of the citation databases (Van Raan, 2004). Bibliographic coupling and co-citation data for the 45 journals under analysis was obtained through the local database at CWTS in Leiden. The author would like to thank Nees Jan van Eck and Ludo Waltman for their help.

picture of contextual relationships between journals. Figure 3.33 shows a similarity cluster map based on normalized similarities derived from the combination of bibliographic coupling and co-citation values. The map was generated with VOSViewer[15] a free tool that combines clustering and mapping techniques (Van Eck & Waltman, 2010; Waltman, Van Eck, & Noyons, 2010). Journals are similar and thus situated closely together, if they are frequently cited by and/or cite the same documents. Co-occurrence data is normalized automatically by VOSViewer with association strength, which is defined as the similarity s_{ij} between two items i and j:

$$s_{ij} = \frac{c_{ij}}{w_i w_j} \tag{3.8}$$

where cij represents the number of co-occurrences of i and j and w_i and w_j stand for the total number of occurrences (or co-occurrences) of i and j, respectively (Van Eck & Waltman, 2010). Refer to Van Eck and Waltman (2009) for a comparison of association strength to other similarity measures, i.e. cosine and Jaccard.

For the 45 journals analyzed, five clusters grouping periodicals of similar content emerge, which can be labeled 'Applied Physics', 'Condensed Matter', 'Mathematical and Statistical Physics', 'General Physics' and 'Superconductivity'. The median number of journals per cluster is 10, while 'General Physics' contains the most items i.e. 14 journals. The cluster of 'Superconductivity' forms an outlier since it consists of only two journals, Physica C and Supercond Sci Technol. While all other clusters are connected through journals that function as bridges between two components, i.e. Eur Phys J B, which is closely related to journals from the 'General Physics' cluster, or Phys Stat Sol B, which belongs to 'Applied Physics' but is located almost in the center of 'Condensed Matter Physics'. It can be seen that 'Superconductivity' is located apart from the other journals.

3.4.2 Co-word Analysis

Similarity based on term co-occurrences is based on the overlap of identical index terms assigned to two documents. Term co-occurrence is able to measure and map similarity between documents, authors or journals. If two documents share common words or phrases or are assigned the same index terms or class notations, they are regarded as thematically related. The larger the share of common terms, the greater the similarity. Similarity cannot only be measured on the document level but can be accumulated on the meso- and macro-levels by applying common terms to the documents' authors, affiliated institutions or countries or to the journal that published them. Similarity values can be computed by normalized similarity measures, e.g. cosine, Jaccard, Dice etc., which allow for a computation of similarity clusters as depicted in figure 3.33.

A 2-mode network, which includes both the similar items and the respective terms that connect them, is able to depict not only similarity but also to include the actual content descriptive terms. Section 3.2.1 introduces such similarity networks based on the co-occurrence of journals in the WoS (figure 3.6) and ERA (figure 3.7) classification schemes. Periodicals as a whole are classified into one or more of the prescribed classes.

15 http://www.vosviewer.com

Following the principles of classification, journals belonging to the same category are similar. As previously outlined, journal classification schemes are in general able to reflect the broad subject area but fail to provide details. Index terms assigned to single documents allow for a more specific analysis of content, if accumulated on the journal level. Term frequency information can be used to measure the degree of similarity between periodicals.

Figure 3.34 shows a network graph visualizing the connection of seven journals through common Inspec indexer terms and class notations. In order to produce a meaningful similarity map, it is necessary to apply certain thresholds. Figure 3.34 is based on the most frequently assigned classification codes and Inspec Headings. Only those journals are considered where document coverage in Inspec exceeds 95% (compare p. 114).

For each of these seven journals, all notations and headings used to index to its publications were accumulated and ranked in descending order by frequency of occurrence. For classification codes, the threshold was set to the most frequent codes accounting for at least 15% of all assignments, for Inspec headings the threshold was set to the top 5% of all term assignments, because frequency distributions are more skewed (compare p. 119). The most frequent class notations, which varied between the fourth and the sixth level of hierarchy, were subsumed under the third sublevel of the classification scheme. This aggregation resulted in the following categories, which are ranked by frequency of assignment:

- A6100 Structure of liquids and solids; crystallography
- A7400 Superconductivity
- A6800 Surfaces and interfaces; thin films and whiskers
- B2500 Semiconductor materials and devices
- A4600 Mechanics, elasticity, rheology
- A5200 The physics of plasmas and electric discharges
- A7500 Magnetic properties and materials
- A6600 Transport properties of condensed matter
- A8100 Materials science
- A7100 Electron states in condensed matter
- B2200 Printed circuits, hybrid integrated circuits and molecular electronics
- A6400 Equations of state, phase equilibria, and phase transitions
- B1200 Electronic circuits
- A7300 Electronic structure and electrical properties of surfaces, interfaces, and thin films
- B0500 Materials science for electrical and electronic engineering
- A6200 Mechanical and acoustic properties of condensed matter
- A7700 Dielectric properties and materials

The assignment of classes reveals a thematic focus on condensed matter physics, which can be regarded as the main subfield of solid-state physics. The majority of notations most frequently applied to index the seven journals derive from A6000 and A7000 of the Inspec classification scheme. Both classes refer to different aspects and properties of condensed matter: A6000 refers to 'structure, thermal and mechanical properties' of condensed matter, while A7000 deals with its 'electronic structure, electrical, magnetic, and optical properties'. Figure 3.34 contains three components, of which the largest connects five journals while the other two each contain only one. According to the thresholds described above, which consider the most frequent terms and thus do not depict thematic similarities in detail but rather focus on the journals' main subject areas, J Rheol and Physica C are not directly connected to any of the other periodicals. Remote similarity can be retraced through the distance between the notations. For example, Physica C is classified under subgroups of A7400 'Superconductivity', while J Phys Condens Matter is indexed by A71*, A73* and A75*. Edge width indicates the frequency of assignment in relation to the total of all term assignments per journal. This reveals that some journals focus on specific areas, i.e. Act Cryst A and Physica C, which respectively place emphasis on the 'structure of liquids and solids; crystallography' and superconductivity, while others, i.e. J Phys Condens Matter and J Phys D, cover more diverse topics. The same thematic tendencies are reflected in the indexer terms, although connections are fewer. Only six out of 40 unique Inspec headings are applied to more than one journal. 5% of all indexing applied to J Rheol and Physica C refers to two or three unique terms. For publications from J Phys Condens Matter and J Phys D, on the other hand, 14 and 15 different headings are needed, respectively. 'X-ray diffraction', which stands for a technique used to identify crystalline solids, can be attributed a certain importance due to its central position which emerged through its connections to four journals. This particular term was the most frequently used heading to index J Phys Condens Matter, J Phys D and J Vac Sci Technol A and the second most frequent to index publications from Act Cryst A.

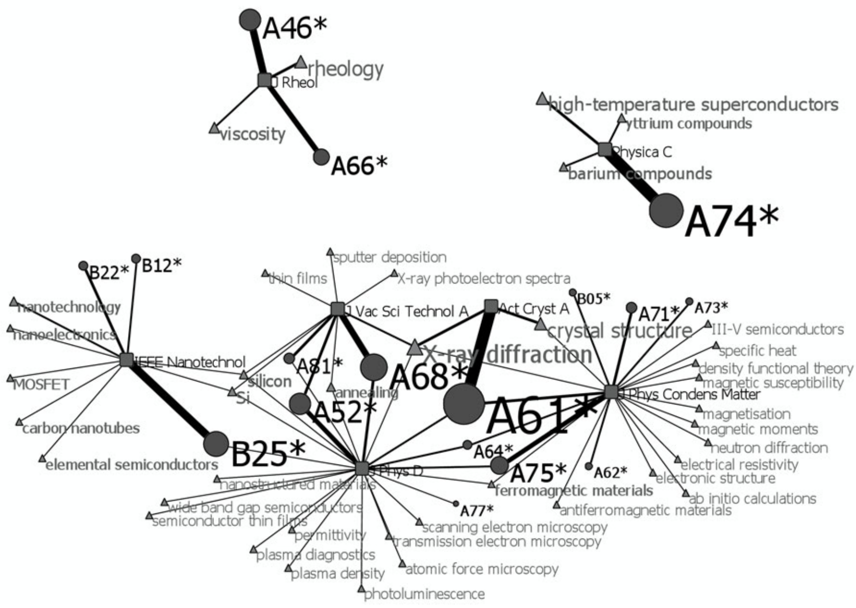

Figure 3.34 2-mode network of seven journals and most frequently assigned Inspec notations and headings.

3.4.3 Co-occurrence of Users and Tags

Analogous to similarity computation based on the co-occurrences of assigned indexer terms or class notations, users bookmarking journal articles and the tags they assign to them can be applied to discover thematic relations (Van Damme et al., 2007; Cattuto et al., 2008; Zanardi & Capra, 2008; Peters, 2009). Academic readers who use social bookmarking services to manage their references save articles from a particular area of research. If bookmarking applications are accumulated on the journal level, each user can be linked to the journals that cover the field of research he or she is interested in. If a large number of users read the same journals, a network can be generated that groups periodicals from a similar research areas (Pierce et al., 2008; Zanardi & Capra, 2008).

Figure 3.35 shows the network graph of all users who bookmarked at least two different journals. Of the initial 2,441 users who bookmarked publications from 45 journals under analysis (compare section 4.3.1), 1,442 users had to be excluded because they read only documents from one journal and thus did not contribute to the linking of similar journals. The final matrix of 999 users and 45 bookmarked periodicals was connected sparsely. It contained 3,713 actual out of 44,955 possible connections. Network density was thus 0.083.

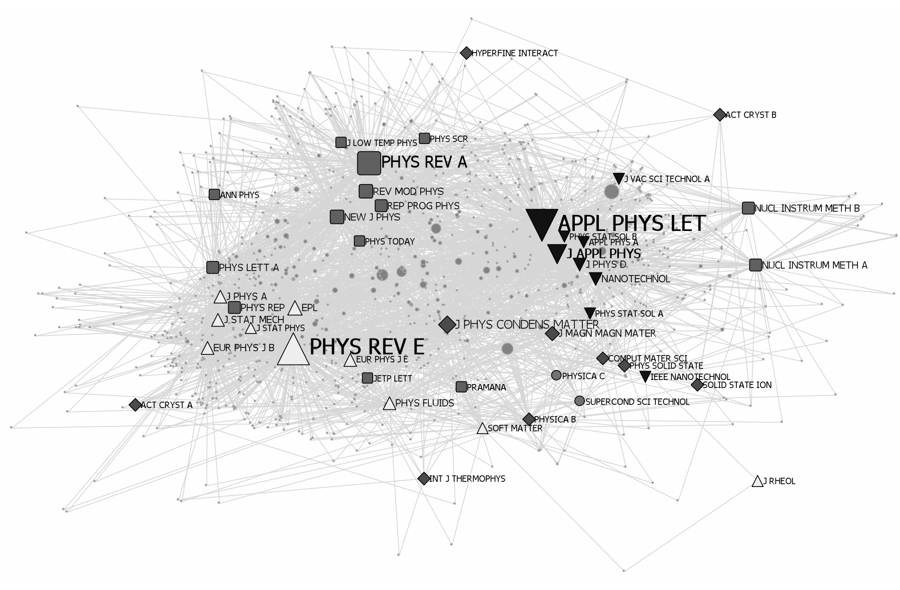

Figure 3.35 2-mode network of 45 journals and 999 users of social bookmarking.

Although the number of bookmarks and users was rather low in comparison to the number of analyzed publications and in contrast to the global community of physicists in solid-state research, the user similarity network produced quite robust results: figure 3.35 includes the information on the journal clusters produced by ten years of bibliographic coupling and co-citation data. Journals belonging to the 'Applied Physics' cluster are indicated by downward triangles, the upward triangles represent

'Mathematical and Statistical Physics', the square labels 'General Physics', the circles 'Superconductivity' and the diamonds stand for journals belonging to the cluster of 'Condensed Matter'. Except for a few outliers (i.e. Act Cryst A, Hyperfine Interact, Nucl Instrum Meth A or Nucl Instrum Meth B), the overlap between the two similarity maps is strong. The outliers are merely caused by the small database: figure 3.35 takes into account every single connection between the 999 users and 45 journals. In order to obtain more robust results, a threshold can be applied which excludes random usage and provides more accurate data on journal similarity. The similarity matrix is reduced to the strongest connections by limiting the database to 98 users who bookmarked at least five documents per journal from at least two different periodicals. 14 journals, including all outliers from figure 3.35, did not meet the criteria of the threshold so that the 2-mode network consists of 31 periodicals, 98 users and 765 connections. Network density is 0.252. The network graph including the cluster allocation based on citation similarities (figure 3.33) can be seen in figure 3.36. As described above (p. 121), user-generated tags differ from indexer or author terms and offer a reader-specific view on journal content. Hence, similarity maps derived from tags may depict the users' perspective on similarities and differences of published subjects.

Figure 3.37 shows the visualization of journal similarity based on the connections through common tags. If two journals are tagged by the same terms, they are assumed to publish similar content. Since no vocabulary control is applied in social tagging, it is crucial to unify spelling variants as far as possible before generating content maps based on similarity calculations (Peters, 2009). Tags underwent the excessive automatic cleaning processes described above (p. 121ff.). Equally it is crucial to apply thresholds regarding number of tag occurrences and co-occurrences. In total, 8,090 unique terms (cleaned and stemmed tags) were assigned 35,804 times by 1,992 users (see p. 121ff.). As a first reduction, only journals with more than 50 unique tags are considered. The remaining 32 periodicals were described by 7,970 unique tags. This set was further limited by excluding all terms applied less than five times per journal and assigned to at least two different periodicals. Five of the initial 32 journals and 96.9% of unique terms did not meet the criteria so that the final journal-tag network contained 27 journals, 245 unique tags and 10,702 total tag applications. Network density was low ($d = 0.109$) due to the sparse matrix. The network can be subdivided into three sections with applied physics journals on the left hand side, a group of general physics journals on the top, and mathematical and statistical physics on the right. Although 'network' was the most frequently used tag it is not that important for the whole network. The terms that apply to the majority of journals are mapped in the center of the graph. The most frequent tags are general terms and either describe very broad subjects ('physic', 'simul') or refer to the type of documents ('review', 'theori'). There are some periodicals that occupy central positions because they are described by a large number of different tags (e.g. Appl Phys Let, J Appl Phys and Phys Rev E). Others are located on the periphery of the network because they are indexed by a rather small number of terms, i.e. Phys Lett A, Phys Stat Sol A and Phys Stat Sol B.

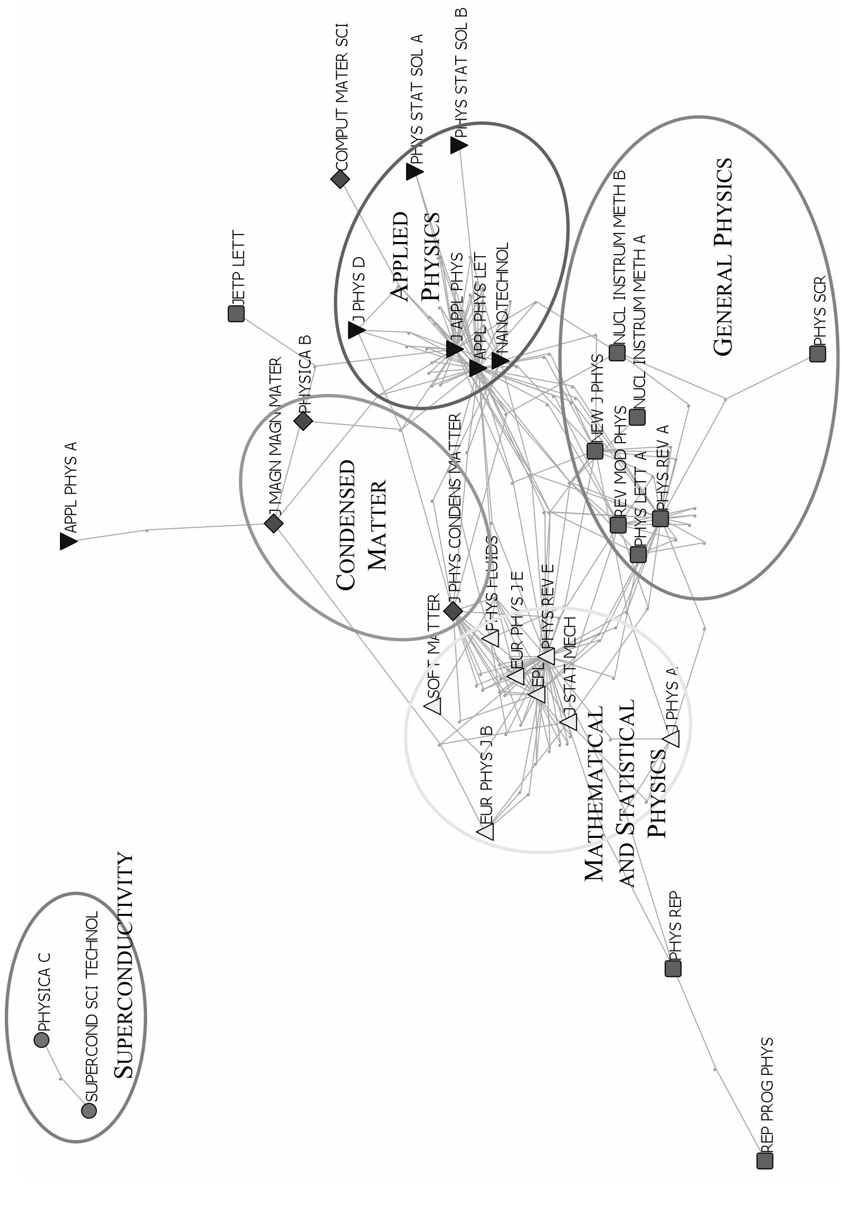

Figure 3.36 2-mode network of 31 journals and 98 users of social bookmarking.

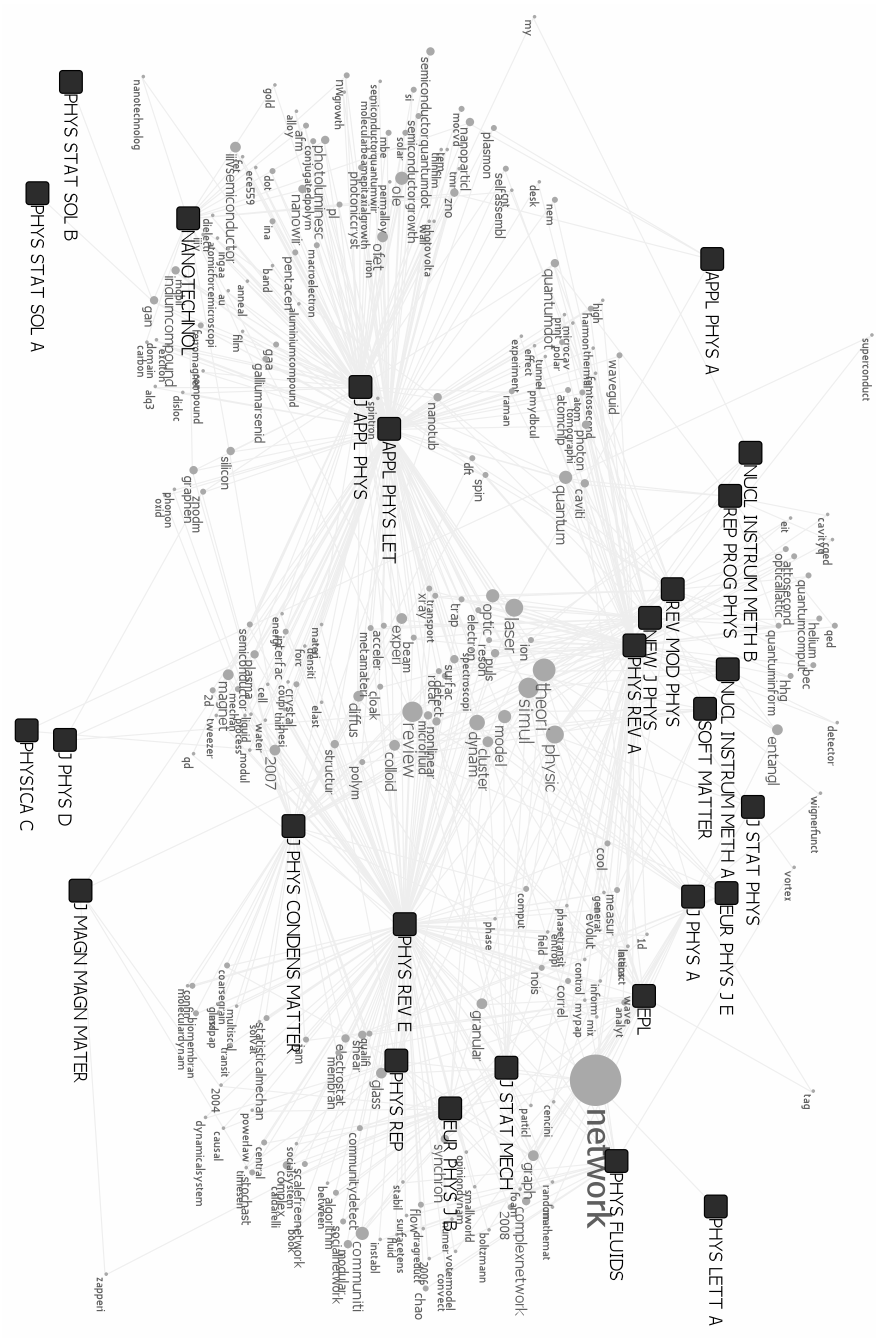

Figure 3.37 2-mode network of 27 journals and assigned tags.

Summary

This chapter showed that subject analysis represents a central point in journal evaluation. A periodical's scope can either be broad and generally cover an entire discipline or specialize in a sub-area of a particular research field. Readers thus have to choose a journal that is most likely to fulfill their information needs and an author will submit to a periodical which addresses the target audience for his publication.

Different indexing methods such as classification schemes and thesauri, author keywords and citation indexing have been described and applied to reflect the content published in a periodical on the journal level or the level of single documents. Three actors can be identified who deliver information about the content of scientific publications. The author provides the fulltext, an abstract and access to relevant literature in the references. Sometimes he lists author keywords, which reduce the articles content to a few significant terms. The second stakeholder in subject indexing is the professional indexer, who engages as an intermediary between author and reader and tries to integrate the particular content into a knowledge organization system in order to make the vast amount of scholarly publications manageable and improve information retrieval. The third actor is the reader, who has recently been introduced into subject indexing through social tagging. It was shown that journal content analysis can profit from the application of user-generated tags, as they add a third layer of perception besides the author and indexer perspectives.

There are various forms of subject indexing, which all have particular advantages and disadvantages. While a more complex structure of the knowledge organization system involves the coverage of only a small knowledge domain, subject indexing of large research fields is usually less complex. With respect to content evaluation of scholarly periodicals, the most profound shortcoming is that a comprehensive, multidisciplinary subject classification system is missing on the article level and existing journal level schemes such as the WoS subject categories are imperfect, so that the user has to work with what is available. In physics, Inspec provides a detailed document classification system and thesaurus. Aggregated on the journal level, frequency distributions of index terms reflect thematic focus areas.

As citations represent contextual connections between documents, methods of citation indexing such as bibliographic coupling and co-citation analysis can be used to discover content relatedness on the document and journal level. Journal maps identify and display clusters of similar content.

Social tagging has been introduced as a new method to provide the reader's point of view on journal content. Tagging on social bookmarking platforms in STM is initially meant for personal reference management but can also help other readers to find useful literature. Aggregated on the journal level, tags and tag frequencies show the user's point of view. In a comparison to traditional indexing methods, it was shown that tags, applied to journal articles by users of social bookmarking services, represent a different aspect of journal content and can thus be used as an additional or alternative approach to the author's and indexer's perspective. Due to their uncontrolled nature, they do, however, suffer from inaccuracies, i.e. no differentiation of synonyms and homonyms and no control for any semantic relations. Moreover, social tagging depends on the participation of many readers. A bias towards web 2.0-savvy users cannot be ruled out at present.

Aggregated on the journal level and year, term frequencies reflect thematical trends over time. Such a trend analysis can be applied to various kinds of index terms, i.e. classification and thesaurus terms, author keywords or tags. The number of index terms applied to documents published each year can reveal the development of hot topics and thematic trends over time.

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Chapter 4
Journal Perception and Usage

One of the most important aspects contributing to a journal's prestige is how it is perceived by its readers. Authors want to publish in periodicals which are read frequently by the targeted audience:

> Metrics based on usage data can provide transparent information for authors about how visible or how popular their work is. This can support authorsÕ decisions about where to publish. Readers can evaluate a publication or an author on this basis. (Merk, Scholze, & Windisch, 2009)

Librarians want to make sure that their limited budgets are spent on subscriptions which will satisfy their customers' information needs (Hahn & Faulkner, 2002; Anderson, 2007). Editors and publishers want to increase readership, since it impacts their journal's market value. Reading statistics will help authors, librarians and publishers to estimate the audiences (D. King, 2009).

Readers can be divided into two groups: pure readers and readers who also publish (Tenopir & King, 2000; Vastag & Montabon, 2002; Roick, 2006). The impact on the latter can be and is captured by traditional citation analysis (chapter 5), since publishing readers indicate the use of an article by citing it:

> If a scholar cites an article of a colleague, he raises that colleagueÕs reputation. The information scientist, scientometrician, or sociologist of science gets the required empirical evidence with this reference. However, the situation is different for nonpublishing readers who were inspired by an article they read and who may later even be able to translate some new ideas from it successfully into practice. Here, the impact of an article is not documented by a reference, making it impossible for a scientometrician to realize any effect. (Schlögl & Stock, 2004, p. 1155 f.)

Being not or only rarely cited hence does not necessarily mean that scholarly publications are not used:

> An article may demonstrate the strength of analysis or synthesis or data collection capacities of an active researcher. It may clarify their thinking. It might demonstrate their research competence and clarity of thinking. It may flow into their teaching, or be read by students and others, whom it may influence. Articles may be read and used without citation, contribution to one's background knowledge in a field. (Cope & Kalantzis, 2009, p. 42)

Stock (2009) pinpoints the problem for journal evaluation:

> When authors do not cite correctly or when they do read, but do not write (and hence do not cite), journal impact indicators have a serious problem. (Stock, 2009, p. 2193)

Analyzing usage by citation analysis means the loss of measuring the impact of journal content on pure readers, who apply new information in their daily work and in the development of new technologies instead of academic publications (Vastag & Montabon, 2002; Schlögl & Stock, 2004; Rowlands & Nicholas, 2007). The ineffectiveness of the impact factor especially for practice-oriented journals was coined by Brian D. Scanlan, senior editor at Pergamon Press, and is thus known as Scanlan's hypothesis (Scanlan, 1987). In universities, pure readers are represented largely by undergraduate and graduate students (Duy & Vaughan, 2006). As Rowlands and Nicholas (2007) states,

> [i]t is easy to forget that these two populations, authors and readers, are not the same. They have different needs and different requirements of the journals literature. (Rowlands & Nicholas, 2007, p. 222 f.)

Tenopir and King (2000) describe the differences between pure and publishing readers in a similar manner:

> The scientific community represents the universe of potential authors of scientific and technical journal articles, but not all scientists publish regularly or even one time. The characteristics of the author community are therefore somewhat different from the characteristics of the scientific community as a whole. (Tenopir & King, 2000, p. 142)

This shows that in order to accurately reflect usage, journal impact measures should factor in the whole readership.

Price and Gürsey (1976) distinguish between seven different groups of researchers as members of the scientific community depending on publication frequency. Nonpublishing researchers are estimated to amount for one third of the scientific community (Price & Gürsey, 1976; Tenopir & King, 2000). These members of the scientific communication represent that part of the readership, i.e. journal usage, which is not covered by citation analysis.

Readership evaluation can analyze usage from different perspectives. Traditionally, the number of readers was measured through reshelving (D. King, 2009; Bar-Ilan, 2008), i.e. the number of times the volume of a journal was put back on the shelf by the librarian after being used, and examination of interlibrary loan and document delivery data (R. Rousseau, 2002; Schlögl & Gorraiz, 2006). These kind of reading statistics started out in the form of simple tally sheets and were then compiled by scanning barcodes (McDonald, 2007). Of course, this method was time consuming and inaccurate when readers put the volumes back themselves. Davis (2004) reports that 70 to 80% of actual usage is not captured by reshelving statistics. Also usage could range from taking a quick glance at the table of contents up to photocopying several articles of an issue (Davis, 2004; Duy & Vaughan, 2006). Nevertheless, reshelving and lending statistics helped libraries to get an impression as to whether their subscriptions were of use to their customers. Reading statistics helped to identify unused titles and at the same time justify cancellations (D. King, 2009; Hahn & Faulkner, 2002)

While librarians have always used methods for monitoring their print holdings, in the 1990s surveys focused on reading preferences regarding print and online (Tenopir

& King, 2002). Since the new medium has been widely accepted and more and more libraries are changing to e-only, readership analyses largely consist of quantitative evaluations of download rates (Keller, 2005; Craig & Ferguson, 2009).

> With the transition from print to online delivery of journal content, a new method for evaluating journals was born based on the actual activities that the user undertook while at the journal website, namely measuring the number of full-text articles downloaded. (Craig & Ferguson, 2009, p. 175 f.)

With the development from print to electronic publishing, the measurement of journal usage became more feasible (Merk et al., 2009; Schlögl & Gorraiz, 2011). Reader-based usage studies were rediscovered and reintroduced in libraries for collection management (Emrani, Moradi-Salari, & Jamali, 2010; Gorraiz & Gumpenberger, 2010; Bollen, Van de Sompel, Hagberg, & Chute, 2009; Leydesdorff, 2009). Local usage statistics are used in order to optimize journal subscriptions by basing them on actual cost-benefit equations (Cowhig, 2001; Keller, 2005).

> Many libraries already rely on cost-per-use analyses to identify when to switch a serial subscription between print and electronic format. An e-serial, or an entire e-serial package, may potentially be canceled if there is insufficient use recorded. (Anderson, 2007, p. 255)

> With good e-serials usage statistics, libraries can improve their effectiveness in managing e-serials, make and defend tough budget decisions, and identify new directions in library activities for the future. (Anderson, 2007, p. 259)

There are however numerous problems involved in download-based usage data. This chapter will explain the different ways of analyzing reader perception by especially focusing on practicability. Different kinds of usage data and ways of obtaining statistics are described. Journal indicators based on usage data are introduced, as are the many problems involved.

4.1 Reader Surveys

Reader surveys are able to analyze readership and reading behavior in detail. They can ask scientists about the journals they read and how often and to what extent they make use of them. Participants can also be asked directly to rank periodicals according to subjectively perceived importance. These surveys are often called perception studies (Kohl & Davis, 1985; Nisonger & Davis, 2005).

Reader surveys differ in terms of participants, which range from 20 to several thousand respondents, and can be conducted in the form of simple print or online questionnaires or complex personal interviews (Keller, 2005). Readership analyses also vary regarding their scope. Surveys can either cover an entire discipline (Nisonger, 1999; Schlögl & Stock, 2008) or focus on the evaluation of a specific journal as is often done by journal editors to gather information about readers and improve journal content, e.g. Lundberg and Paul (1998), Roick (2006) and Lipscomb (2011). Local surveys are often conducted by libraries to evaluate and optimize their collections, for example see Wilson and Tenopir (2008).

Major contributions to readership analysis come from Carol Tenopir, who has conducted several reader surveys since 1977 and frequently published important results about the reading behavior of scientists, for example in Tenopir and King (2000), Tenopir and King (2002), Tenopir, King, Spencer, and Wu (2009), Tenopir, King, Edwards, and Wu (2009) or Tenopir, Wilson, Vakkari, Talja, and King (2010).

While surveys provide the most detailed and comprehensive information about readership, they reflect the subjective views of only a small sample of readers or subject experts and are extremely time-consuming to conduct (Nisonger & Davis, 2005). Furthermore, surveys only provide a snapshot of reading behavior at a given instant, which makes it problematic to draw general conclusions about readership (Keller, 2005). Hence, more objective and easier methods, which allow for comparability, are preferred in a comparative journal evaluation. A reader survey was therefore not conducted for the 45 journals under analysis. For reasons of completeness, this section gives a brief general description of the possibilities of reader surveys.

4.1.1 Journal Rankings

In a survey, participants can be asked to rank journals by prestige or subjective assessment of their impact within the scientific community. They can be asked to list the most influential periodicals in their area of research or the ones they read frequently.

Ranking of practitioners (P) (n1 = 228)				Ranking of scientists (S) (n2 = 22)			
Rank	Journal	No.	Rank S	Rank	Journal	No.	Rank P
1	*Bibliotheksdienst*	178	5	1	*NfD*	16	7
2	*Buch und Bibliothek (BuB)*	160	5	2	*Password*	14	10
3	*ABI-Technik*	142	3	3	*ABI-Technik*	12	3
4	*ZfBB*	119	10	3	*Bibliothek. Forschung und Praxis*	12	5
5	*Bibliothek. Forschung und Praxis*	99	3	5	*Bibliotheksdienst*	11	1
6	*BIT Online*	92	5	5	*BIT Online*	11	6
7	*NfD*	70	1	5	*Buch und Bibliothek (BuB)*	11	2
8	*ProLibris**	55	–	8	*Intl J of Information Management**	10	–
9	*VOeB Mitteilungen**	47	–	8	*JASIST**	10	–
10	*Password*	36	2	10	*ASLIB Proceedings**	9	–
11	*Libri**	22	–	10	*ISI Proceedings**	9	–
12	*Online*	17	10	10	*J of Information Science**	9	–
13	*Internet World**	15	–	10	*Online*	9	12
14	*College & Research Libraries**	12	–	10	*ZfBB*	9	4

*Journal not included in the other ranking.

Figure 4.1 Ranking of library and information science journals by German-speaking practicioners and scientists based on reading frequency. Source: Schlögl and Stock (2004, p. 1165)

Schlögl and Stock (2004) conducted a survey in the German-language library and information science community and asked the respondents to list the journals they read, apply in their everyday work, in which they publish and want to publish. These indicators, i.e. reading frequency, journal applicability, publication frequency and publication preference, were used to rank the periodicals according to relevance as perceived by their readers. Figure 4.1 shows the rankings resulting from reading frequency by library and information science practitioners and scientists.

S. Rousseau (2008) surveyed 150 researchers from the field of environmental and resource economics (determined by conference attendance in 2004) to rank eleven journals from their area of research as top or subtop journals. Correlations of the subjective ranking with that based on the impact factor were not significant, suggesting "that researchers interpret the current quality of journals based on other factors in addition to the impact factors." (S. Rousseau, 2008, p. 223)

Another important aspect often evaluated in reader surveys is the time readers spend reading the journal. In contrast to reshelving and download statistics or citation analysis, surveys can find out how much and how long readers make use of the contents. Journal editors can analyze if certain document types are preferred to others and which topics or parts of the journal are hardly used (Tenopir & King, 2000; Lipscomb, 2011). In general, journal articles are the most frequently read publication types in science (Tenopir & King, 2002; Tenopir, King, Edwards, & Wu, 2009). Moreover, the majority of publications read are no older than 12 months (D. W. King, Tenopir, Hansen Montgomery, & Aerni, 2003; D. W. King, Tenopir, Choemprayong, & Wu, 2009).

Table 4.1 Average importance ratings of factors used by physics authors for selecting journals in 1976 and 1979. Source: Tenopir and King (2000, p. 155)

Factors	**Average importance rating**
Circulation	4.60
Speed of publication	4.40
Publisher's reputation	4.12
Refereeing arrangements	3.93
Quality of production	3.70
Available within own institution	3.58
Frequency of publication	3.42
Page charges	3.30
Charges for off-prints	2.20
Price of journal	2.16
Tradition within department	1.86
Published by member society	1.76
Instructed to do so	1.52

Participants can also be asked about the reasons behind selecting a particular journal either in their role as readers or as authors. Table 4.1 lists the importance of factors influencing the selection of choosing a periodical for publication. The results stem from two surveys conducted by the IOP in 1976 and 1979. Readership was considered most important, while economic factors played minor roles (Tenopir & King, 2000). Similar results were found by other studies. Schauder (1994) surveyed 582 Australian, British and American academics about electronic journals. Journal impact factor, prestige and circulation were the factors influencing journal selection most. Rowlands and Nicholas (2005) found reputation, readership and impact factor to be the most influential factors for choosing a journal for publication among 5,513 authors from different fields of science.

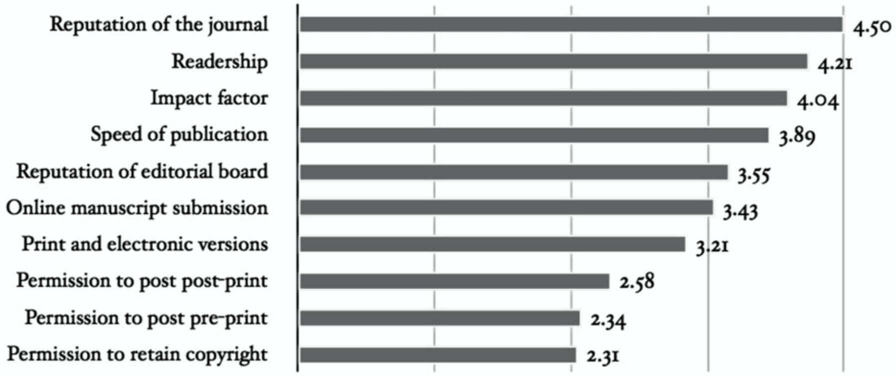

Figure 4.2 Reasons for selecting a journal for publication (averages, where 5 = 'very important', 1 = 'not at all important'). Source: Rowlands and Nicholas (2005, p. 17)

With the emergence of electronic publishing in the 1990s, reader surveys helped editors and publishers to monitor the acceptance of the new medium. Although online access to journals has found general approval and many libraries and journals have switched to e-only, reader surveys revealed that a large number of readers prefer to read articles in print instead of on screen. This has lead publishers to provide documents in printer-friendly PDF format (Tenopir & King, 2002; D. W. King et al., 2003; Keller, 2005; Tenopir & King, 2008).

4.1.2 Demographic Readership Analysis

Surveys allow information to be gathered about the readership which would not be available through other methods of analysis. Demographic information collected supplements information about reading behavior, e.g. the readers' age, geographic distribution, their educational backgrounds, areas of work and levels of experience, and also provides information about who is reading the journal and in how far journal rankings and reading behavior differ among various readership groups (Wormell, 1998; Schlögl & Stock, 2004; Lipscomb, 2011).

In their survey of the German-speaking library and information science community, Grazia Colonia (2002) asked respondents to state their age, sex, level of education, job description and the sector they are employed in, and whether they would describe themselves as scientists or information practitioners, in order to discover differences in journal ranking between different user groups. They found that in the library and information science community, reading behavior is influenced by the employment sector and differs between practitioners and scientists (Grazia Colonia, 2002; Schlögl & Stock, 2004, 2008).

Lipscomb (2011) reports results from the 2010 Journal of the American Dietetic Association Reader Survey, which collected information on 3,750 of its readers and asked about their education, practice area, years of work experience and internet use.

The study revealed that readers working in education and research are the most frequent and intense users of the Journal of the American Dietetic Association and that readers with more experience in the field spend most time reading the journal. Position papers of the association were identified as the most frequently read section of the journal, followed by the table of contents (Lipscomb, 2011).

Tenopir and King (2000) and D. W. King et al. (2003) found that the average number of read articles per researcher per year increased from 150 in 1977 to 216 in 2000 to 2003 and that scientists at universities read more scholarly articles than non-academic researchers. As can be seen in table 4.2, reading behavior does differ between specific disciplines as do publication and citation characteristics: medical researchers read significantly more documents (322) than researchers in engineering (72). Physicists read 204 articles per year, which takes them 153 hours on average (Tenopir & King, 2000).

Table 4.2 Average article readings and the time spent reading by workfield per year per scientist (UT = University of Tennessee. Source: Tenopir and King (2002, p. 262)

	Article readings	**Approx. time spent reading (hours per year)**
UT medical faculty	322	118
UT all faculty	240	139
Engineers	72	92
Physicists	204	153
Chemists	276	198

Reading time differs between disciplines as well: the average reader in medicine takes 20 minutes per document, while an engineer spends 80 minutes on an publication. To some extent this is influenced by the discipline-specific differences in average article length. Physicists take 45 minutes to read one average article. This explains the wide difference between the average number of papers read (Tenopir & King, 2000).

4.2 Download Data

As mentioned before, it is important to include the readers' perspective when evaluating impact of journals on the whole scientific community (Rowlands & Nicholas, 2007). In times of electronic publishing of scientific journals, technically usage data can be collected quite easily. With electronic publishing it became easier to evaluate the influence of periodicals on the whole readership (Schlögl & Gorraiz, 2008, 2010). Usage of electronic articles can be evaluated by monitoring the user during literature retrieval. Click and download data of electronic articles can be analyzed to measure journal perception. Statistics of how often electronic articles are downloaded can be computed by analyzing log files generated by the servers storing journal content (Merk et al., 2009). Log files provide detailed information about what content was accessed where, when, how and by whom. By analyzing the article downloads on the journal level, reading statistics can be calculated.

With electronic publishing, collection of usage data has become feasible (Nicholas et al., 2008; Schlögl & Gorraiz, 2011). In contrast to elaborate reader surveys, journal usage can be monitored through log files almost automatically (Bollen, Van de Sompel, Hagberg, & Chute, 2009; Leydesdorff, 2009; Gorraiz & Gumpenberger, 2010). A high correlation between local print (measured by reshelving) and online usage (local downloads) found by Duy and Vaughan (2006) and Emrani et al. (2010) support the assumption that reading behavior, i.e. journal perception, can in fact be measured by download statistics. In contrast to citation-based measurements, usage statistics

> reflect the activities of a larger community as they record the interactions of all users of scholarly portals, including scientific authors, practitioners of science, and the informed public [. . . and] scholarly dynamics in real time. (Bollen, Van de Sompel, Hagberg, Bettencourt, et al., 2009, p. 1)

A survey by Rowlands and Nicholas (2005) among 5,513 authors from various fields of research, who had published at least one article in an ISI journal in 2004, showed that researchers agreed that article downloads are a better indicator of the 'usefulness of research' than citations. The majority of 1,138 authors surveyed by Shepherd (2007a, 2007b), favored the introduction of usage-based journal rankings, as did librarians. Respondents from the publishing sector were however more reserved.

The huge advantage of electronic usage over survey-based reader evaluations lies in its automation which permits fast and continuous data acquisition. This is why user and readership evaluations today focus on the analysis of electronic usage data (Keller, 2005). While reshelving and reader surveys are elaborate to conduct and only reflects usage by a small group of readers and citation analysis disregards non-publishing readers, electronic usage data can be generated automatically and reflect usage by the whole readership without a publication delay (Bollen, Van de Sompel, & Rodriguez, 2008).

The disadvantage is a lack of specificity. In electronic usage statistics article usage is equated with access to its full text. On no account can one be certain whether the user actually read the article or, on the contrary, how many people gained access through one download.

> A terminology question arises when describing usage statistics. What does a full-text download actually represent? One cannot be certain that the users read the item they downloaded, or even that they truly intended to download the item in the first place. Further, while specific filters have been developed to eliminate double-counting of multiple versions of the same article (i.ýe. toggling between HTML and PDF formats), users may choose to re-download an item every time they wish to view it, or they may download the PDF and store it locally for subsequent use. (Craig & Ferguson, 2009, p. 176)

To make data comparable and reliable, a definition is needed of what exactly is measured. Should it be counted as usage when a user searches for an article in a database, when he displays the abstract, views the full text in HTML or when the PDF is downloaded successfully (Luther, 2001)? While the click-rate can be helpful to analyze search behavior and provide information as to whether there are usability problems keeping the user from reaching the requested content, it was agreed that the number of actual PDF downloads and HTML views best fits usage of journal content. One reason why access to abstracts or tables of content, although the most frequently used items, is not regarded as journal usage is that full text access reflects the particular parameter which is of major interest to librarians because this is the form of access that has to be paid for (Keller, 2005).

Of course, these kinds of usage statistics are limited to that effect that they can only measure whether an article was downloaded and not whether it was actually read (Cope & Kalantzis, 2009). Davis (2007) warns that in contrast to citations, download statistics can be easily influenced and manipulated to serve authors', publishers' or library interests.

Journal usage can be analyzed on a local or global scale. While global download statistics try to measure worldwide usage, local analyses focus on the members of a specific institution which provides access to content. When comparing local statistics, one should consider that the reading behavior of a small specific may differ greatly from that of the global research community (Bollen & Van de Sompel, 2008). While the local focus is crucial to the librarian compiling subscriptions for these very particular readers, an author who needs to choose a suitable venue to reach an international audience should preferably use global data for evaluation. How local (section 4.2.1) and global reader statistics (section 4.2.2) can be generated is explained below. Problems concerning consistency and comparability of download data are discussed and usage-based indicators introduced (section 4.2.3).

4.2.1 Local Usage Data

> The first step in developing usage statistics is to address the task of retrieving high quality usage data. This is an ongoing challenge where the impediments include missing data, inconsistent data, or even no data at all. (Anderson, 2007, p. 246)

This quote from Anderson (2007) reflects the current situation in the analysis of electronic usage data perfectly. The quality of the underlying database is crucial when it comes to usage-based journal evaluation, especially if it is used for decisions regarding cancellation of library subscriptions. Even though data is often inconsistent or not available in a sufficient manner, it has been adopted to conduct studies on the basis of almost any numbers available. Data is taken up without further reflection, which leads to statistics without any or even with misleading informative value. Librarians often do not know how the available data should be interpreted (Luther, 2001; Keller, 2005; Lorenz, 2010).

Data of local journal usage by institution members can be collected in two different ways. Either publishers provide statistics for the journals to which the institution subscribes or the institutions monitor these activities on their own. Both possibilities are described below.

Vendor-supplied Usage Data

The most common method of monitoring local, i.e. institutional, journal usage is the approach based on data provided by the publishers. Most publishers deliver statistics about local access to and downloads of journal articles to the subscribing institution so that it can monitor local use of electronic resources. Standards such as COUNTER were developed to enable comparison between usage data provided by different publishers (Bollen & Van de Sompel, 2008).

> As online journals proliferated from the late 1990s, and data on page impressions (views), numbers of sessions, and crucially the number of articles downloaded could be easily collected, it became clear that a common standard was required in reporting usage information, in order to make valid comparisons between journals supplied by different publishers. (Craig & Ferguson, 2009, p. 176)

COUNTER was brought into being in December 2002. Standards are formulated in a Code of Practice, which defines counting usage to bring consistency to the acquisition of statistics among publishers (Keller, 2005; Baker & Read, 2008; Craig & Ferguson, 2009). Vendors who report usage according to the Code of Practice may call themselves COUNTER-compliant. COUNTER compliance has become a necessity in the scholarly publishing market (Gedye, 2009).

There are two separate Codes of Practice referring to 'Journals and Databases'[1] and 'Books and Reference Works'[2], respectively. The code is a handbook which defines and specifies the data that are to be delivered in terms of coverage, form, file type and date of delivery (Keller, 2005). The first code mentioned lists journal usage and its currently valid version is Release 3 published in August 2008. According to the 'COUNTER Code of Practice for Journals and Databases Release 3', compliant vendors have to deliver different kinds of reports, namely:

Journal Report 1	number of successful full-text article request by month and journal
Journal Report 1a	number of successful full-text article requests from an archive by month and journal
Journal Report 2	turnaways by month and journal
Journal Report 3	number of successful item requests and turnaways by month and journal (optional)
Journal Report 4	total searches run by month and service (optional)
Journal Report 5	full text article requests by year and journal
Database Report 1	total searches and sessions by month and database
Database Report 2	turnaways by month and database
Database Report 3	total searches and sessions by month and service
Consortium Report 1	number of successful full-text journal article or book chapter requests by month
Consortium Report 2	total searches by month and database

For a detailed description of the requirements and the contents of the reports, refer to Project COUNTER (2008).

1 http://www.projectcounter.org/r3/Release3D9.pdf
2 http://www.projectcounter.org/cop/books/cop_books_ref.pdf

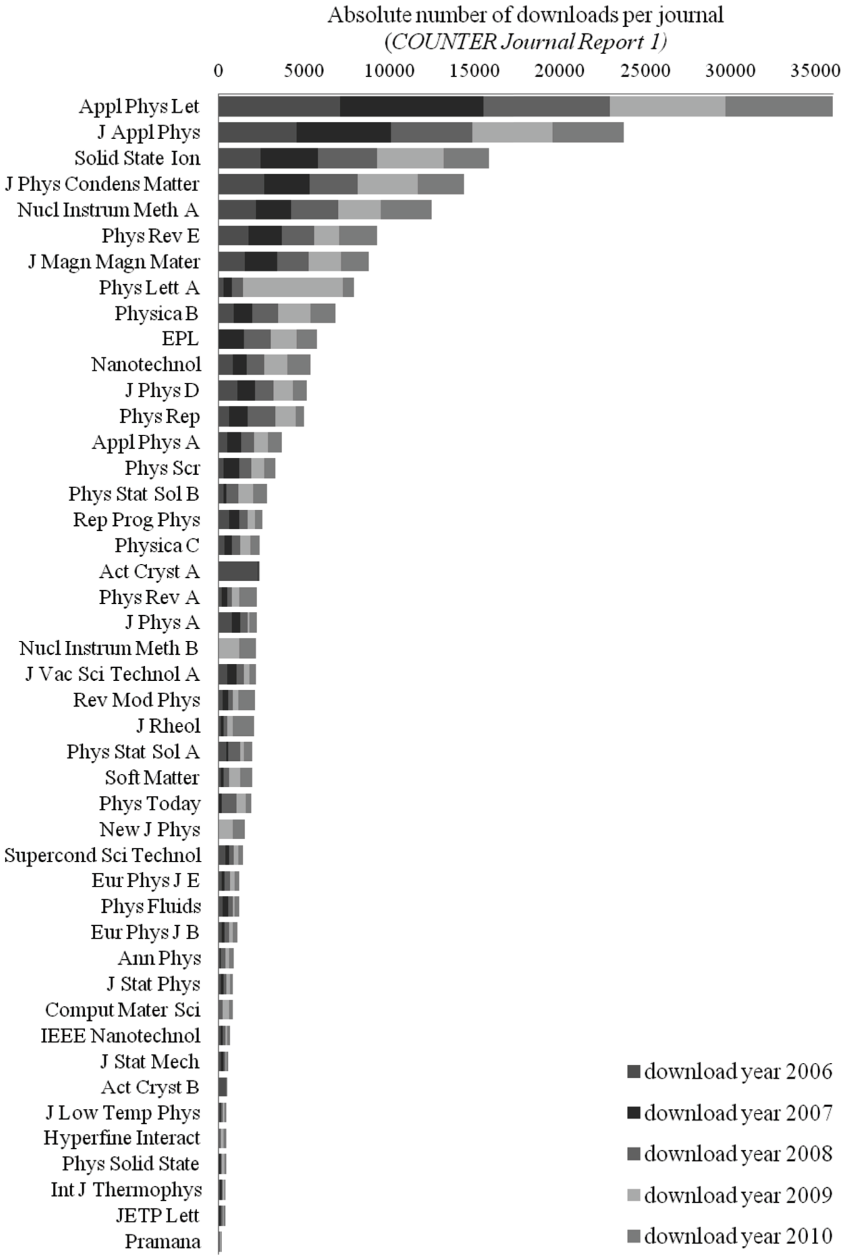

Figure 4.3 Absolute number of downloads per journal based on downloads at Forschungszentrum Jülich from 2006 to 2010 as listed in COUNTER Journal Reports 1.

Any vendor who did not fulfill all requirements from release 3 by August 2009 was no longer listed as COUNTER-compliant. As of July 2011, 130 vendors[3] are listed[4] as COUNTER-compliant. Currently COUNTER is evaluating suggestions for the fourth release, which is scheduled for publication in March 2012 and is meant to be implemented by December 2013.[5]

However, not all of the reports listed in the current COUNTER Code of Practice are mandatory for compliance: Journal reports 3 and 4 are altogether optional and vendors can decide between delivering 1a and 5:

> Vendors that provide journal archives as a separate acquisition from the current journals must provide either Journal Report 1a: Number of Successful Full-text Article Requests from an Archive by Month and Journal (which was an optional additional usage report in Release 2) OR Journal Report 5: Number of Successful Full-Text Article Requests by Year-of-Publication and Journal. (Project COUNTER, 2008, p. 1)

The three reports concerning full-text requests, i.e. 1, 1a and 5, are important for journal evaluation purposes. COUNTER counts only successful requests for full-text in HTML and PDF by deleting multiple requests by a single user within 10 (HTML) or 30 seconds (PDF), respectively. Non-human access is identified and excluded by a reference list of robots and crawlers (Merk et al., 2009).

Although COUNTER has standardized vendor-supplied usage statistics to a great extent – especially in terms of defining a full-text request – there are still a lot of problems in terms of comparability and usefulness of the data when it comes to evaluating and comparing journal usage. Since it is cumbersome for librarians to collect all reports from various publishers websites and combine them, SUSHI Protocol[6] was developed to collect and compile statistics from different sources (Anderson, 2007; D. King, 2009).

Most problems are, however, caused by the data itself. A study by Baker and Read (2008), which examined experiences of research librarians with gathering and analyzing local usage data, showed that in practice even COUNTER-compliant vendors do not necessarily supply comparable results (Duy & Vaughan, 2006). One librarian in the survey complained:

> The biggest challenge in the use of vendor usage statistics is the lack of consistency. [. . .] The major vendors have moved to COUNTER-compliant statistics, but even those are sometimes less than consistent. (Baker & Read, 2008, p. 53)

Another respondent stated:

> Not everyone does COUNTER the same way. (Baker & Read, 2008, p. 55)

The biggest problem of COUNTER data is that it is not detailed enough to provide useful information to compare journal usage. The number of requests is aggregated on

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3 http://www.arl.org/news/enews/enews-apr2011#31
4 http://www.projectcounter.org/articles.html
5 http://www.projectcounter.org/news.html
6 The protocol was developed as ANSI/NISO Z39.93-2007 standard. http://www.niso.org/workrooms/sushi/#about

journal level only. The number of downloads for a specific document is not reported separately (Merk et al., 2009). It is thus not possible to analyze the number of articles that have been accessed but only how many times full texts have been requested. As Gedye (2009) mentions, it was considered whether to include article-level data when COUNTER was initiated but was regarded as "too much information" (Gedye, 2009, p. 24) at that time.

Table 4.4 and figure 4.3 show the number of full-text requests for the 45 periodicals at Forschungszentrum Jülich based on the respective COUNTER Journal Reports 1 from 2006 to 2010. Journal Report 1 lists the number of requests, i.e. HTML access and PDF downloads, made by members of the institution during a certain period of time for each of the subscribed journals. It is not shown when the requested documents were published let alone how many unique documents were accessed at all. Hence the information provided in Journal Report 1 does not allow for any form of normalization. A comparison of different journals is out of the question (Luther, 2001; Hahn & Faulkner, 2002). Rowlands and Nicholas (2007) describe the problem as follows:

> Librarians and publishers are awash with mountains of usage data but the problem is one of data overload and little real comparability. By linking article publication year to full text downloads, we argue that very considerable value could be extracted from what, in many cases, is almost uninterpretable data. (Rowlands & Nicholas, 2007, p. 226)

Journal Report 1 statistics assume that a journal like Soft Matter established in 2005, publishing about 150 documents annually, has the same probability of being downloaded as a periodical like Appl Phys Let, which has a publication history of more than one hundred years and publishes over 5,000 articles per annum. As can be seen in table 4.4, Journal Report 1 reported 6,279 full-text requests for Appl Phys Let and 738 for Soft Matter at Forschungszentrum Jülich in 2010. According to these statistics Appl Phys Let was used 8.5 times as much as Soft Matter.

Table 4.4 Number of publications per journal between 2004 and 2008 ($P^{2004-2008}$) and full-text requests at Forschungszentrum Jülich according to Journal Report 1 ($JR1$) from 2006 to 2010.

Journal	$P^{2004-2008}$	$JR1^{2006}$	$JR1^{2007}$	$JR1^{2008}$	$JR1^{2009}$	$JR1^{2010}$
Rev Mod Phys	173	238	328	271	321	943
Rep Prog Phys	220	597	629	461	450	395
Ann Phys	296	58	45	297	194	295
Act Cryst A	326	2263	55	8	18	5
Phys Rep	341	611	1064	1648	1188	483
J Rheol	347	121	183	196	316	1252
Act Cryst B	493	438	22	5	5	16
IEEE Nanotechnol	519	130	116	125	149	140
Soft Matter	654	105	180	340	608	738
Eur Phys J E	707	162	180	320	257	285
Int J Thermophys	757	45	121	85	76	75

continued on next page

Journal	$P^{2004-2008}$	$JR1^{2006}$	$JR1^{2007}$	$JR1^{2008}$	$JR1^{2009}$	$JR1^{2010}$
J Stat Mech	958	119	144	106	104	99
Hyperfine Interact	1006	34	*n/a*	90	159	162
J Stat Phys	1049	137	155	176	196	170
Pramana	1258	*n/a*	*n/a*	61	58	69
J Low Temp Phys	1260	56	88	81	132	115
Comput Mater Sci	1299	*n/a*	*n/a*	249	336	246
JETP Lett	1487	36	91	89	86	85
J Vac Sci Technol A	1580	480	565	417	346	371
Supercond Sci Technol	1685	374	256	250	294	229
Phys Today	1780	0	192	833	545	345
New J Phys	1926	*n/a*	*n/a*	*n/a*	815	703
Phys Solid State	1970	34	100	67	151	91
Eur Phys J B	2056	159	191	236	251	236
Solid State Ion	2270	2446	3357	3472	3903	2636
Phys Scr	2543	308	878	726	750	632
Appl Phys A	2685	478	831	768	816	805
Phys Stat Sol B	2691	301	125	714	890	825
Phys Fluids	2702	240	330	246	143	234
Phys Stat Sol A	2721	435	125	684	255	480
EPL	3291	*n/a*	1482	1566	1489	1203
Physica C	3947	327	424	519	605	527
J Phys D	4554	1098	1018	1070	1140	842
Nanotechnol	4852	809	810	1063	1313	1356
J Phys A	5244	774	474	442	138	389
Phys Lett A	5328	304	482	620	5848	645
Physica B	5561	889	1090	1474	1923	1469
Nucl Instrum Meth B	5973	*n/a*	*n/a*	*n/a*	1213	987
J Phys Condens Matter	7427	2683	2635	2792	3536	2716
J Magn Magn Mater	7549	1545	1879	1822	1910	1649
Nucl Instrum Meth A	7670	2163	2094	2717	2508	2994
Phys Rev A	11027	200	311	281	436	1031
Phys Rev E	12117	1734	1945	1912	1483	2210
J Appl Phys	17827	4563	5533	4766	4672	4179
Appl Phys Let	25983	7127	8393	7416	6751	6279
Total	*168109*	*34621*	*38921*	*41481*	*48777*	*41636*

The absolute number does not provide any information other than whether articles were downloaded or not. Basically, it can only provide information about the acceptance of the medium of electronic journals in general (Luther, 2001; Keller, 2005). Rowlands and Nicholas (2007) call the total number of downloads in one year article download indicator. It can monitor whether readers use electronic access to publications or whether usage in total has increased over the years. A comparison of the number of full-text requests made per year shows a gradual increase in the number of annual accesses at Forschungszentrum Jülich from 2006 to 2009 (table 4.4). In 2006, 34,621 full-text downloads were made, while in 2010 41,636 documents were accessed. This increase is, however, partly caused by the fact that the number of COUNTER-compliant journals has increased. In 2006 and 2007 five and in 2008 two of the 45 periodicals did not deliver usage reports. Only in 2009 and 2010 data was available for all analyzed journals. As a matter of fact, the medium of electronic publications was widely accepted at Forschungszentrum Jülich before 2006. Electronic access to journals was introduced in the early 2000s and the central library went e-only in 2005.

Journal Report 1 also provides a breakdown as to whether journal articles were accessed in their HTML or PDF versions. As can be seen in figure 4.4, in 2010 55.6% of all full texts at Forschungszentrum Jülich were requested in PDF, 14.2% in HTML format. For 30.2% of the downloads this information was not provided, although it is meant to be included in Journal Report 1.

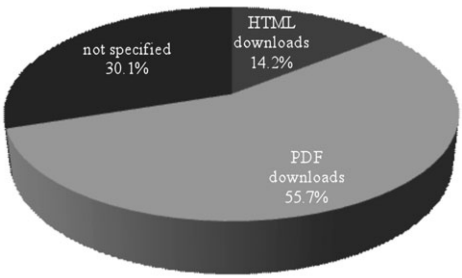

Figure 4.4 Percentage of full texts accessed in PDF and HTML at Forschungszentrum Jülich in 2010 according to Journal Report 1 for the 45 selected journals.

In practice, many studies analyzing journal usage (e.g. Shearer, Klatt, and Nagy (2009)) and numerous libraries nevertheless base their evaluations on the absolute number of download events, although these download events are, of course, related to an undefinable large set of articles (Craig & Ferguson, 2009). The most common approach taken to normalize absolute downloads, at least to some extent, is the cost-effectiveness calculations consulted by many libraries basing cancellation decisions on usage data: the subscription price is divided by the number of absolute downloads as listed in COUNTER Journal Report 1. Thus one obtains an average price-per-download ratio, which is supposed to provide information about the journal's value for money. A fictitious Journal A, whose annual subscription price amounts to €3,000 and reported usage adds up to 6000 full-text requests during the same year, would thus have a price-per-download ratio of €0.50. Ficticious Journal B with an average price per download of €10 (subscription price: €5,000 / full-text requests: 500) would be cancelled in favor of Journal A due to – supposedly – bad value for money. Since the number of unique articles accessed is not known, these calculations may cause bad decisions (Hahn & Faulkner, 2002). If users of Journal A requested access to 50 unique documents and those of Journal B to 400, it would have in fact been better to keep Journal B and cancel Journal A, while providing access to the 50 requested articles from Journal A on a pay-per-view basis (Tonta & Ünal, 2008). Such obvious shortcomings of cost-effectiveness analysis based on Journal Report 1 have, however, not prevented librarians from calculating price-per-download rates.

Release 3 of the Code of Practice tried to put things right to some extent and followed the proposal of Rowlands and Nicholas (2007): with the introduction of Journal Report 5 information about the particular publication years of the requested documents is provided. As displayed in figure 4.5, the number of downloads are allocated to the year of publication (YOP) in which the particular document appeared in the journal. Although it still remains unclear how many unique articles were accessed, it is possible to normalize to some extent by the number of documents available in a particular journal in a particular year (see section 4.2.3).

Since Journal Report 5 is not mandatory for COUNTER compliance, many publishers still deliver the absolute number of downloads per journal only. Vendors can alternatively provide Journal Report 1a, which again does not provide any details about the number of requested documents. Instead of specifying the downloads by year of publication, Journal Report 1a lists the downloads in the same manner as Journal Report 1 with the only difference that it refers to publications from the journal's archive. Since the archive is not defined more closely, COUNTER 1a statistics do not report any additional information, except whether 'older' articles were used or not. Figure 4.6 lists all 17 journals for which Journal Report 1a (instead of 5) was provided[7], and shows that the share of full-text requests from the journal archive can differ between the journals. While 47.4% of Ann Phys documents used at Forschungszentrum Jülich in 2010 were from the journal archive, readers of Phys Rev A, Rev Mod Phys, Comput Mater Sci and Act Cryst A only accessed current literature. For the Physical Review Series (Phys Rev A, Phys Rev E and Rev Mod Phys), this may be partly due to the twigging of Physical Review (see chapter 2). Archive access will thus be to the parent journal Physical Review.

	A	B	C	D	E	F	G	H
1	Journal Report 5(R3)	Number of Successful Full-text Article Requests by Year and Journal						
2	Forschungszentrum Juelich GmbH Zentralbibliothek - WIB6315 - 3_84							
3	Date run:							
4	2011-01-06							
5		Publisher	Platform	Print ISSN	Online ISSN	YOP 2010	YOP 2009	YOP 2008
6	Total for all journals	IOP	IOPscience			3526	2433	1744
7	EPL (Europhysics Letters)	IOP	IOPscience	0295-5075	1286-4854	256	151	129
8	Journal of Physics A: General Physics	IOP	IOPscience	0022-3689		0	0	0
9	Journal of Physics A: Mathematical and General	IOP	IOPscience	0305-4470	1361-6447	0	0	0
10	Journal of Physics A: Mathematical and Theoretical	IOP	IOPscience	1751-8113	1751-8121	55	20	12
11	Journal of Physics A: Mathematical, Nuclear and General	IOP	IOPscience	0301-0015		0	0	0
12	Journal of Physics B: Atomic and Molecular Physics	IOP	IOPscience	0022-3700		0	0	0
13	Journal of Physics D: Applied Physics	IOP	IOPscience	0022-3727	1361-6463	141	108	73
14	Journal of Physics: Condensed Matter	IOP	IOPscience	0953-8984	1361-648X	442	343	395
15	Journal of Statistical Mechanics: Theory and Experiment	IOP	IOPscience		1742-5468	39	18	13
16	Nanotechnology	IOP	IOPscience	0957-4484	1361-6528	451	255	192
17	New Journal of Physics	IOP	IOPscience		1367-2630	219	148	121
18	Physica Scripta	IOP	IOPscience	0031-8949	1402-4896	12	270	4
19	Reports on Progress in Physics	IOP	IOPscience	0034-4885	1361-6633	33	37	45
20	Superconductor Science and Technology	IOP	IOPscience	0953-2048	1361-6668	96	29	24

Figure 4.5 COUNTER Journal Report 5 listing full-text requests at Forschungszentrum Jülich in 2010 for documents from selected IOP journals published between 2008 and 2010.

7 For J Vac Sci Technol A, J Rheol and Phys Fluids neither Journal Report 5 nor 1a was provided. For Soft Matter, the publisher only provided Journal Report 1a accumulated for the whole journal archive.

For 22 out of the 45 journals, Journal Report 5 was available and provided download data for documents published between 2004 and 2008[8]. The reports were run in January 2011 and cover all usage at Forschungszentrum Jülich in 2010. Figure 4.7 displays the total of documents published within the five-year period and the number of full-text requests made for them in 2010. It can be seen that J Appl Phys is the journal with the highest publication output (17,827) but only 3 documents were requested during the same period according to Journal Report 5. J Phys Condens Matter was accessed most frequently (1,070 times) and published a large amount of articles (7,427) as well. High discrepancies between output and full-text requests can be observed for J Phys A, which published 5,244 documents between 2004 and 2008 but only 63 full texts were accessed at Forschungszentrum Jülich in 2010.

Table 4.5 reports the absolute number of full-text requests at Forschungszentrum Jülich in 2010 by publication year. These numbers differ from those in table 4.4 because they are based on Journal Report 5, monitoring all usage made in 2010 differentiating between the publication years of the downloaded documents, e.g. in 2010, 442 full-text requests were made for articles published in J Phys Condens Matter in the same year, 343 for documents published in 2009, 395 in 2008 and so on. Journal Report 1, on the other hand, reports a total of 2,716 full-text requests at Forschungszentrum Jülich in 2010 without differentiating by publication year (table 4.4).

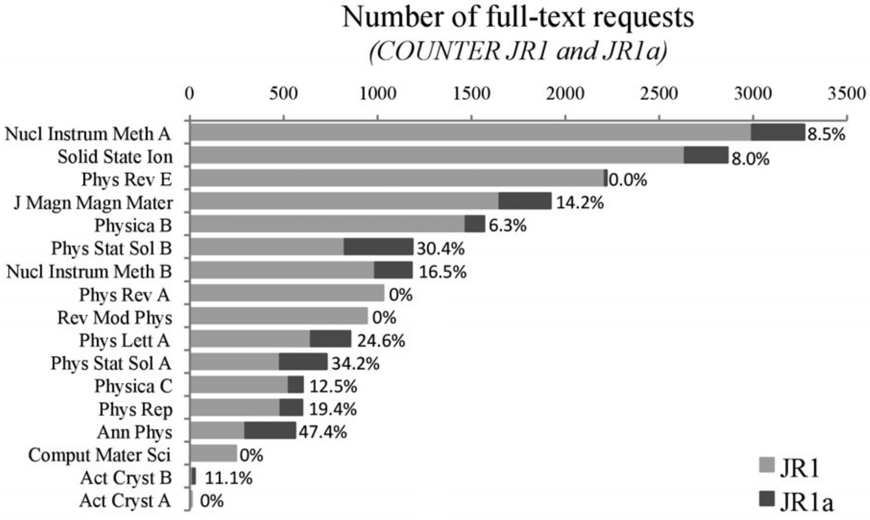

Figure 4.6 Share of full-text requests for 'current' articles (Journal Report 1) and documents from the journal archive (Journal Report 1a). Lists all 17 journals for which Journal Report 1a was available in 2010 at Forschungszentrum Jülich.

8 Journal Report 5 was available for Appl Phys Let as well but no usage was reported for the publication years 2004 to 2008. It was thus excluded from the analysis.

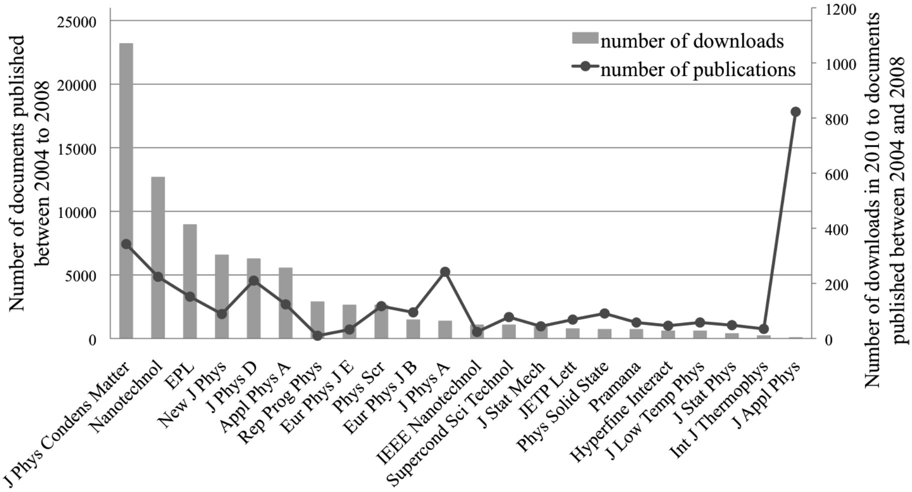

Figure 4.7 Absolute number of downloads and publications per journal based on downloads at Forschungszentrum Jülich in 2010 as listed in COUNTER Journal Reports 5.

Although there are some outliers for single journals, the total number of downloads monitored by Journal Report 5 (table 4.5) increases with the year of publication. Of the 7426 full-text requests[9] made in 2010, 27.2% were for documents published in the same year. This is in agreement with general findings according to which the most recent publications are the most frequently read.

Table 4.5 Absolute number of full-text requests in 2010 per publication year at Forschungszentrum Jülich according to COUNTER Journal Report 5. Values in italics represent rounded 5-year means because Springer supplied only accumulated data for publication years 2002 to 2006.

Journal	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
J Phys Condens Matter	146	167	134	228	395	343	442
Nanotechnol	76	62	90	165	192	255	451
EPL	60	80	51	93	129	151	256
New J Phys	86	42	16	38	121	148	219
J Phys D	16	41	49	110	73	108	141
Appl Phys A	*47*	*47*	*47*	69	45	95	62
Rep Prog Phys	11	23	41	13	45	37	33
Eur Phys J E	*18*	*18*	*18*	27	39	52	54
Phys Scr	24	26	21	46	4	270	12
Eur Phys J B	*12*	*12*	*12*	16	16	40	34
J Phys A	16	10	12	13	12	20	55

continued on next page

9 Since Springer provided only accumulated values for the publication years 2002 to 2006, the values from 2004 to 2006 are rounded 5-year means (compare table 4.5).

Journal	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
IEEE Nanotechnol	0	6	13	3	27	12	76
Supercond Sci Technol	5	3	10	7	24	29	96
J Stat Mech	3	3	13	10	13	18	39
JETP Lett	*6*	*6*	*6*	3	13	11	5
Phys Solid State	*7*	*7*	*7*	0	13	12	12
Pramana	*4*	*4*	*4*	8	12	0	1
Hyperfine Interact	*4*	*4*	*4*	8	8	41	0
J Low Temp Phys	*2*	*2*	*2*	6	14	8	13
J Stat Phys	*4*	*4*	*4*	3	2	11	7
Int J Thermophys	*2*	*2*	*2*	4	1	1	11
J Appl Phys	0	2	0	1	0	0	0
Total	549	571	556	871	1198	1662	2019
Total in %	7.4	7.7	7.5	11.7	16.1	22.4	27.2

Although it is not possible to determine the percentage of documents that were read in contrast to those that were not, usage can be normalized by the number of documents published per year (Cowhig, 2001). This makes it possible to compare journals that differ in terms of output and publication history. Based on Journal Report 5, a mean download rate can be computed as well as usage-based versions of the impact factor and immediacy index. Usage metrics are introduced in section 4.2.3 and computed for those of the 45 journals, for which sufficient data was available.

Similar to the citations, the distribution of the number of downloads per document is highly skewed. A large number of publications are not used at all, while a few articles are accessed by a large number of readers. The ACCELERATE project, which evaluated electronic journal usage at the University of Düsseldorf in 1999, showed that 2.5% of all Elsevier journal articles were used in contrast to 97.5% that were not accessed at all (Keller, 2002). Davis (2002) found similar skewness patterns evaluating an American research library consortium: 4.9% of journals covered 44% of usage, while 24.3% periodicals accounted for 80% of downloads, which conforms to the Pareto principle. Emrani et al. (2010) reported that 80% of usage targeted 26.67% of the collection titles of an Iranian consortium. Tonta and Ünal (2008) found similar results examining the usage of Elsevier's Freedom Collection at Turkish universities: 80% of all full-text requests targeted 29% of all journals. As mentioned above, article-based information is not provided through COUNTER statistics, therefor the percentage of used and unused documents is not available.

Journal usage normalized by output, of course, depends on the size of the local institution, in particular the size of the local readership: the more researchers, the higher the usage rates. Without further normalization this factor can cause extreme local biases (Craig & Ferguson, 2009). In the case of the 45 journals analyzed, the local bias is believed to be the same for all journals, which is caused by the selection process of the periodicals that is based on publication data by an institute at Forschungszentrum Jülich (compare section 1.4).

Like citation and publication data, usage statistics vary between scientific disciplines as well. Even if detailed data is available to normalize downloads by annual publication output, usage rates will differ between different areas of research. In the same way as publication output and citation rates, download data should not be used without further normalizations to compare journals of different scientific disciplines. For example, one must not cancel all mathematics journals because their average usage rate is lower than that of chemical journals (Luther, 2001; Hahn & Faulkner, 2002).

These examples have shown that vendor-supplied data is currently far from perfect and reliable. Therefore all download statistics need to be handled cautiously. As an alternative to relying on publisher-provided data, institutional usage can be self-monitored as well.

Self-Monitoring Institutional Usage

Even if a lot of problems concerning standardization have been solved by COUNTER, there is another reason which could prevent libraries from relying on vendor-supplied usage reports. The question is whether publishers provide usage of their own journal objectively if low usage can be a reason for libraries to cancel subscriptions (Duy & Vaughan, 2003). An alternative for monitoring local usage independently is for the library to analyze the log files of institutional library users.

> Usage data for e-serials do not have to come only from vendors. In the absence of vendor-supplied usage data, libraries have other options for developing a usage history for their electronic titles. (Anderson, 2007, p. 247)

Journal usage is counted, if users access journal content through links from the library or other institutional websites. Although this self-monitoring data provides details on the user – through the IP address information about who is accessing the data – it tracks only the steps up to the point where the user leaves the library's website.

> ÒHome-grownÓ library data collection methods are often relatively simple, and only provide minimal information about usage, usually in the form of counting the number of user attempts to access an electronic product. Once the patron leaves a libraryÕs Web site, it is impossible for the library to track how they are making use of the electronic resource; only the vendor can track these use details. (Duy & Vaughan, 2003, p. 17)

Since usage can only be monitored if journal websites are contacted through a link from the institutional website via a proxy server (Duy & Vaughan, 2003; Coombs, 2005), direct access through other channels (direct links like DOIs or bookmarks to journal websites etc.) is lost as well (Merk et al., 2009). Therefore this method is far from monitoring complete usage of electronic content (Keller, 2002; Duy & Vaughan, 2003; Anderson, 2007). The method's biggest shortcoming is that usage can range from taking a quick look at the journal's table of content to downloading a dozen papers. Duy and Vaughan (2003), who compared self-collected usage data to vendor-supplied statistics, found a dramatic difference between the two metrics for Elsevier journals, caused by direct access by users within the Science Direct platform. While the log file analysis counted only 200 attempts to access Elsevier journals during one month, the publisher reported 3,919.

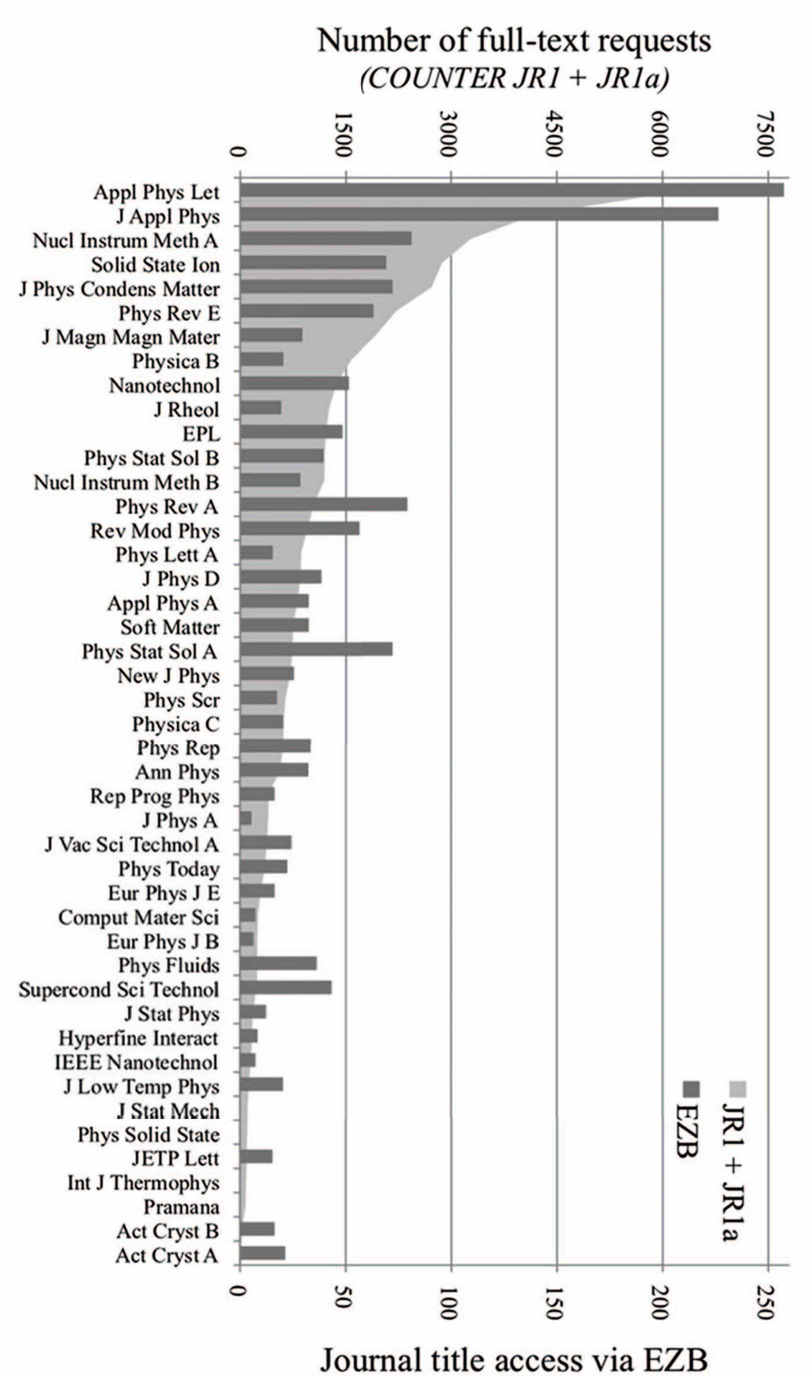

Figure 4.8 Number of title accesses via EZB and COUNTER Reports 1 and 1a at Forschungszentrum Jülich in 2010.

Nicholas et al. (2008) used deep log analysis to conduct a detailed evaluation of users' viewing habits of scholarly full texts. This extensive log-file analysis revealed that two-thirds of all article views take less than three minutes indicating that a considerable amount of full-text views is possibly cursory.

A simple approach for monitoring log files regarding journal access is used by the Elektronische Zeitschriften Bibliothek (EZB – Electronic Journals Library)[10], which provides participating institutions with statistics about local access to journal titles via the EZB website (Hutzler, 2008, 2009). It counted 19.1 million clicks on journal titles in 2009.[11]

Figure 4.8 shows the EZB statistics for Forschungszentrum Jülich in 2010 in comparison to the vendor-supplied COUNTER reports. In total, 25,414 journal titles were accessed by researchers at Forschungszentrum Jülich in 2010. 37.1% of all clicks targeted journals from physics. 41 of the 45 analyzed journals were accessed 1,727 times. Data was not available for Int J Thermophys, J Stat Mech, Phys Solid State and Pramana, which means that these were accessed less than five times during the entire year through the EZB website. A comparison of the two methods shows that access through the EZB website makes up only a small portion of electronic journal usage. On average the EZB statistics report only one sixth of the usage covered by COUNTER reports 1 and 1a. Spearman's $\rho = 0.748$, meaning that both sets of statistics reveal the same general tendency. As figure 4.8 shows, there are, however, large differences for single journals, e.g. Physica B, where EZB covers only 1.3% of usage compared to COUNTER, or Supercond Sci Technol, where EZB values are relatively high.

The data examined for the 45 journals has shown that, despite existing standards, statistics of local, i.e. institutional, journal usage suffer from inconsistencies and lack of normalization. Article-based usage data would be necessary in order to normalize sufficiently. Only then will librarians be able to adequately compare journals based on usage and make reliable subscription and cancellation decisions. Due to its local biases, institutional journal usage is less interesting for authors and readers. Global usage data is needed to choose a suitable periodical for publication and reading.

4.2.2 Global Usage Data

While local download statistics are important for libraries in order to monitor institutional usage of electronic resources and optimize their holdings, they always contain a certain bias depending on the thematic scope of the institution or whether it is rather research or educationally oriented. Reading behavior differs between a university with a large undergraduates program and a research center (Bollen & Van de Sompel, 2008; Craig & Ferguson, 2009).

Since publishers have detailed information about all users accessing electronic articles stored on their servers, statistics of global usage can be compiled with the same methods used to compute them at the institutional level. Based on publisher data, detailed analysis of worldwide readership would be possible. Figure 4.9 shows that collected usage is so detailed that even the location of users is available to publishers.

10 http://ezb.uni-regensburg.de
11 http://ezb.uni-regensburg.de/anwender/Jahresbericht_EZB_2009.pdf

On the occasion of their 40th anniversary, Phys Scr published a report including statistics of the geographical distribution of 319,000 full-text requests made in 2010 (Physica Scripta, 2011).

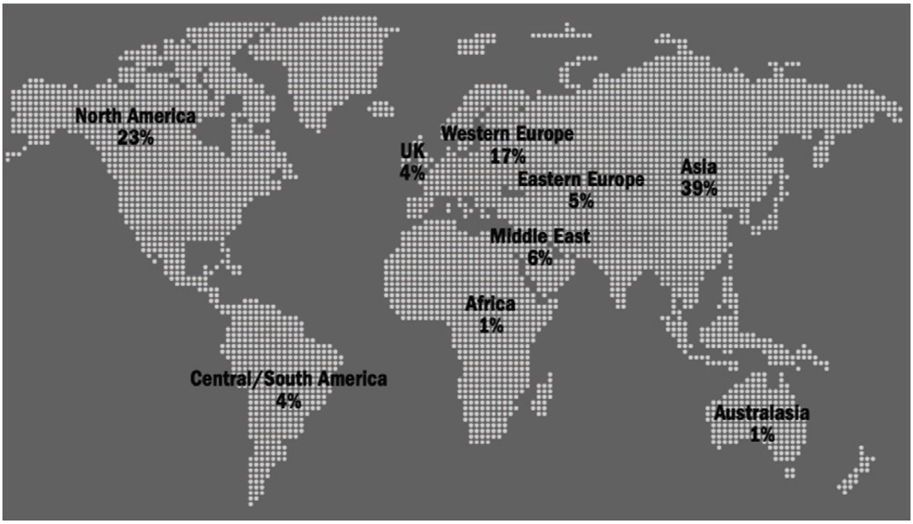

Figure 4.9 Global distribution of full-text requests to Phys Scr. Source: Physica Scripta (2011, p. 4)

The publication of these statistics is the exception rather than the rule. When it comes to analyzing global journal usage, publishers wrap the numbers in mystery. Requests for global download data are generally turned down.[12]

Although publishers deny access to the data for detailed analyses, they make use of download statistics internally and especially for promotional and journal self-portrayal purposes. Figure 4.10 shows the usage statistics of J Low Temp Phys as displayed on the journal's homepage. Of the 45 serials studied, 26 gave some information regarding journal usage (see table 6.1 in section 6.1.3). While Elsevier lists the 10 most frequently downloaded documents without indicating any values, Springer (as displayed in figure 4.10) provides the most detailed data. Springer usage statistics include the number of full-text requests of the five most frequently used documents of the last 7, 30 or 90 days and a diagram displays the total number of daily downloads. These figures do, however, only serve self-portrayal purposes and cannot be used for a comprehensive analysis of journals usage, since they only provide snapshot information about a few of the most frequently used documents.

Studies have to focus on areas where global usage data is made available, i.e. open access journals and repositories (Schlögl & Gorraiz, 2008, 2010). Brody, Harnad, and Carr (2006), Davis and Fromerth (2007) and Haque and Ginsparg (2009) have analyzed downloads from arXiv and compared usage to citation data. Kurtz et al. (2005) studied 1.7 million usage events to observe obsolescence patterns of four astrophysical journals

12 A request to provide global usage data for the subset of Elsevier journals included in the test set was denied under specification of legal reasons.

available through the NASA Astrophysics Data System and Wan, Hua, Rousseau, and Sun (2010) examined a Chinese academic full-text database.

Other studies are based on sets of usage data that were made available by the journal or publisher for evaluation purposes. These analyses usually focus on one single journal or examine usage behavior of a whole subject area within one platform in general without distinguishing between single journals. Journals from different publishers are not compared. An exception is the MESUR project, which is described in section 4.2.2.

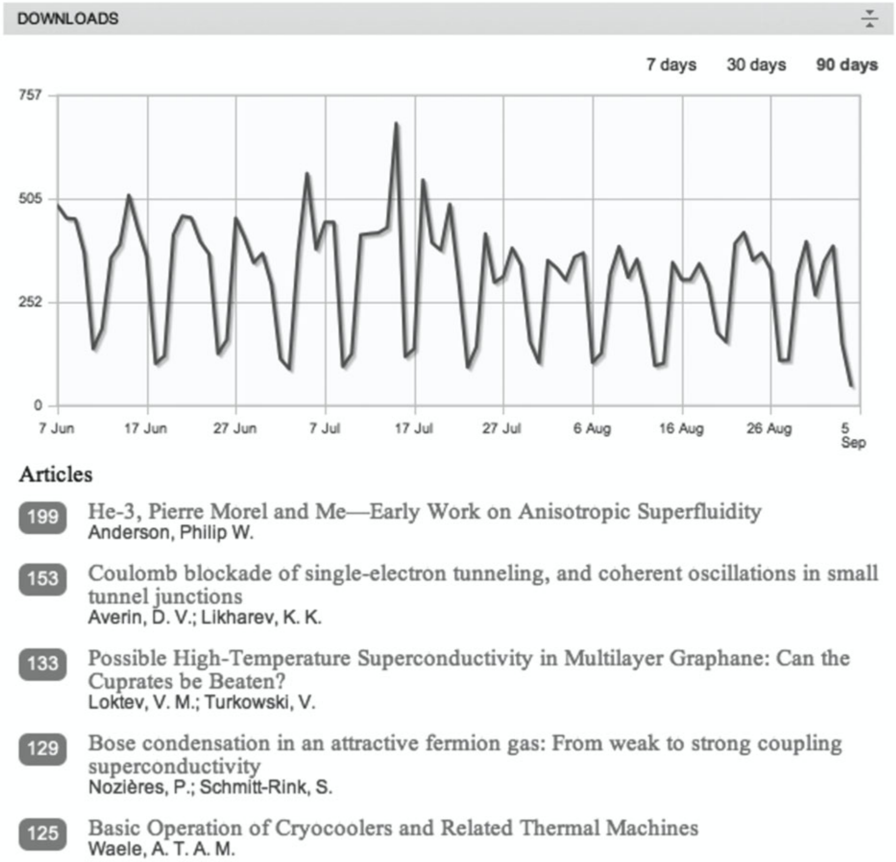

Figure 4.10 Usage data displayed under the journal scope section of J Low Temp Phys.

In an early study, Perneger (2004) analyzed download rates one week after publication of 153 papers published in one volume of the British Medical Journal in 1999 and compared these with WoS citation rates in 2004. A correlation of Pearson's $r = 0.50$ was found.

Moed (2005a) also focused on a single journal, i.e. Tetrahedron Letters, to analyze in how far downloads influence citations and vice versa. Based on usage data reported at ScienceDirect between January 2001 to June 2004, he computed download half-life (see section 4.2.3) in analogy to cited half-life of Tetrahedron Letters to study the journal's obsolescence patterns. Schlögl and Gorraiz (2010) computed usage half-life and impact factor (see section 4.2.3) for oncology journals from ScienceDirect in 2006 and compared them to the citation equivalents. For a subset of journals, they analyzed the relation between downloads and citation on the article level as well. In 2011 the same authors conducted a similar study based on pharmacy and pharmacology journals. Regarding their obsolescence pattern, discipline-specific differences can be observed. Usage half-life was higher for the pharmacology than the oncology journals (Schlögl & Gorraiz, 2010, 2011).

Davis, Lewenstein, Simon, Booth, and Connolly (2008) tried to control for different factors influencing downloads and citations by randomly providing free access to articles from 11 journals published by the American Physiological Society. Usage and citation rates of 1,619 articles were examined, of which 247 were randomly chosen as available for open access during the four month of analysis. Article-level usage and citation data were collected from the publisher's log files and WoS, respectively. By comparing both sets, traditional subscription and freely available articles regarding download and citation characteristics, the study revealed that open access documents were downloaded more often. However, no difference was observed in terms of citations received within one year after publication, which contradicts previous findings stating an open access citation advantage (see section 6.4.2).

A reliable source of global journal usage can be found in open access journals. These often make global download statistics available. In contrast to traditional subscription journals, open access periodicals do not have to worry about low usage reflecting badly on profits. The Public Library of Science (PLoS) journals are exemplary when it comes to usage statistics. Since 2009 they provide article-based usage data which can hardly be outdone in terms of detailedness. Jamali and Nikzad (2011) and Yan and Gerstein (2011) have used this data to analyze global reading behavior.

Public Library of Science

The Public Library of Science (PLoS) is a non-profit organization of scientists founded in 2000 with the goal of making all scientific and medical literature freely available online. In 2003, PLoS Biology was the first of currently seven peer-reviewed open access journals published by PLoS, financed through author publication fees and funding.[13]

In 2009, PLoS added article-level metrics to all documents published in their journals, because they intended to

> place transparent and comprehensive information about the usage and reach of published articles onto the articles themselves, so that the entire academic community can assess their value.[14]

Currently article-level metrics include the number of citations, full-text requests, usage on social bookmarking platforms, users' comments, notes and blogs and an article rating

13 http://www.plos.org/about/index.php
14 http://article-level-metrics.plos.org/

system[15], which together reflect article impact in a multidimensional way (Neylon & Wu, 2009). Figure 4.11 shows the metrics tab for an article published in PLoS ONE in June 2010. As of August 1, 2011, the article was accessed 1,610 times, 1,185 of which were in HTML, 23 in XML format and it was downloaded in PDF 402 times. This breakdown is available separately for each month.

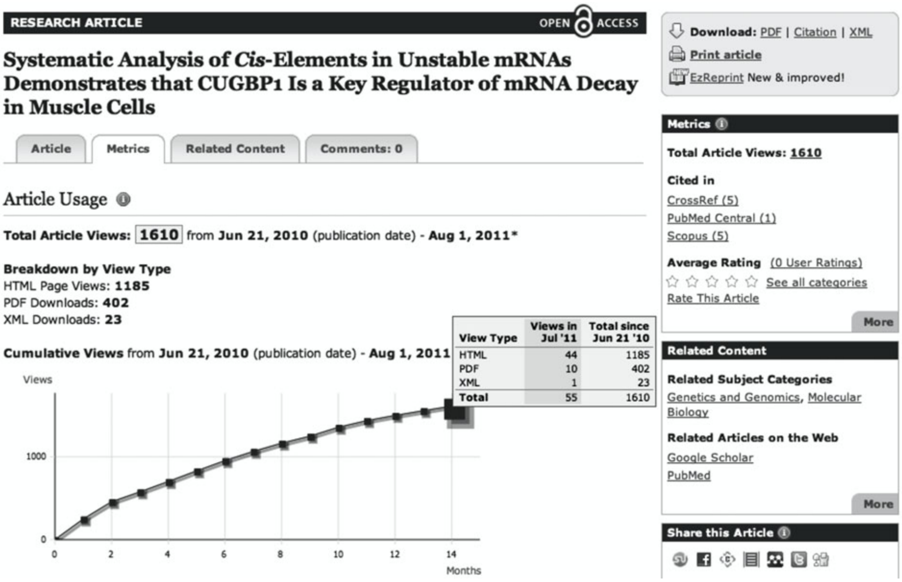

Figure 4.11 PLoS usage metrics on the article level. Source: http://www.plosone.org/article/metrics/info\%3Adoi\%2F10.1371\%2Fjournal.pone.0011201\#usage

Article-based metrics are made available on the PLoS homepage[16] as a detailed Excel file[17], which is updated approximately once a year. The current version (October 2010) contains data for almost 24,000 documents published in PLoS Biology, PLoS Clinical Trials, PLoS Computational Biology, PLoS Genetics, PLoS Medicine, PLoS Neglected Tropical Diseases, PLoS ONE and PLoS Pathogens since 2003. Linked to the DOI, all article-based metrics data is included, as are the number of monthly full-text requests since publication.

With its open and transparent approach, PLoS acts as a role model regarding global usage statistics. In this way, and only with this form of data aggregation, it is possible to normalize journal usage correctly and compute all usage-based indicators described in section 4.2.3. Jamali and Nikzad (2011) and Yan and Gerstein (2011) made use of PLoS data. While Yan and Gerstein (2011) also examined obsolescence patterns of article usage and discovered a difference with respect to XML compared to PDF and HTML full-text requests, Jamali and Nikzad (2011) focused on the influence of

15 http://www.plosone.org/static/almInfo.action
16 http://www.plosone.org/static/journalStatistics.action\#PLoSONE
17 http://www.plosone.org/static/plos-alm.zip

article titles on usage. They tested whether usage rates differed between articles with declarative, descriptive or interrogative titles. Their study is based on 2,712 documents published in six PLoS journals in 2007.

MESUR

MESUR[18] is the most advanced project in the area of analyzing global download statistics. Funded by the Andrew W. Mellon Foundation, MESUR collected 1 billion article-based usage events from six major publishers, four large US university consortia, and four aggregators including WoS and Scopus, between 2002 and 2007 aiming to "define, validate and cross-validate [...] usage-based metrics of scholarly impact" (Bollen, Rodriguez, & Van de Sompel, 2007, p. 274).

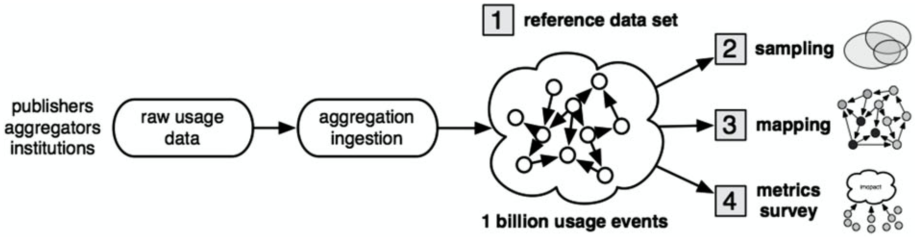

Figure 4.12 Structure and purposes of the MESUR project. Source: Bollen et al. (2008, p. 232)

Figure 4.12 depicts the structure and purposes of the project. MESUR aimed to provide a reference data set on the global usage of scholarly literature (1), examine sampling biases and representativeness of the scholarly community (2), map the structure of science based on readership in contrast to authorship (3) and to define and validate indicators of journal usage (4) (Bollen et al., 2007, 2008).

Instead of being confined to the number of downloads, MESUR identified single users and IP addresses (both anonymized) and extracted time, date and type of request from the log files in order to generate clickstream data. Full-text requests are thus grouped, generating information about which articles were used in one session by one user. Articles accessed together were taken to be topically related. In analogy to citation-based similarity measures such as bibliographic coupling and co-citations (section 3.4.1), clickstreams thus provided information about journal similarity (Bollen, Van de Sompel, Hagberg, Bettencourt, et al., 2009).

> [T]he degree of relationship between any pair of journals is a function of the frequency by which they are jointly accessed within user sessions. [...] This frequency determines the strength of the connection between this particular pair of journals. The connections thus extracted for each pair of journals can then be combined to form a journal usage network. (Bollen et al., 2008, p. 235)

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18 http://www.mesur.org

Bollen, Van de Sompel, Smith, and Luce (2005) found high co-retrieval frequencies for Physica B and Physica C and Physica B and J Magn Magn Mater at Los Alamos National Laboratory.

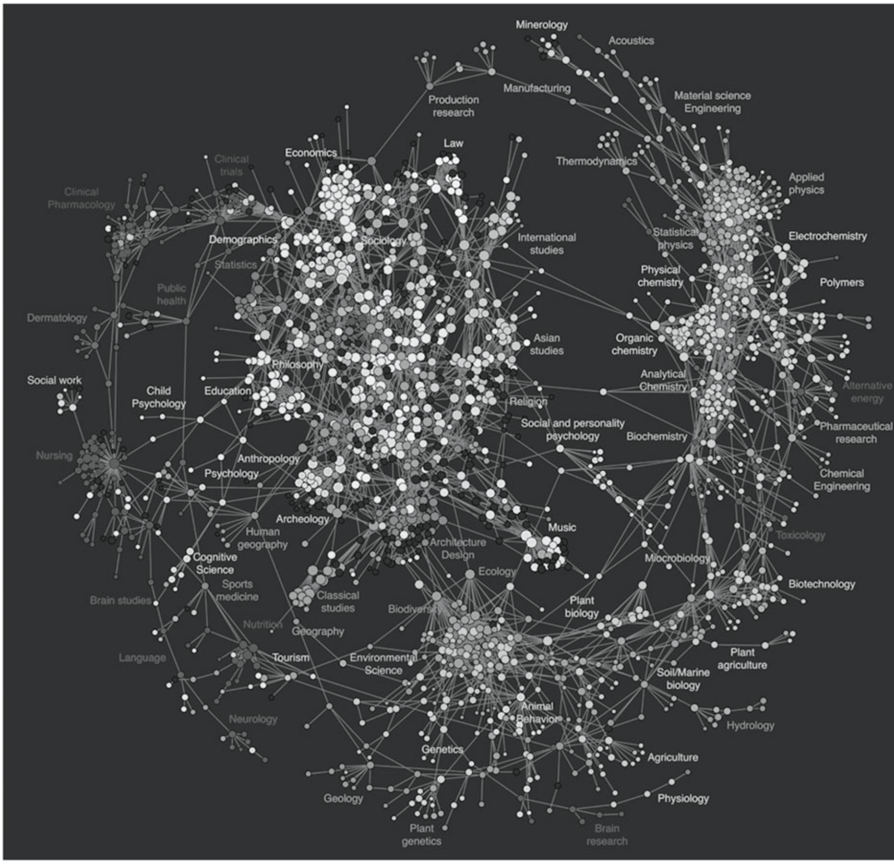

Figure 4.13 Map of science derived from clickstream data by the MESUR project. Source: Bollen, Van de Sompel, Hagberg, Bettencourt, et al. (2009, p. 5)

Results affirm the huge potential of usage data in the evaluation of scholarly communication (Bollen et al., 2008). A map of science based on clickstream data can be seen in figure 4.13. It is based on the 50,000 strongest connections between two journals generated through the clickstreams extracted from 346 million usage events between March 2006 and February 2007. Since further reductions were needed, for each of the remaining 2,307 journals only the five strongest connections were considered. Figure 4.13 only depicts the largest connected component of the journal network. Its center shows periodicals from the social sciences and humanities, which are very well connected within the network, indicating interdisciplinarity. These assumptions are validated by high betweenness centrality and PageRank values of these journals (Bollen, Van de Sompel, Hagberg, Bettencourt, et al., 2009). Physics and engineering, which can be found at the top right of the network, are interconnected to economics through periodicals from the area of manufacturing and production research. Bollen et al. (2008) compared a usage-based journal network to one based on citations and found that

> equally valid, rich and definitely more current maps of science can be generated from usage data than from citation data. (Bollen et al., 2008, p. 235)

Bollen et al. (2008) introduced journal indicators based on usage (compare section 4.2.3) and contrasted them with traditional citation-based metrics in order to show similarities and dissimilarities between both aspects of scholarly communication. Journal usage metrics and the clickstream map of science are available on the project's website[19] to use and adapt interactively. However, as Gorraiz and Gumpenberger (2010) have stated, MESUR creates "a complex semantic model of the scholarly communication", which targets a minority of experts instead of the broad audience of readers and authors.

SERUM

With SERUM, the University Library of the University of Vienna is taking a different approach to generating journal usage statistics representing worldwide readership. SERUM aims to create a JCR-like platform containing journal usage metrics based on detailed global download data provided by publishers and managed by an independent network of academic libraries (Gorraiz & Gumpenberger, 2010). The platform will contain a number of indicators computed from a detailed list of journal usage statistics, which will to be provided by the publishers including COUNTER Journal Report 1 and 5-like statistics plus the number of documents accessible online, the number of downloaded documents and the percentage of non-accessed documents, disaggregated by document type and IP addresses to localize the origin of usage.

It is beyond all doubt that the project's aims are desirable and that such a platform of globally aggregated detailed statistics would be helpful to access journal impact from a broader perspective reflecting the entire readership. Currently SERUM is however nothing but a 'blue-sky project', with the most crucial task still ahead, i.e. winning over publishers and libraries to provide and manage the underlying data set. Against the background of lack of cooperation on the publishers' side, it is doubtful whether the project will be able to realize this difficult objective.

Usage Factor Project

In association with COUNTER, the UKSG[20], an interest group of librarians and publishers, initiated the Usage Factor Project[21] (Merk et al., 2009). It started out in 2007 with a market research study (Shepherd, 2007b) investigating the feasibility of implementing a usage-based journal impact indicator in analogy to the impact factor based on citation data (see section 4.2.3 for the definition of the metric). Authors, librarians and

19 http://www.mesur.org/services
20 http://www.uksg.org
21 http://www.uksg.org/usagefactors

publishers were surveyed to gain an overview of current journal evaluation assessments and whether a journal indicator based on full-text requests would be accepted as a new measure (Shepherd, 2010).

Based on the positive outcome of the stakeholders survey, the project entered its second stage in 2009, which involved testing and validating the usage factor with actual usage data from publishers (Shepherd, 2011b). Seven publishers participated and reported usage data for documents published in 326 journals from five fields of research between 2006 and 2009 in order to test for the most appropriate time window of publications and usage to be covered by the usage factor. The data was additionally controlled for different document types and journal article versions (NISO/ALPSP, 2008), i.e. accepted manuscript, proof, version of record etc. (Shepherd, 2011b). The final report comes to the conclusion that it is best to measure usage on all document types and all article versions and to evaluate usage during a two-years period for documents published during the same years in the form of an arithmetic mean. However, the recommendations also consider using the median instead of the mean to account for the skewness of the data, and ideally providing various versions of the usage factor for different document types, article versions and shorter usage time spans (Shepherd, 2011a). Future research is planned to validate these recommendations on a larger set of journals. Before the usage factor can be implemented, COUNTER Journal Reports have to be adjusted and the calculations automated (Shepherd, 2011b). Results of the project's third stage are expected at the same time as the release of the new COUNTER Code of Practice in March 2012 (Shepherd, 2011a).

4.2.3 Download-based Usage Indicators

Quite a number of journal indicators based on usage have been introduced. Most of them are based on and calculated in analogy to citation measures (Schlögl & Gorraiz, 2008, 2010). However, as described in section 4.2.1 and section 4.2.2, aggregating the necessary usage data remains problematic. Despite existing standards such as COUNTER, local download statistics are often incapable of being compared and lack consistency, and global data is not generally available for subscription journals. Thus, the general practicability of these metrics is currently limited. Since most of the indicators introduced can only be computed if usage statistics were available on the article level in the degree of detail provided by PLoS (section 4.2.2) which is not the case for the 45 journals under analysis, the proposed usage indicators are described in terms of their theoretical background and computed for a subset, where possible.

Table 4.6 Mean number of full-text requests per document per publication year at Forschungszentrum Jülich in 2010 according to COUNTER Journal Report 5.

Journal	2004	2005	2006	2007	2008
Rep Prog Phys	0.256	0.460	0.788	0.325	1.286
New J Phys	0.424	0.164	0.048	0.084	0.177
Eur Phys J E	0.135	0.125	0.123	0.200	0.281
J Phys Condens Matter	0.099	0.141	0.104	0.136	0.218

continued on next page

Journal	2004	2005	2006	2007	2008
EPL	0.106	0.134	0.079	0.150	0.150
Nanotechnol	0.165	0.095	0.085	0.130	0.136
Appl Phys A	0.076	0.078	0.125	0.133	0.080
IEEE Nanotechnol	0.000	0.055	0.113	0.029	0.227
J Phys D	0.031	0.061	0.062	0.096	0.051
Phys Scr	0.049	0.036	0.047	0.113	0.008
J Stat Mech	0.034	0.018	0.060	0.041	0.054
Eur Phys J B	0.029	0.028	0.027	0.045	0.037
Supercond Sci Technol	0.013	0.009	0.028	0.022	0.087
Hyperfine Interact	0.014	0.018	0.018	0.063	0.041
Pramana	0.014	0.019	0.020	0.031	0.047
JETP Lett	0.022	0.021	0.026	0.009	0.042
J Low Temp Phys	0.009	0.009	0.014	0.024	0.044
J Stat Phys	0.018	0.025	0.019	0.014	0.009
Phys Solid State	0.017	0.016	0.016	0.000	0.034
Int J Thermophys	0.012	0.012	0.013	0.024	0.005
J Phys A	0.017	0.012	0.010	0.011	0.011
J Appl Phys	0.000	0.001	0.000	0.000	0.000

Mean Download Rate

As early as 2001, Cowhig proposed computing the average download per paper for journals over a certain period of time, in order to compare journal popularity regardless of output (Cowhig, 2001). Shortly after this, Hahn and Faulkner (2002) suggested a similar approach to normalize the number of full-text requests by the number of documents available online and called the indicator content-adjusted usage. Basically, these metrics are calculated like a mean citation rate (see section 5.1.1).

> As with counting citations, the number of downloads is determined by the number of articles online and accessible. All things being equal, a larger journal will experience more downloads than a smaller journal. This size effect can be mitigated by calculating an average number of downloads per article [. . .] (Craig & Ferguson, 2009, p. 177)

Such a mean download rate can be defined for certain periods of observed download t and publication years of evaluated documents y:

$$MDR_j^y = \frac{R_t(P_j^y)}{P_j^y} \tag{4.1}$$

where $R_t(P_j^y)$ stands for the number of full-text requests during period t to articles from journal j published in year y and P_j^y represents the number of documents published in journal j during y.

For the subset of journals where sufficient data was available, i.e. COUNTER Journal Report 5 delivered, mean download rates were computed annually with t defined as all full-text requests at Forschungszentrum Jülich in 2010 and y ranging from 2004 to 2008. Results are listed in table 4.6. Overall, mean annual download rates are low. The highest download rates can be observed for Rep Prog Phys, New J Phys, Eur Phys J E and J Phys Condens Matter, which are shown in figure 4.14. Rep Prog Phys is the only journal that scores a mean download rate above 1 in 2008, meaning that there were more downloads than papers published: Rev Mod Phys published 35 documents in 2008 and COUNTER reports 45 full-text requests for that particular year of publication. J Phys Condens Matter, which had the highest number of absolute downloads in 2010 (figure 4.7), has lower normalized rates than Rep Prog Phys and Eur Phys J E.

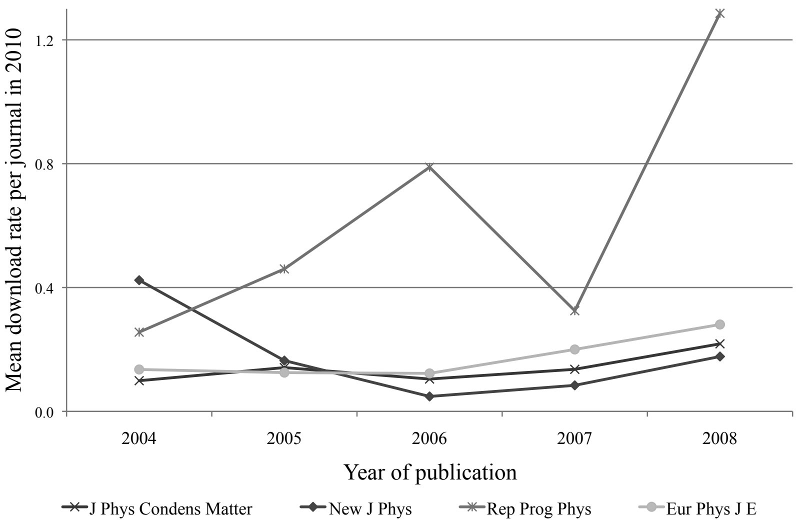

Figure 4.14 Mean download rates for J Phys Condens Matter, New J Phys, Rep Prog Phys and Eur Phys J E based on COUNTER Journal Report 5 for Forschungszentrum Jülich in 2010.

Usage Impact Factor and Immediacy Index

In general, usage metrics are constructed according to citation-based predecessors. Due to its popularity, most indicators evaluating journal downloads try to imitate the impact factor. This section subsumes all usage indicators constructed on the lines of the impact factor and immediacy index since they only differ in terms of publication years and usage periods covered. Quite a number of authors introduced similar measures that often differ in nothing but their names, which unnecessarily increase the complexity of the journal indicator landscape.

The first impact-factor-like download metric was proposed by Cowhig (2001), who suggested measuring journal usage by the number of downloads during one month of articles published during the previous 12 months, divided by the number of the latter. Rowlands and Nicholas (2007) argued that the time was ripe for usage-based journal indicators and adopted citation metrics known from the JCR (see section 5.1). One to one, they transferred citations to downloads and named the indicators accordingly, i.e. usage immediacy index, article impact factor and usage half-life.

Bollen and Van de Sompel (2008) were the first to apply a usage-based impact factor to a large number of usage events, namely a predecessor of the MESUR reference set described in section 4.2.2. The usage impact factor is defined in exact analogy to the impact factor:

$$UIF_j^y = \frac{R_y(A_j^{y-1} \cup A_j^{y-2})}{|A_j^{y-1} \cup A_j^{y-2}|} \tag{4.2}$$

where $|A_j^{y-1} \cup A_j^{y-2}|$ represents the number of documents published in journal j in the two years preceding year y. $R_y(A_j^{y-1} \cup A_j^{y-2})$ stands for the number of uses of these publications in year y. Bollen and Van de Sompel (2008) collected all full-text downloads of nine major institutions from the California State University (CSU) system in 2004 with respect to articles published in 2003 and 2002. Overall publications from 6,423 unique journals were requested 140,675 times. For 3,146 a valid 2004 impact factor could be identified. Spearman rank order correlation found a modest negative correlation between impact factor and usage impact factor, indicating that the journals used most at CSU have low impact factor values. This is because the publications being downloaded most frequently by CSU affiliates have a strong focus on social science. High-impact journals from medicine or multidisciplinary periodicals like Science and Nature are hardly read at CSU. This confirms the assumption that local download statistics can differ strongly from the reading behavior of the global scholarly community (Bollen & Van de Sompel, 2008).

There have been numerous discussions about the adequate time span the impact factor should take into account. When evaluating downloads, the chosen time frame is even more debatable. Only the usage, which appears one to two years after publication, is measured. While this is comprehensible for citation-based indicators due to the underlying publication process, applying the same time window to download-based analyses is rather arbitrary. As previous studies (Brody et al., 2006; Schlögl & Gorraiz, 2010) have shown, downloads function as an early indicator of later citation impact. As a matter of fact, the time lag between publication and download event can be almost zero. Most downloads are generated in the first few months after publication. A usage indicator following the citation-based impact factor, which covers only citations of documents from the two preceding years, misses a large part of usage. When computing the usage-based impact of publications, usage events taking place in the year of publication should not be disregarded. Due to the differences in obsolescence patterns of citations and downloads, a more adequate time window is needed (Kurtz et al., 2005; Moed, 2005a; Schlögl & Gorraiz, 2008).

Schlögl and Gorraiz (2010) followed Bollen and Van de Sompel (2008) and computed Usage impact factors for journals assigned to the oncology category of ScienceDirect with the same time frames as the citation-based original. Since the authors found extreme differences in the obsolescence patterns of downloads and citations showing that most of the downloads were to articles published during the current year, which are not covered by the impact factor time windows, they adjusted the method in Schlögl and Gorraiz (2011) and included downloads of current year publications of pharmacology journals by following Wan et al. (2010) and adopting the time frame of the immediacy index.

Wan et al. (2010) take up the JCR's definition of the immediacy index for the evaluation of usage of 6,000 journals in a Chinese academic full-text database in 2006, "because it fully embodies quick response time, one of the main advantages of electronic resources available on the Internet" (Wan et al., 2010, p. 558). Analogously to the citation-based metric, the Download immediacy index measures the number of downloads for journal articles during the year of publication:

$$DII_j^y = \frac{R_y(A_j^y)}{A_j^y} \tag{4.3}$$

where $R_y(A_j^y)$ stands for the number of downloads in year y to articles from journal j published in the same year and A_j^y represents the documents published in journal j in year y.

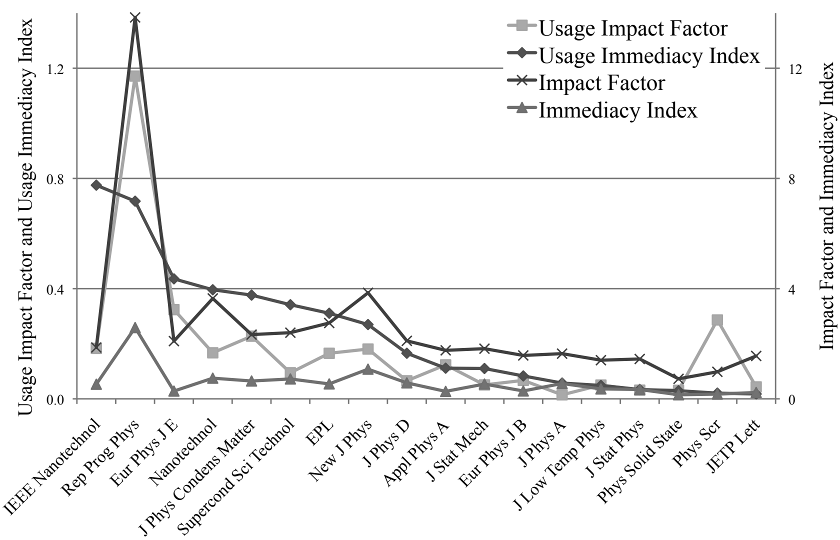

Figure 4.15 Usage impact factor, usage immediacy index, impact factor and immediacy index for 18 journals. Usage indicators are based on downloads at Forschungszentrum Jülich in 2010, impact factor and immediacy index are based on JCR 2010.

Regarding the time window under analysis, this indicator seems more suitable for the evaluation of journal perception based on download statistics. High Pearson correlations are found through normalized cross-covariance between citation and download curves, i.e. if the citation curve is shifted backwards by two ($r = 0.943$) or three years ($r = 0.946$). This implies that while the time frame selected by the impact factor works well for measuring citation impact, it is insufficient for measuring downloads.

For 18 of the 45 journals, sufficient data was available[22] to compute the usage immediacy index and usage impact factor based on local downloads at Forschungszentrum Jülich. Figure 4.15 shows the results compared to the corresponding 2010 impact factor and immediacy index values. Pearson and Spearman coefficients are computed for the four indicators on the basis of the 18 journals (table 4.7). Due to the small number of journals and a possible bias of the local usage data, results should be interpreted with caution and are not comparable to global values as discovered by Schlögl and Gorraiz (2011) or Wan et al. (2010).

Table 4.7 Pearson correlation r (lower half) and Spearman rank order ρ (upper half) of number of local usage impact factor (UIF_{2010}), usage immediacy index (UII_{2010}), impact factor (IF_{2010}) and immediacy index (II_{2010}). Usage indicators are based on downloads at Forschungszentrum Jülich in 2010, impact factor and immediacy index are based on JCR 2010.

	UIF_{2010}	UII_{2010}	IF_{2010}	II_{2010}
UIF_{2010}		.695**	.643**	.825**
UII_{2010}	.642**		.304	.577*
IF_{2010}	.629**	.862**		.860**
II_{2010}	.611**	.932**	.971**	

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level(2-tailed).

Usage factors constructed like the impact factor and immediacy index have also been suggested by Gorraiz and Gumpenberger (2010) in the context of the SERUM project (section 4.2.2) and by the UKSG for COUNTER data in their Usage Factor Project (Shepherd, 2011b). Recommendations of the latter concerning coverage and time frames are described in section 4.2.2 above. For details refer to Shepherd (2011a).

Usage Half-life

Moed (2005b) introduced a usage-based version of cited half-life in order to evaluate obsolescence patterns of article usage. The indicator was defined in exact analogy to cited half-life (section 5.1.4) as the median age of the documents accessed during the year of analysis. The value indicates the median age of the downloaded documents sorted descendingly according to their age or, in other words, for how long 50% of all articles are downloaded after publication. In contrast to the citation-based measure, Moed (2005b) computed the median age on a monthly instead of annual basis. For Tetrahedron Letters usage or download half-life was 12.6 months.

Most authors, e.g. Nicholas et al. (2005), Rowlands and Nicholas (2007) and Gorraiz and Gumpenberger (2010), however, calculate usage half-life based on years, simply because data is often not detailed enough to examine obsolescence per month. Schlögl and Gorraiz (2010) found a mean value of 1.7 for oncology journals in 2006,

22 Usage impact factor and usage immediacy index were computed if at least 20 full-text requests were made according to Journal Report 5 (section 4.2.1) at Forschungszentrum Jülich in 2010 for documents published between 2008 and 2010. Hyperfine Interact was excluded because it is no longer listed in JCR, thus impact factor and immediacy index were not available for comparison.

indicating that the articles from these journals downloaded in 2006 were on average 1.7 years old.

Usage half-life cannot be computed for the analyzed physics journals because the number of used documents is not given, so it is impossible to calculate the median.

Other Usage-based Metrics

Besides the usage impact factor, Bollen et al. (2008) introduced additional usage-based indicators derived from social network analysis, which are also known in citation analysis. A principal component analysis compared both sides, author and reader use of scholarly journals. Calculations are based on the MESUR reference data set (see section 4.2.2). Since some of the citation-based equivalents are described in section 5.2 and currently available usage data does not provide enough information to apply these metrics, a detailed description is not provided at this point. For more information regarding the different variants, refer to Bollen, Van de Sompel, Hagberg, and Chute (2009).

4.3 Usage Data from Social Bookmarking

Due to ongoing practical problems with acquisition of download data, i.e. inconsistencies in local and unavailability of global download statistics, alternative, publisher-independent ways to measure global readership are needed.

Scholarly communication is changing, Web 2.0 technologies are entering the academic world. Researchers make use of a number of collaborative tools like wikis, blogs, social networking and bookmarking services (Cope & Phillips, 2009). Designed on the pattern of Delicious[23], bookmarking services specializing in STM enable users to store, search and share interesting resources on the Web. Platforms like CiteULike, Connotea and BibSonomy were developed to accommodate the special requirements of academics, i.e. managing bibliographic metadata of scientific literature (Hammond, Hannay, Lund, & Scott, 2005; Reher & Haustein, 2010). By bookmarking and tagging articles, academic prosumers generate new information about resources.

Thus, it is proposed to apply social bookmarking data to journal evaluation and examine the extent to which it can be used to describe reader perception (Haustein & Siebenlist, 2011). Alt-metrics took a similar approach and emphasized the importance of explore different impact metrics (Priem & Hemminger, 2010; Priem, Taraborelli, Groth, & Neylon, 2010). Their ReaderMeter[24] calculates impact indicators for authors based on the number of users who stored their articles in the reference management system Mendeley[25]. ReaderMeter allows you to view the geographic location, discipline and professional status (if provided) of the Mendeley users who bookmarked the particular article online. Figure 4.16 shows the results for Bollen, Van de Sompel, Hagberg, Bettencourt, et al. (2009), which was bookmarked by 122 users from the US, UK and Germany. Of whom one third work in computer and information science, 25% in biological and 11% in social sciences. 20% of the Mendeley users were listed as

23 http://www.delicious.com
24 http://readermeter.org
25 http://mendeley.com

PhD students, 16% as researchers at an academic institution and 11% claimed to be professors. The remaining 31% and 53% of users did not indicate status or discipline, respectively. [26]

Figure 4.16 Geographic location, discipline and status of 122 Mendeley users bookmarking the article by Bollen, Van de Sompel, Hagberg, Bettencourt, et al. (2009). Source: http://readermeter.org

In analogy to download and click rates, usage can be indicated by the number of times an article is bookmarked. Compared to a full-text request as measured by conventional usage statistics, which does not necessarily imply that a user reads the paper, the barrier to setting a bookmark is rather high. Hence, bookmarks might indicate usage even better than downloads, especially if users took the effort to assign keywords. By tagging, academics generate new information about resources: tags assigned to a journal article give the users' perspective on journal content (section 3.2.2).

4.3.1 Data Collection

Today there are four social bookmarking tools serving academic purposes: CiteULike, Connotea, BibSonomy and 2collab (Reher & Haustein, 2010).[27] The latter has been contending with serious server problems and closed registration to new accounts in 2009. Hence, data collection was limited to bibsonomy.org, citeulike.org and connotea.org (Haustein, Golov, Luckanus, Reher, & Terliesner, 2010). A schematic representation of data collection is given in figure 4.17.

Currently, the three platforms are competing for a critical mass of users. For the set of journals under analysis, 78% of bookmarks and 84% of users appeared in CiteULike. Similar results were found for medical, biological and chemical journals (Reher, 2010). CiteULike also had the largest retrieval functionality (Reher & Haustein, 2010) and most complete metadata.

26 http://readermeter.org/Bollen.Johan/98c1f5c0-6d00-11df-a2b2-0026b95e3eb7/details
27 Mendeley is not considered, because it did not have a bookmarking function when this study was initiated.

A great proportion of the metadata of the bookmarking entries proved to be incomplete or erroneous. This often caused an article bookmarked by more than one user not to be recognized as one and the same publication. Thus, not only the social aspect of the bookmarking service is lost, i.e. similar content or users cannot be identified, but also the distribution of bookmarks among journal articles cannot be analyzed correctly. In order to obtain reliable and comparable results on journal usage, the data has to be normalized by journal output. Thus, the bookmarks should be matched on the article level.

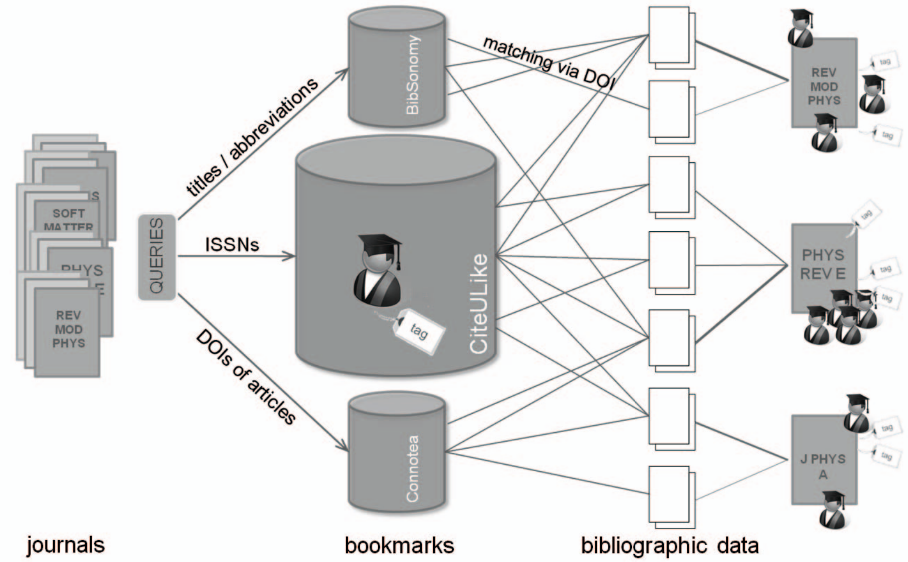

Figure 4.17 Schematic representation of data collection.

Retrieval of Bookmarks

To make up for the errors and incompleteness of the metadata of the bookmarking entries, four different search strategies were applied to find all bookmarks matching the publications: searching the titles of the periodicals plus their common abbreviations, ISSNs and DOIs of the 168,109 documents. The journal information was obtained from ZDB and Ulrich's Periodicals Directory. For 95.0% of the documents, the DOI was available from the WoS data. When errors were discovered in the WoS data, which seemed to be caused by optical character recognition, all of the DOIs were rechecked via http://dx.doi.org. If the character string from the WoS download was recognized as a correct DOI, it was assumed to be the DOI of the particular article. If the DOI database did not verify the specific character string as a DOI, it was marked as wrong and subsequently corrected. Checking revealed that 2,273 identifiers from the WoS data were erroneous. Out of the 10,711 erroneous or missing DOIs, 8,286 could be generated with CrossRef or added manually, so that 98.6% of the articles were searchable in the bookmarking services via their DOI.

Data acquisition had to be adapted to the different search and retrieval functionalities available at the platforms. In BibSonomy, bookmarks were retrieved in XML format via API. Since the API did not provide the capability to search for a specific field, the full text was searched for via the journal titles, abbreviations, ISSNs and DOIs. The initial results were subsequently checked to determine whether the query term was found in the correct field, e.g. the periodical's name found in the field for journal title instead of article title. This led to a set of 3,537 posts, which were cleaned from incorrect results, e.g. wrong journals or publication years outside the 5-year period. Eventually, 940 bookmarks were retrieved in BibSonomy that linked to the set of articles under analysis. All of these could be matched to 802 unique articles from the WoS data (see figure 4.19). Out of the 45 periodicals, articles from 39 were bookmarked at least once in BibSonomy.

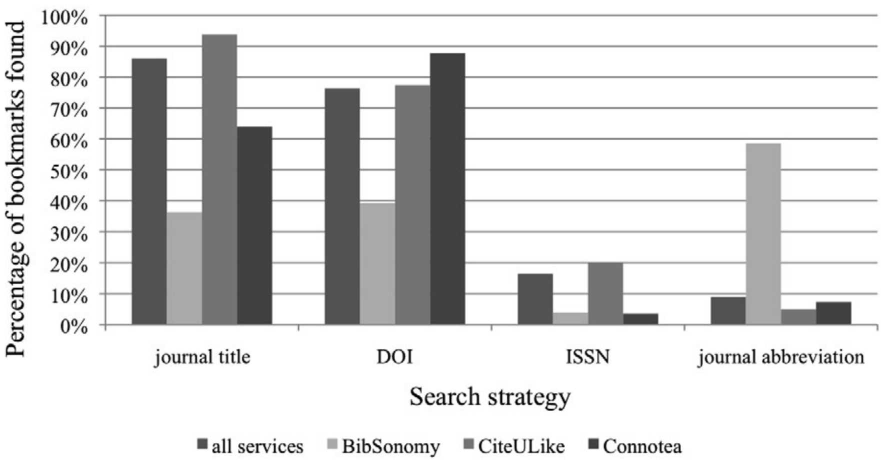

Figure 4.18 Bookmarks retrieved by four different search strategies.

As mentioned above, the metadata of all of the three social bookmarking services was incomplete and a lot of of entries suffered from discrepancies in spellings. In BibSonomy, 65.1% of the bookmarks were found by one of the search strategies only, meaning that only one of the particular metadata fields was correct. The most successful strategy was the search for the abbreviations of the journal title (compare figure 4.18). Only 0.7% of the 940 posts contained all the required information, i.e. title, abbreviation and ISSNs of the periodical and DOI of the particular article. 41.5% of the bookmarks in BibSonomy contained a DOI but for the remaining 550 they had to be generated via CrossRef or retrieved manually.

CiteULike is the only service where a field search for journal title, ISSN and DOI was possible and the results could be limited to certain publication years. However, CiteULike does not offer an API, so that results were retrieved via web search, parsed and downloaded in RIS format. Overall, 10,778 posts corresponded to publications during the 5-year period under analysis. Searching for journal title retrieved 93.7% of all bookmarks (compare figure 4.18). For 2,404 posts the DOI was missing and was retrieved either automatically by CrossRef or manual search. 10,640 bookmarks were matched to 8,082 unique articles of the WoS data (figure 4.19). All of the 45 journals had at least one user in CiteULike.

Connotea does offer an API but it only allows a search for a specific tag, user or date. Although it is possible to apply a free text search, phrase searches are not supported. For example, a search for the journal "Soft Matter" would retrieve all items including "soft" and "matter" but the results can neither be limited to the exact phrase nor ranked by occurrence of the phrase. Hence, it was not possible to retrieve all bookmarks for a specific article or even journal via API. The only way to retrieve all bookmarks for the set of documents was to download all Connotea entries via date search and save them temporarily in a field structure, which allowed filtering for journal title, DOI and ISSN. 2,042 bookmarks in Connotea matched the queries. 88.1% of the Connotea posts already contained a DOI, the remaining 242 had to be added. 2,028 (99.3%) Connotea entries were matched to the WoS dataset via their DOI. 1,995 unique articles from 43 of the journals were bookmarked in Connotea (figure 4.19). 61.4% were found by more than one search strategy with DOI and title being the most successful.

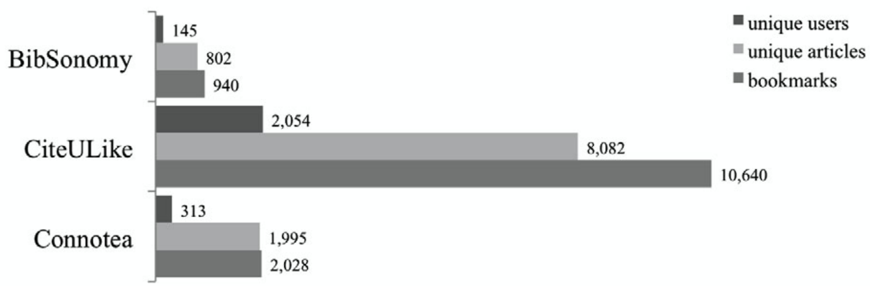

Figure 4.19 Number of unique users, articles and bookmarks per social bookmarking service for the 45 journals.

Analyzing the bookmarking services in detail, one discovers a lot of entries including spam, mainly in the form of advertisements for watches or pharmaceuticals. A filtering system should be applied in order prevent such spam from being added to the database of bookmarks.

Merging Different Sources

Since all of the bookmarking tools offer the same service, i.e. storing, managing and sharing literature, it can be assumed that in general researchers choose one service to store and share their literature and do not bookmark the same articles in different services in parallel. This assumption was confirmed by a check for doubles among the user names of the three services: only one user name was listed in all three tools and 70 user names appeared in two. Hence, the overlap was 2.8%. A double of user names was defined as an identical character string. Due to the fact that user names can be freely chosen, it cannot be guaranteed that each character string represents a distinct person (Kipp, 2006).

In BibSonomy our set of articles was bookmarked by 145 unique users and by 2,054 and 313 users in CiteULike and Connotea, respectively. Although BibSonomy, CiteULike and Connotea currently have a comparable number of users as measured by traffic statistics (Reher & Haustein, 2010), CiteULike is by far the most important service for the 45 journals from solid state research (compare figure 4.19). This confirms results by Reher (2010), who found that out of the three services, CiteULike covered the most publications in physics, chemistry, biology and medicine. It was only outdone in computer and information science by BibSonomy.

Since for the evaluation of journal usage the source platform of the bookmarks is irrelevant, the result sets of BibSonomy, CiteULike and Connotea were combined. The final dataset contained a total of 13,608 bookmarks from 2,441 unique users, which matched 10,280 articles from the WoS dataset.

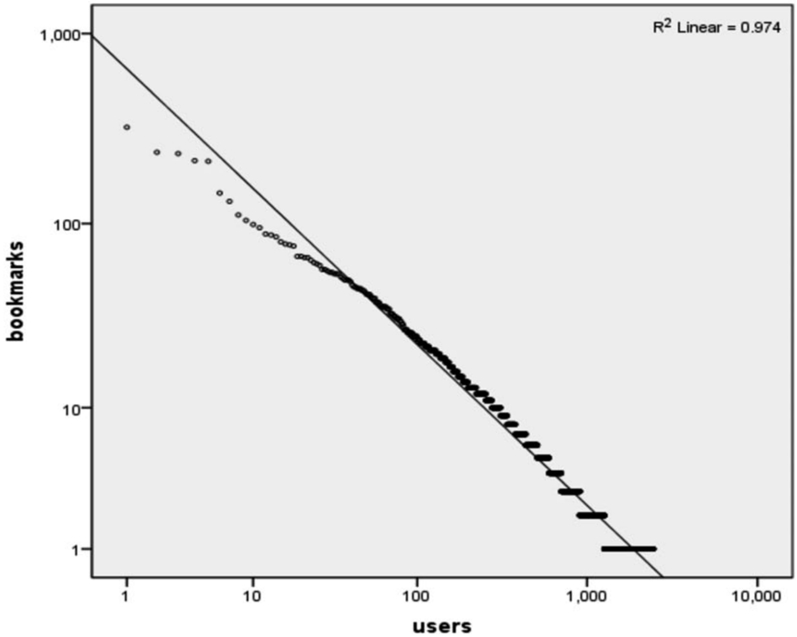

Figure 4.20 Log-log distribution of number of bookmarks per user in BibSonomy, CiteULike and Connotea.

The distributions of the bookmarking activity per user (see figure 4.20) and the number of bookmarks per article both conform to a power law. 75% of the content was created by 21% of the users. The most active user stored 322 articles from the set of journals. The publication with the highest number of users from the analyzed set of physics articles was bookmarked 67 times. In contrast, there were 1,179 users who bookmarked just one publication and 8,511 articles that were bookmarked only once.

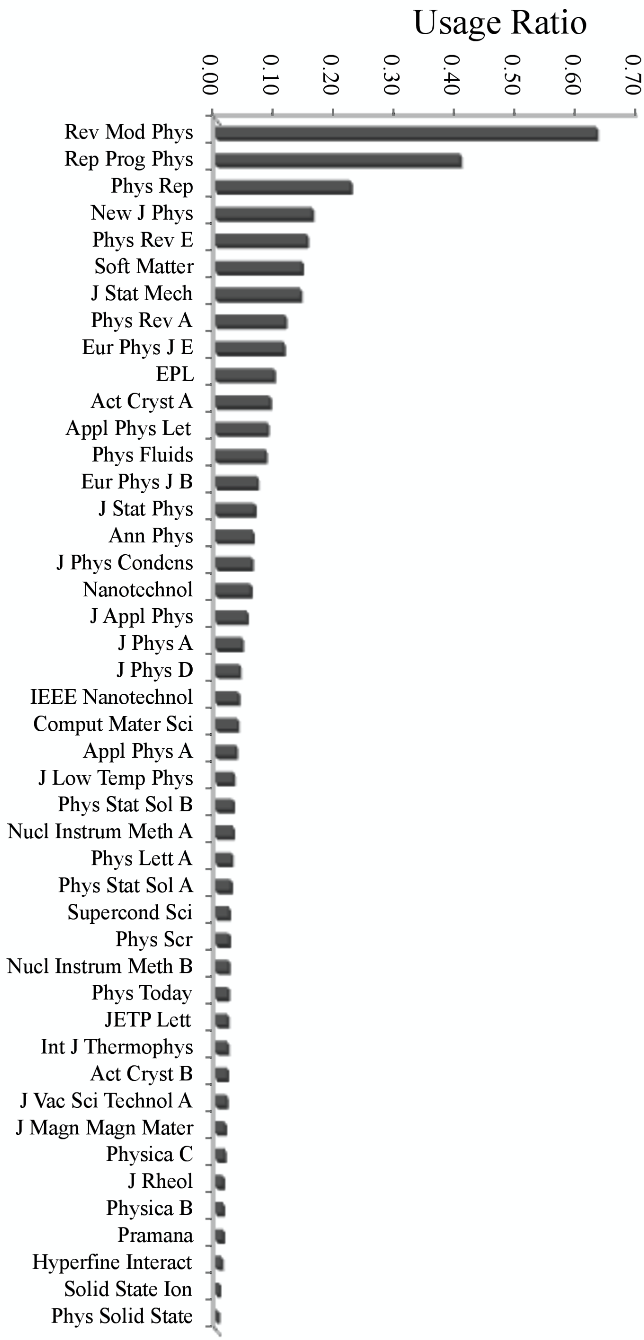

Figure 4.21 Usage ratio for the 45 journals.

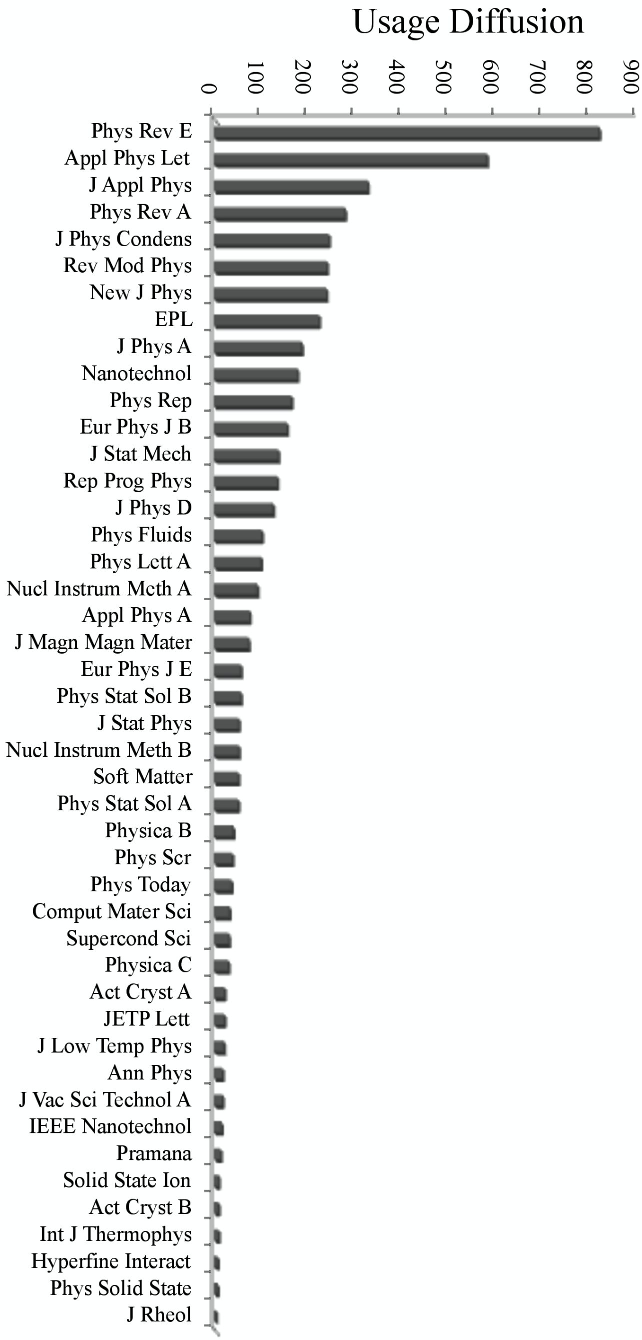

Figure 4.22 Usage diffusion for the 45 journals.

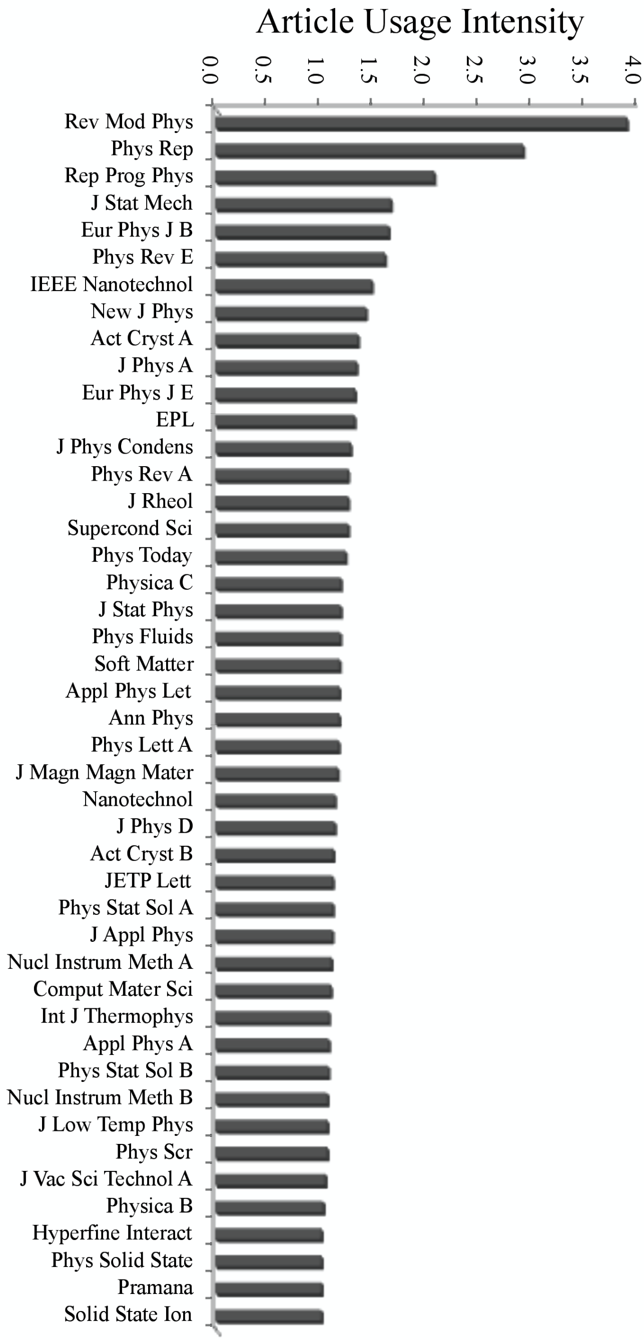

Figure 4.23 Article usage intensity for the 45 journals.

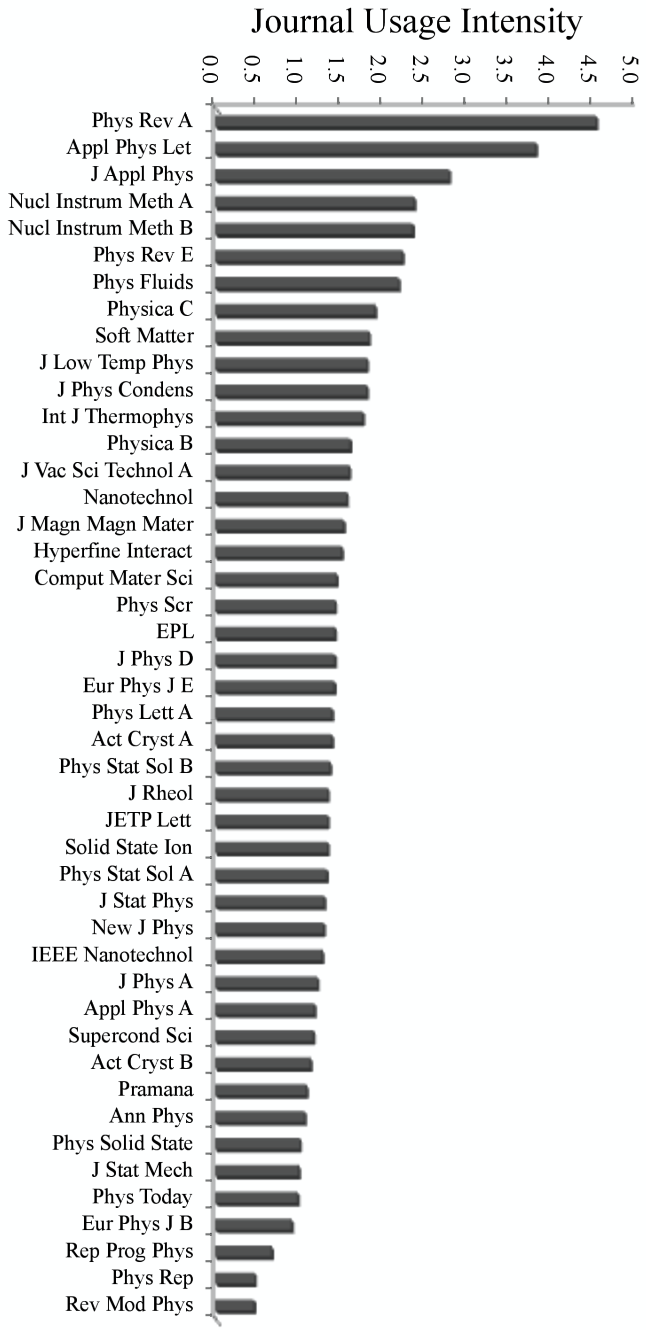

Figure 4.24 Journal usage intensity for the 45 journals.

Since academics are not necessarily known to be at the leading edge of social media (Huwe, 2011), a certain bias towards a Web 2.0-savvy readership can be conjectured. However, local statistics are influenced by institution-specific biases as well. Although social bookmarking in STM is still in its infancy, developments at Mendeley show that this can change rather quickly. Within the nine months from October 2010 to July 2011 the number of documents in Mendeley more than doubled from 44 to 99 million articles (Jack et al., 2010). As of July 2011, Mendeley reports more than one million users[28]. As ArXiv became an overnight success in the physics community, social bookmarking and reference managing systems are likely to become a reliable source for global usage of scholarly literature in the future.

4.3.2 Bookmarking Indicators

The combined set of bookmarks from BibSonomy, Connotea and CiteULike provides the basis for the calculation of four alternative indicators of global journal usage, which are described in the following: usage ratio, usage diffusion, article usage intensity and journal usage intensity. It should be noted that these indicators represent a basic way of representing journal usage, and function primarily as tools to explore the potential of bookmarking data. The usage indicators described in section 4.2.3, such as the usage impact factor introduced by Bollen and Van de Sompel (2006), could not be computed due inconsistencies of date and time the bookmark was set, which is required to calculate all bookmarks in year *y* to articles published in the two preceding years. The same applies to usage or download immediacy index (Rowlands & Nicholas, 2007; Wan et al., 2010) and usage half-life (Rowlands & Nicholas, 2007; Schlögl & Gorraiz, 2010). The application of weighted indicators to the bookmarking data would be possible as well, if weights such as the importance of bookmarking users were allocated to bookmarks.

However, due to the rather small database of this exploratory study the validity of the results of these indicators is limited. As soon as a critical mass of users bookmark their literature online, a large number of measures based on citations and downloads should be applicable to bookmarking data as well. Furthermore tags assigned to the publications are explored to discover a user-specific view on journal level.

Table 4.8 Usage indicators for the 45 journals based on social bookmarking data: number of publications (P_j), number of bookmarks (B_j), number of bookmarked articles (P_b), usage ratio (UR_j), usage diffusion (UD_j), article usage intensity (UI_p) and journal usage intensity (UI_j).

Journal	P_j	B_j	P_b	UR_j	UD_j	UI_p	UI_j
Act Cryst A	326	39	29	0.089	21	1.34	1.86
Act Cryst B	493	10	9	0.018	8	1.11	1.25
Ann Phys	296	21	18	0.061	17	1.17	1.24
Appl Phys A	2685	94	88	0.033	75	1.07	1.25
Appl Phys Let	25983	2587	2214	0.085	581	1.17	4.45

continued on next page

28 http://www.mendeley.com

Journal	P_j	B_j	P_b	UR_j	UD_j	UI_p	UI_j
Comput Mater Sci	1299	50	46	0.035	32	1.09	1.56
EPL	3291	414	316	0.096	223	1.31	1.86
Eur Phys J B	2056	229	140	0.068	155	1.64	1.48
Eur Phys J E	707	104	79	0.112	56	1.32	1.86
Hyperfine Interact	1006	9	9	0.009	6	1.00	1.50
IEEE Nanotechnol	519	28	19	0.037	15	1.47	1.87
Int J Thermophys	757	15	14	0.018	8	1.07	1.88
J Appl Phys	17827	1002	909	0.051	327	1.10	3.06
J Low Temp Phys	1260	38	36	0.029	20	1.06	1.90
J Magn Magn Mater	7549	128	111	0.015	73	1.15	1.75
J Phys A	5244	299	225	0.043	186	1.33	1.61
J Phys Condens Matter	7427	558	438	0.059	244	1.27	2.29
J Phys D	4554	199	177	0.039	125	1.12	1.59
J Rheol	347	5	4	0.012	3	1.25	1.67
J Stat Mech	958	222	134	0.140	136	1.66	1.63
J Stat Phys	1049	79	67	0.064	52	1.18	1.52
J Vac Sci Technol A	1580	28	27	0.017	17	1.04	1.65
JETP Lett	1487	31	28	0.019	21	1.11	1.48
Nanotechnol	4852	311	276	0.057	177	1.13	1.76
New J Phys	1926	436	307	0.159	239	1.42	1.82
Nucl Instrum Meth A	7670	235	215	0.028	91	1.09	2.58
Nucl Instrum Meth B	5973	129	122	0.020	52	1.06	2.48
Phys Fluids	2702	259	220	0.081	101	1.18	2.56
Phys Lett A	5328	159	137	0.026	99	1.16	1.61
Phys Rep	341	221	76	0.223	164	2.91	1.35
Phys Rev A	11027	1575	1259	0.114	278	1.25	5.67
Phys Rev E	12117	2916	1822	0.150	820	1.60	3.56
Phys Scr	2543	57	54	0.021	38	1.06	1.50
Phys Solid State	1970	6	6	0.003	6	1.00	1.00
Phys Stat Sol A	2721	73	66	0.024	50	1.11	1.46
Phys Stat Sol B	2691	81	76	0.028	56	1.07	1.45
Phys Today	1780	43	35	0.020	36	1.23	1.19
Physica B	5561	65	64	0.012	40	1.02	1.63
Physica C	3947	65	55	0.014	29	1.18	2.24
Pramana	1258	14	14	0.011	13	1.00	1.08
Rep Prog Phys	220	184	89	0.405	134	2.07	1.37
Rev Mod Phys	173	424	109	0.630	240	3.89	1.77
Soft Matter	654	109	93	0.142	51	1.17	2.14
Solid State Ion	2270	12	12	0.005	9	1.00	1.33
Supercond Sci Technol	1685	45	36	0.021	31	1.25	1.45
all journals	168109	13608	10280	0.035	2441	1.17	1.63

Usage Ratio (Share of Publications Bookmarked per Journal)

With 2,214 papers, Appl Phys Let was the journal with the highest absolute number of bookmarked articles, followed by Phys Rev E (1,822 articles) and Phys Rev A

(1,259 articles, table 4.8). Since the number of bookmarks depends on the total number of articles published in the journal, normalization is needed. The usage ratio gives the percentage of bookmarked articles in comparison to the total number of articles published between 2004 and 2008 in the particular journal. The indicator analyzes the proportion of articles with users, i.e. publications that were read compared to those that were not. This normalization is not possible with COUNTER Journal Report 1 and 1a, which indicate neither how many articles were downloaded nor list the span of years when used articles were published (see section 4.2.1). The usage ratio of a journal is defined as the number of bookmarked articles divided by the total number of articles published in the same journal during a certain period of time:

$$UR_j = \frac{P_b}{P_j} \tag{4.4}$$

where P_b represents the number of unique articles bookmarked and P_j stands for the number of articles published in journal j. As can be seen in figure 4.21 for the journals under analysis the usage ratio is highly skewed. It ranges from 0.003 for Phys Solid State to 0.630 for Rev Mod Phys. With 173 articles published within the timespan under analysis, the latter published the smallest number of documents of the 45 journals. However, 109 of these were bookmarked. The median usage ratio for the whole journal set is 0.074.

Usage Diffusion (Unique Users per Journal)

Usage diffusion depicts the absolute number of unique readers and thus the diffusion of journal content into the scientific community.

$$UD_j = R_j \tag{4.5}$$

where R_j is the number of unique readers of journal j. Usage diffusion indicates whether the periodical is perceived by a broad audience or a narrow readership. It should be kept in mind that in general journals covering more general topics within the field can reach a larger number of readers than a periodical focusing on a specific area of research and thus targeting a small number of specialists. For the analyzed journals the mean number of users per periodical was 114.6. The median usage diffusion is 52. The number of different users ranges from only 3 for J Rheol to 820 for Phys Rev E (compare table 4.8 and figure 4.22).

Article Usage Intensity (Bookmarks per Publication per Journal)

Usage ratio and usage diffusion give information about the proportion of articles used and the number of unique readers, but they do not analyze the intensity with which the content of a journal is used. Article usage intensity does so by computing the distribution of readers per article. The mean number of posts, i.e. the number of unique users per bookmarked article, is given.

$$UI_p = \frac{B_j}{P_b} \tag{4.6}$$

where B_j represents the total number of bookmarks to articles published in journal j and P_b is the number of unique articles bookmarked. The mean article usage intensity for the journals under analysis was 1.32 and the median was 1.17, so on average there is only one user per article. This is due too a highly skewed distribution of readers and articles. As stated above, 82.79% of all 10,280 articles were only bookmarked once. The article that was bookmarked most within the publications analyzed had 67 unique readers and was published in Phys Rep. With a citation score of 1,049 in WoS it was also amongst the most frequently cited articles within the whole dataset. This would confirm assumptions of usage data being an early indicator of citation impact (Brody et al., 2006; Bollen et al., 2007). However, hardly any correlation (Pearson's $r = 0.215$) could be found between the citation and bookmarking distribution on the article level. This would support the assumed difference of publishing and pure readers. With an article usage intensity of 3.89, Rev Mod Phys was the periodical with the most intensively read publications (see table 4.8 and figure 4.23).

Journal Usage Intensity (Bookmarks per User per Journal)

Journal usage intensity identifies the mean number of articles per unique user for each journal and thus measures how intensively the average user bookmarks publications from a specific journal.

$$UI_j = \frac{B_j}{R_j} \tag{4.7}$$

where B_j is the number of bookmarks for articles published in journal j and R_j represents the total number of unique readers of the particular journal. journal usage intensity reflects the loyalty of the readers towards the periodical. In the set of 45 journals, the median number of articles a reader bookmarked per journal is 1.63. Phys Rev A was the periodical that was used most intensively by its readers: 278 unique users bookmarked Phys Rev A 4.53 times on average (compare table 4.8 and figure 4.24).

4.3.3 Comparison with Citation Indicators

Table 4.9 shows Pearson and Spearman correlations for the four bookmark-based and seven citation indicators and the number of publications P_j, bookmarks B_j and bookmarked publications P_b per journal. The citation indicators include simple citation-publication ratios (see section 5.1.1) such as impact factor and immediacy index, a time-based measure such as cited half-life (section 5.1.4), the journal h-index (section 5.1.3) and weighted measures such as Eigenfactor and article influence score and SCImago journal rank (compare section 5.2).

The lower half of the matrix shows Pearson's correlation coefficient r and the upper half lists the results of Spearman's rank order correlation ρ for each of the indicator pairs on the basis of the 45 journals under analysis. Pearson's r calculates the differences between two sets of values, while Spearman analyzes changes in rank order. In general, high values of r are found between P_j, P_b and B_j, which is to be expected, since the number of bookmarked articles depends on the number of documents published in a journal. There is also a high positive correlation between the number of users and number of bookmarked articles and total bookmarks ($r = 0.906$ and $r = 0.949$). The impact factor, as the most commonly used measure of journal impact shows only a correlation of $r = 0.571$ to usage ratio and no correlation with the number of readers UD_j. Hence, at least for the data under analysis, users of social bookmarking services do not seem to be influenced by the impact factor. Pearson values for h-index, Eigenfactor, number of publications, bookmarks and users show positive correlations, which can be explained by dependence on size of these indicators (West, Bergstrom, & Bergstrom, 2010). In contrast, immediacy index, impact factor, SCImago journal rank, article influence and usage ratio are normalized by number of publications and thus size-independent measures. They show positive correlations among each other as well. Usage ratio and usage intensity (article) show a high value of $r = 0.899$. This might show a social effect of the bookmarking platforms: the higher the share of bookmarked publications per journal, the more people bookmark these articles. No correlation can be found between UI_j and UR_j.

For some values Pearson and Spearman correlations differ significantly. If ρ is higher than r, the difference in indicator results did not have a large effect on the ranking produced on the basis of these indicators. Vice versa, small differences of measured values affect the rank orders, if ρ is significantly larger than r. The latter can be observed for UR_j and UD_j with $\rho = 0.737$ and $r = 0.333$.

Summary

Researchers publish in journals in order to inform the scholarly community about their research. Journal articles function as a means to communicate and advance scientific knowledge. In their role as authors, researchers are thus interested in as wide a distribution of their publications as possible. One of the central issues contributing to the success of a journal as a means of communication, and thus its standing, is how frequently and by whom it is read. The more researchers read a journal, the more interesting it becomes for authors to submit their manuscript. It is hence a central point of journal evaluation to measure readership.

Before being largely replaced by citation analysis, reader surveys and statistics about library use and interlibrary loans were the only methods that tried to capture journal usage. Due to their local limitation and biases and the time and effort needed to conduct such studies, surveys and reading statistics have largely been replaced by citation analysis, which tries to reflect usage through the analysis of cited references.

Since there are readers who do not publish themselves, not all usage is reflected in citation counts, however. Readers can be divided into pure and publishing readers, hence, citation analysis is not able to capture usage entirely. Journal literature is not only used as groundwork for new publications but may also influence readers who do not publish. Journal content can, for example, serve informational purposes, be applied in everyday work and teaching or contribute to background knowledge and clarify complex issues. All these kinds of usage are not captured by citations.

Monitoring usage directly through reader-based statistics has experienced a comeback in the times of electronic publishing. Download and click rates show which documents have been accessed how many times and by whom and thus indicate article

Table 4.9 Pearson correlation r (lower half) and Spearman rank order ρ (upper half) of number of publications (P_j), bookmarked publications (P_b), bookmarks (B_j), usage ratio (UR_j), usage diffusion (UD_j), article usage intensity (UI_p), journal usage intensity (UI_j), impact factor (IF), immediacy index (II), h-index (h), SCImago journal rank (SJR), Eigenfactor (EF), article influence (AI) and cited half-life ($T^{\text{cited}}_{\frac{1}{2}}$) computed for 45 solid state physics journals.

	P_j	P_b	B_j	UR_j	UD_j	UI_p	UI_j	IF	II	h	SJR	EF	AI	$T^{\text{cited}}_{\frac{1}{2}}$
P_j		.643**	.547**	-.116	.509**	-.226	.423**	-.185	-.135	.452**	-.150	.627**	-.266	-.340*
P_b	.876**		.981**	.650**	.959**	.420**	.581**	.371*	.414**	.804**	.202	.886**	.380*	-.506**
B_j	.803**	.983**		.722**	.987**	.513**	.555**	.446**	.494**	.842**	.240	.893**	.463**	-.452**
UR_j	-.092	.114	.198		.737**	.764**	.349*	.690**	.621**	.580**	.440**	.545**	.768**	-.270
UD_j	.723**	.906**	.949**	.333*		.533**	.444**	.482**	.520**	.856**	.258	.888**	.501**	-.422**
UI_p	-.162	.015	.113	.899**	.267		.218	.693**	.800**	.469**	.395**	.375*	.770**	-.199
UI_j	.753**	.833**	.794**	.087	.654**	-.030		.136	.154	.374*	.164	.508**	.186	-.280
IF	-.166	-.058	-.011	.571**	.046	.591**	-.025		.814**	.614**	.747**	.500**	.925**	-.172
II	-.136	-.032	.045	.866**	.163	.894**	-.033	.560**		.596**	.596**	.428**	.801**	-.239
h	.695**	.730**	.722**	.499**	.776**	.462**	.591**	.201	.396**		.506**	.887**	.545**	-.394**
SJR	-.161	-.061	-.005	.708**	.058	.650**	-.019	.900**	.768**	.218		.364*	.683**	-.194
EF	.927**	.922**	.855**	.113	.782**	.030	.743**	.015	.028	.796**	.013		.452**	-.343*
AI	-.172	-.047	.030	.893**	.146	.914**	-.050	.754**	.958**	.392**	.868**	.024		-.094
$T^{\text{cited}}_{\frac{1}{2}}$	-.171	-.178	-.162	.020	-.239	.086	-.136	.227	.154	-.223	.199	-.169	.212	

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

usage. Studies have shown that download rates can serve as an early indicator of citation performance. Since this data can be extracted from log files, reader-based analysis has become feasible. Local statistics help librarians to monitor institutional usage and optimize collection management. Although COUNTER has improved publisher provided data by stipulating standards, it has been shown that, at the present time, download statistics are not suitable for journal evaluation.

Global usage data, which would be helpful for authors to find a suitable publication venue in terms of readership, is not available. Open access publishers are the only ones to provide data detailed enough for meaningful usage statistics, since, in contrast to traditional subscription journals, they do not have to worry about low usage reflecting badly on profits. Although most of the latter collect detailed data on the document level, they do not publish these numbers other than for promotional purposes.

A comparison of journals in terms of usage should always involve normalization regarding journal output. Otherwise there will always be a bias in favor of large journal, since much output can generate much usage. Even with the local data currently provided by publishers, this normalization is not possible. Since most usage-based indicators, which have are constructed in the same way as their citation-based equivalents, require statistics that indicate usage frequency on the document level, they cannot be adequately applied in practice at the present time. Unfortunately, these deficiencies do not prevent libraries from computing inaccurate usage statistics.

Against the background of the lack of global usage statistics for scholarly journals, social bookmarking data has been introduced as a new alternative approach to collecting article-based usage data on a global scale. It can be argued that bookmarking a document is a better indicator of reading it than clicks and download. However, social bookmarking in STM is still in its infancy, so that there is currently insufficient data to provide a general, unbiased picture of worldwide journal usage.

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Chapter 5
Journal Citations

This chapter focuses on journal citations as reflections of formal scholarly communication. Today journal evaluation is applied and rankings are used in many different situations:

> A journal's position in the various rankings for its discipline helps define the journal and delineate its role in the scholarly communications process. In a practical sense, journal rankings are used by scholars for manuscript submission decisions and for planning their publication agenda; for assessment of faculty performance regarding tenure, promotion, and annual raise decisions; by librarians for serials collection management decisions; and by journal editors for maintaining and improving the quality of their publications. (Nisonger, 1999, p. 1004)

The first to apply citation-based journal evaluation in order to manage library holdings were Gross and Gross (1927). The study was based on 3,663 references listed in the 1926 volume of the Journal of the American Chemical Society and is considered to be the first journal ranking for college library subscription management by objective, quantitative methods (Archambault & Larivière, 2009).

The first journal indicators based on citation impact were developed by Eugene Garfield with the aim of managing and monitoring sources of the SCI, the database of scholarly literature based on methods of citation indexing (Wouters, 1999b). Citation indexing was originally developed for purposes of information retrieval independent of linguistic barriers (Garfield, 1998). Only later did it become the basis for research evaluation studies. The development of citation indexing and the construction of the SCI in the 1960s are briefly described in section 3.1.4. For an extensive review see Wouters (1999a, 1999b).

The most widespread journal impact measure, the impact factor, was initially designed by Garfield and Irving H. Sher at the ISI in order to compare the scholarly impact of scientific journals (Garfield & Sher, 1963). Since the absolute number of citations, besides many other factors such as discipline and time (Todorov & Glänzel, 1988; Leydesdorff, 2008), depends on the journal's productivity in terms of output (chapter 2), a size-independent metric was needed (Garfield, 1972). Based on the skewed distribution of citations, i.e. the majority of citations in a research field are received by a small number of journals, the journal citation rate was used to identify the core journals of a discipline to be covered by the citation index.

By 1969, 2,200 journals had been identified as "the world's most important scientific and technical journals" (Garfield, 1972, p. 471 f.) and fully indexed by the SCI. The skewed distribution of citations among 2,000 most frequently cited serials is shown in figure 5.1. As few as 25 of the covered journals received 24% of all indexed citations, 50% of all citations were taken from 152 journals, and 767 periodicals accounted for

75% of the total citations received. Around 2,000 journals accounted for 84% of all citations, justifying the impact factor as a legitimate tool to identify suitable candidates on the one hand, and the limitation of the number of periodicals covered on the other (Garfield, 1972).

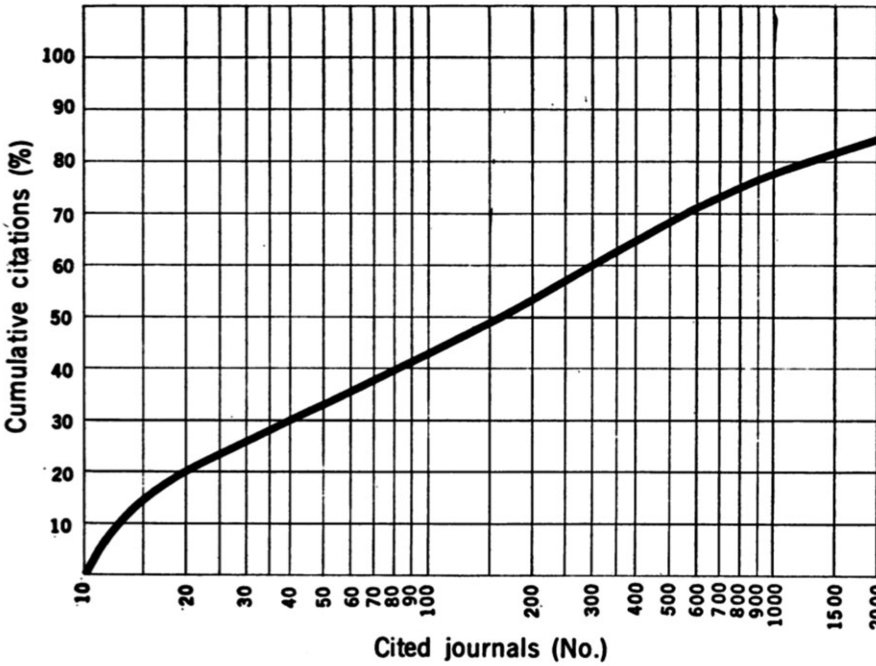

Figure 5.1 Cumulative number of citations among 2,200 journals of the 1969 SCI. Source: Garfield (1972, p. 475)

It was Garfield who extended the application of the impact factor from a tool for monitoring database coverage to the evaluation of scholarly communication (Moed, 2005). In his famous 1972 Science paper, Garfield underlined the potential of citation analysis in research evaluation and outlined the usefulness of the impact factor for librarians, editors and individual scientists (Garfield, 1972). This provided the basis for further developments in the analysis of scholarly periodicals and the design of various impact measures. The number of new indicators and variants has since increased. One gets the impression that new or newly named indicators emerge almost weekly, ranging from entirely new methodologies and minor changes such as the limitation to certain document types or adjustments of the publication and citation.

As long as journals are ranked by impact factors, editors will look for ways to optimize (or manipulate) the metric to leverage the performance of their journals. Archambault and Larivière (2009) describes this as an 'arms race' between scientometricians and editors.

Reviews of journal impact metrics are provided by Todorov and Glänzel (1988), Moed, Van Leeuwen, and Reedijk (1999), Glänzel and Moed (2002) and Rousseau (2002). The general overview of informetrics by Bar-Ilan (2008) contains a section on journal indicators as does the book by Moed (2005). A more recent but less detailed review of journal metrics is provided by Pendlebury (2009).

After a brief introduction to the special characteristics of citation distributions, different citation-based journal indicators will be described. They are classified into three approaches, namely basic (section 5.1), weighted (section 5.2) and normalized citation indicators (section 5.3). Since new types of citation indicators emerge frequently, this chapter is not able to describe all the journal indicators ever proposed. It does, however, claim to cover the major types and most commonly used indicators.

The distribution of citations between documents is highly skewed (Moed, 2005). As a rule of thumb, 20% of all documents account for 80% of all citations. There are also specific differences between document types. Some types of publications are heavily cited, others infrequently or never at all (Van Leeuwen, Moed, & Reedijk, 1999). This has led to a definition of so-called 'citable items', which also plays a role in the calculation of the impact factor, described in section 5.1.1. While articles, reviews and proceedings papers are usually regarded as 'citable', editorials, letters and news items are not. This does not, however, mean that non-citable items cannot be cited but merely that they are not cited as frequently. This reflects in the uncitedness values per document type listed in table 5.1.

Table 5.1 Uncitedness ($P_{uncited}$) in 2010 of different document types of the 168,109 documents published in the 45 journals between 2004 and 2008.

Document type	$P_{uncited}$
Review	4.0%
Article	12.9%
Proceedings paper	27.2%
Editorial material	66.5%
Bibliography	66.7%
Letter	67.4%
Correction	71.4%
Reprint	75.0%
Biographical item	92.1%
News item	93.2%
Book review	100.0%
All document types	17.4%

The uncitedness is the percentage of documents which have not been cited at the point in time of analysis. As shown in table 5.1, the eleven types of documents included in the 168,109 publications can be divided into three groups in terms of their uncitedness values. Biographical, news items and book reviews are almost never cited ($P_{uncited}$ = 92.1% – 100%) and editorials, bibliographies, letters, corrections and reprints remain uncited to a large extent (66.5% to 75.0%). Only reviews, articles and proceedings papers are extensively cited. 96.0% of all reviews are cited by at least one other document, and so are 87.1% of research articles and 72.8% proceedings papers. Hence, all calculations in this chapter are limited to articles, proceedings papers and reviews, unless otherwise noted. According to the WoS classification of document types shown in table 2.4 in section 2.1.4, 163,131 of the initial 168,109 documents remain to be analyzed.

As noted above, citation distributions of scholarly journals are usually skewed to the right, indicating that a few articles receive a very large number of citations, while the majority of documents are only cited infrequently or not at all (Van Leeuwen & Moed, 2005; Leydesdorff, 2008). This is still true if the infrequently cited document types shown in table 5.1 are excluded.

> [T]he distribution of journals according to citedness is extremely skewed, producing a straight line in a double-log plot. (Seglen, 1992, p. 630)

The large number of infrequently or uncited publications is referred to as the long tail of a Pareto or power-law distribution. Figure 5.2 and figure 5.3 show the distribution of citations among the most frequently cited documents per journal in the form of a double-logarithmic scale. Figure 5.2 reveals that Act Cryst A has the most skewed distribution of citations per document. While the first document is cited 6,653 times, the second most frequently cited article received only 107 citations within the analyzed time frame.

> Although the most cited articles constitute a minor fraction of the journals contents, they contribute heavily to the journal impact. (Seglen, 1992, p. 630)

Journal citation indicators seek to reflect the information about the citedness of a journal by one number. The differences in the citation distributions of the 45 journals hypothesizes that it might be a bold venture to capture all information in a single measure. Many bibliometricians have taken up the challenge of constructing such a metric. These approaches can be summarized as basic, weighted and normalized indicators aiming to reflect the citation performance of scholarly periodicals and are described in the following sections.

The differences in annual output (described in chapter 2) suggests the application of size-independent measures (Waltman & Van Eck, 2012). In order to measure the average citation impact of a journal, the obvious and most commonly used method is normalization by number of publications. In a normal distribution, mean and median are the same and provide information about the average item. The mean/median value occurs most often and 50% of all values are above and 50% below the average. In a normally distributed environment, the mean is thus a good representative of the majority of items in the set and for the overall average of the whole set (Calver & Bradley, 2009). For non-normal distributions, such as skewed citation distributions, the mean is not such a suitable metric because it does not reflect the characteristics of the majority of items in the set (Stock, 2009).

> [T]he mean is more sensitive than either the mode or the median to outlying values and therefore is not the best measure of central tendency for markedly non-normal distributions because it is biased by a few extreme values. (Calver & Bradley, 2009, p. 611)

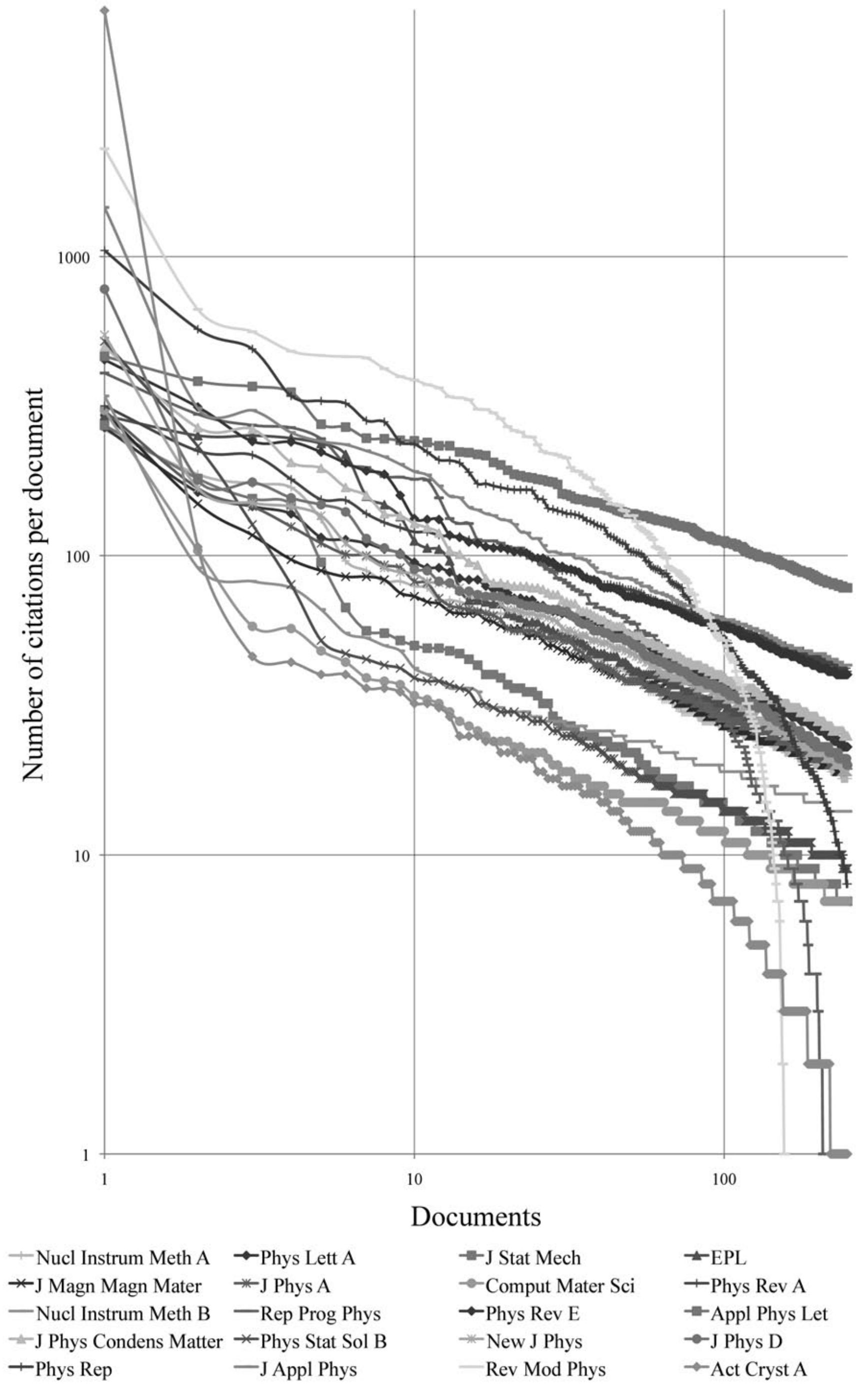

Figure 5.2 Log-log distribution of citations per document for the 250 most frequently cited articles, reviews and proceedings papers.

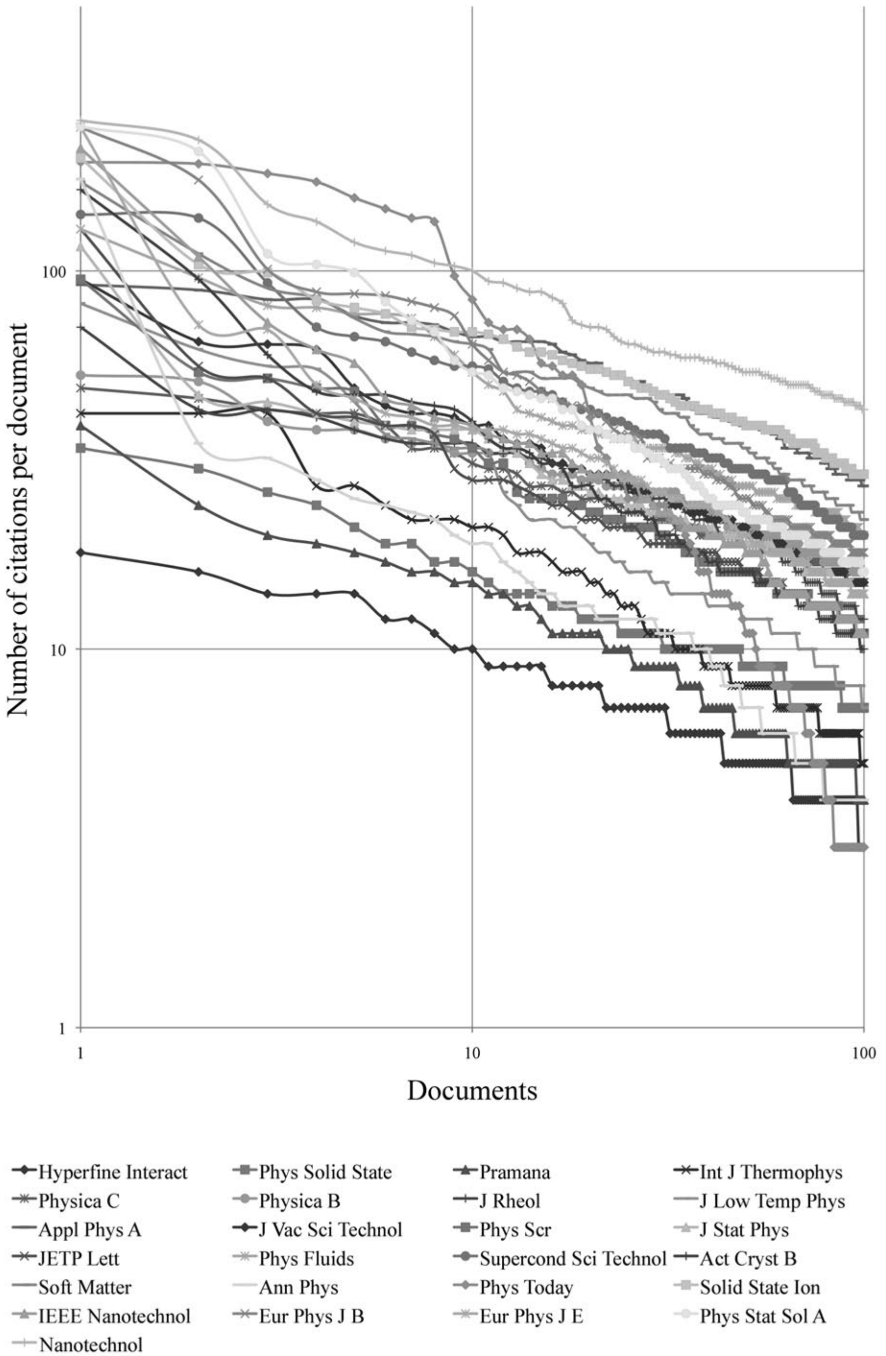

Figure 5.3 Log-log distribution of citations per document for the 75 most frequently cited articles, reviews and proceedings papers.

However, the mean is still the most commonly applied metric to represent the citation impact of authors, research groups, journals, countries and research fields, since it has not yet been replaced by a more suitable indicator. The best approach is thus to apply a set of different citation metrics in order to adequately represent all facets of the citation impact of scholarly journals.

5.1 Basic Indicators

Journal citation indicators are usually size-independent metrics which reflect the average citation impact of a periodical. The most common approach is to normalize for size by calculating the average number of citations per publication (*CPP*). Size-independent measures enable the comparison of small and large periodicals in terms of annual output. This is particularly why Eugene Garfield created the impact factor: to choose those journals with the highest citation impact regardless of journal output size (Garfield, 1972).

In general, journal citation metrics do not only vary in terms of their particular computational methods but apply different citation and publication windows or are limited to certain document types. While some indicators specify document types and exactly define publication and citation years, e.g. impact factor and immediacy index, others can be individually adjusted to those effects, entailing minor to major discrepancies.

As described above, the citation analysis of the 45 journals is limited to publications of the types of ‘article’, ‘proceedings paper’ and ‘review’ as classified in WoS. The number of citations per document were aggregated in July 2010, so that the citation window covers the period from publication up to that point. Although younger publications have a smaller probability of being cited than older ones, no artificial bias is created by limiting the citation window. The problem of choosing an adequate citation window is discussed below together with the impact factor.

Table 5.2 lists the number of documents *P* per journal and particular citation statistics, which aim to reflect the differences of the particular citation distributions shown in figure 5.2 and figure 5.3. High standard deviations and extreme differences between mean and median citation rate reveal the skewness of the citation distribution. In descending order by mean citation rate, the review journals head the list of 45 journals, which can be explained by the low uncitedness and high citation scores of review articles. The highest standard deviation and largest difference between mean and median can be observed for Act Cryst A. The journal provides an excellent example of skewed citation distributions and the impracticality of means to represent them. Garfield (1972) has addressed this particular problem:

> A journal may have published an article that has since been cited with extraordinary frequency. In such a case, a single article will have had an inordinate influence on the ranking of the journal. (Garfield, 1972, p. 473)

Table 5.2 The number of articles, proceedings papers and reviews (P) published between 2004 and 2008 with mean, standard deviation, median and maximum number of citations per document.

Journal	**P**	**Mean**	**Std. Dev.**	**Median**	**Max.**
Rev Mod Phys	160	131.2	213.08	72	2297
Phys Rep	318	55.6	90.42	27	1049
Rep Prog Phys	214	43.8	57.04	26	408
Act Cryst A	315	27.9	374.61	3	6653
Phys Today	218	13.9	33.58	2	194
Soft Matter	622	12.5	15.23	8	172
Appl Phys Let	25566	12.0	16.91	7	464
New J Phys	1925	10.1	18.40	5	547
J Rheol	336	10.0	9.56	7	71
Nanotechnol	4780	9.8	12.44	6	250
Phys Rev A	10588	9.6	12.60	6	317
Solid State Ion	2245	8.6	11.20	5	199
Phys Rev E	11754	8.4	12.64	5	452
EPL	3212	7.9	14.84	4	294
Eur Phys J E	677	7.9	12.38	5	240
IEEE Nanotechnol	505	7.6	13.61	4	211
Act Cryst B	484	7.5	11.55	5	164
J Appl Phys	17655	7.0	15.80	4	1461
J Stat Mech	928	6.9	15.15	3	273
Appl Phys A	2668	6.7	9.54	4	92
J Phys D	4469	6.5	15.78	3	779
Supercond Sci Technol	1658	6.5	9.78	4	141
J Phys Condens Matter	7219	6.1	12.38	3	500
Phys Lett A	5233	6.1	10.90	3	268
Phys Fluids	2566	5.6	7.87	3	129
Eur Phys J B	2027	5.5	10.39	3	240
J Phys A	5086	5.3	9.59	3	305
J Stat Phys	1021	5.2	7.59	3	116
J Vac Sci Technol A	1549	5.0	6.89	3	95
Ann Phys	264	4.9	11.91	2	175
Comput Mater Sci	1277	4.6	10.52	3	306
Phys Stat Sol A	2655	4.3	9.28	2	241
Nucl Instrum Meth A	7503	4.1	8.11	2	263
J Magn Magn Mater	7458	4.0	7.77	2	302
Phys Stat Sol B	2611	3.9	12.49	2	521
Nucl Instrum Meth B	5867	3.8	6.72	2	342
JETP Lett	1455	3.6	6.15	2	129
Physica B	5515	2.9	4.20	2	53
J Low Temp Phys	1233	2.9	5.57	1	82
Int J Thermophys	747	2.8	4.50	2	42
Physica C	3917	2.7	4.27	1	49
Phys Scr	2466	2.6	4.85	1	95
Phys Solid State	1963	2.0	2.78	1	34

*c*ontinued on next page

Journal	P	Mean	Std. Dev.	Median	Max.
Pramana	1216	1.4	2.71	0	39
Hyperfine Interact	986	1.2	2.07	0	18
All journals	163131	7.3	22.81	4	6653

When calculating a mean citation rate, one has to be aware of conflating the information about the actual number of citations per document to an average value for the whole journal. The total number of citations received by each of the documents are summed up and divided by the total number of documents, regardless of how many documents were actually cited and how many were not.

Merely one highly cited article is responsible for Act Cryst A's high citation rate and has caused the impact factor to increase 24-fold from 2.051 in 2008 to 49.926 in 2009 (figure 5.4). 4,893 of 5,966 citations received by Act Cryst A for items published in 2008 addressed Sheldrick (2008). The article describes the history and development of SHELX, a popular program used to analyze crystalline structures, and seems to be cited whenever the software is used. 3,300 of the 4,893 citations come from Act Cryst E. This has caused Act Cryst A to obtain the second highest impact factor in the 2009 and 2010 editions of the whole JCR, while it was ranked 2,118th of 6,620 in 2008. The impact factor thus implies that the scholarly impact of Act Cryst A as a journal has improved, when the extreme increase was caused by a single software review.

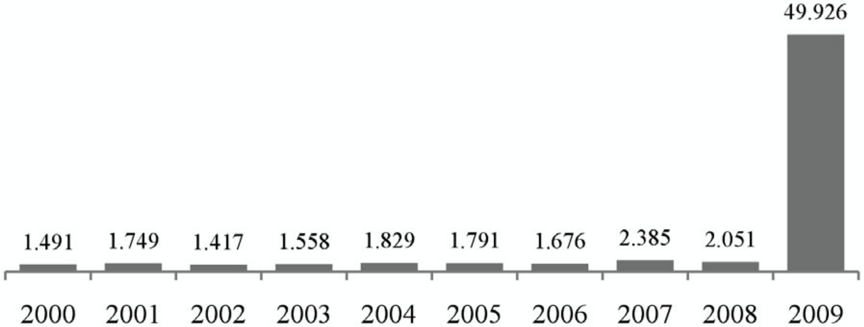

Figure 5.4 10-year trend of annual impact factors for Act Cryst A from 2000 to 2009. Source: JCR Science Editions 2000–2009

This shows that it is not sufficient to represent the standing of a scholarly journal by a single measure but that journal impact is multifaceted and should therefore be measured by a number of indicators (Glänzel & Moed, 2002; Rousseau, 2002; Coleman, 2007). Three types of citation indicators can be determined, namely basic, weighted and normalized journal measures. The basic indicators introduced in this section have in common that they are highly dependent on discipline-specific citation behavior and should thus be applied to a set of journals of the same scholarly field (Garfield, 1979; Todorov & Glänzel, 1988). Across-field comparisons are only possible if adequate normalization is applied. Normalized journal metrics are described in section 5.3.

5.1.1 Mean Citation Rates

Mean citation rates, such as the impact factor, normalize citation counts by the number of documents which received them in order to enable comparison of periodicals of different output size (Garfield, 1972). Citation rates differ in terms of length of their citation and publication windows and document types covered and whether they include or exclude self-citations. They can be calculated synchronously, i.e. citations received in one year for documents published during a range of previous years, or diachronously, considering documents published in one year being cited in several subsequent years (Todorov & Glänzel, 1988).

One major shortcoming of the common mean journal citation rates is that they are based on the arithmetic mean, which, as described above, is not a very suitable indicator for representing the average citation impact of a skewed distribution (Calver & Bradley, 2009; Stock, 2009). It has been suggested that the median is a more appropriate metric (Calver & Bradley, 2009), but since it ignores the most frequently cited document, it does not seem to be a suitable replacement alone either.

Due to differences of subject-specific citation characteristics, basic citation rates are not comparable across scholarly disciplines (Leydesdorff, 2008). Basic citation rates such as impact factor, immediacy index and SCImago cites per document should thus only be applied when comparing journals of one research area (Todorov & Glänzel, 1988; Glänzel & Moed, 2002).

Impact Factor

The impact factor was developed as a size-independent measure to compare journal impact for identifying and monitoring the most influential scientific periodicals:

> In view of the relation between size and citation frequency, it would seem desirable to discount the effect of size when using citation data to assess a journal's importance. We have attempted to do this by calculating a relative impact factor – that is, by dividing the number of times a journal has been cited by the number of articles it has published during some specific period of time. The journal impact factor will thus reflect an average citation rate per published article. (Garfield, 1972, p. 476)

Due to its simple comprehensibility and availability, the impact factor has become the most popular and most debated journal indicator used inside and outside the bibliometric community (Glänzel & Moed, 2002; Rousseau, 2002; Bar-Ilan, 2008).

> Because of its comprehensibility, robustness and its fast availability, the impact factor became very quickly popular and widely used. (Glänzel & Moed, 2002, p. 174)

Jacso (2009) highlights that, although criticism is justified, as pointed out below, the impact factor debate is often highly emotional outside the scientometric community. A large part of the debate takes place in biomedical journals.

The original impact factor has been computed by ISI and listed in Thomson Reuters' annual JCR since 1974 (Yanovsky, 1981; Magri & Solari, 1996) together with other journal citation metrics such as the total number of citations received, cited half-life (section 5.1.4) and (since the 2007 edition) Eigenfactor and article influence score (section 5.2.2).

The impact factor is a synchronous approach which evaluates the citations received in one year for documents published in the two previous years. The impact factor of journal j in year y is thus defined as:

$$IF_{j,y} = \frac{C_{jy-1,y} + C_{jy-2,y}}{P_{y-1} + P_{y-2}} \tag{5.1}$$

where $C_{jy-1,y}$ and $C_{jy-2,y}$ denote the number of citations received by journal j in year y to all documents published in the two previous years $y-1$ and $y-2$. Whereas P_{y-1} and P_{y-2} represent only those documents published in journal j in the years $y-1$ and $y-2$ which are defined as 'citable', i.e. articles, notes and reviews. Counting all citations received in the numerator while limiting the publication count in the denominator, leads to an asymmetry in the calculation of the metric (Moed & Van Leeuwen, 1995; Archambault & Larivière, 2009). Non-citable items are far from being uncited, thus they increase the numerator without increasing the denominator. As far as the calculation of the impact factor is concerned, non-citable items thus generate 'free' citations for the journal (Van Leeuwen & Moed, 2002; Moed, 2005; Moed & Van Leeuwen, 1996). This has lead journal editors to cultivate the publication of non-citable items such as letters or editorial material (Moed & Van Leeuwen, 1995; Stock, 2009). Moed et al. (1999) showed that free citations have caused the impact factor of the journal Lancet in 1992 to amount to 14.7 instead of a symmetric citation rate of articles, notes and reviews of 8.3. The publication of non-citable items has thus improved the outcome of Lancet's impact factor by 77%.

The reason for the asymmetry, i.e. counting all citations in the numerator, is basically a technical one:

> The impact factor's numerator is determined by counting in the total database cited references containing the name of a particular journal. The advantage of this procedure is that a reference to a journal paper is counted, even when it is inaccurate in the sense that it indicates an erroneous starting page number or first author. It is appropriate to count such an erroneous reference as the citing author intended to cite a particular paper in the journal. (Moed, 2005, p. 97 f.)

More accurate citation matching processes are needed to compute a symmetric version of the impact factor, where citations are directly matched to the cited document despite errors in the cited reference data. While today these problems can be solved by advanced algorithms, these possibilities were not available in the 1970s. The asymmetry between numerator and denominator is hence a relict from the first years of the JCR, which, however, has not yet been changed.

The presumably first definition of citable items in terms of journal indicator computation was provided by Martyn and Gilchrist (1968), who evaluated the citedness of British science journals in the 1965 edition of the SCI:

> What constitutes a citable item is a nice point, and we proceeded on an *ad hoc* basis, arguing that we were more interested for correction purposes in preserving the ratios between journal sizes than in achieving a pure and absolute accuracy based on a set of complex (but ultimately subjective) rules. [...] We counted what we loosely called 'papers', 'communications' and 'letters'. [...] Records of the counts of these three sorts of items were summed to provide the number of citable items per journal, for applying corrections to our figures of numbers of items cited. (Martyn & Gilchrist, 1968, p. 5)

Martyn and Gilchrist's ad-hoc definition was most likely adopted by Garfield, who cited the paper in Garfield (1972).

Another technical limitation of the impact factor calculation is the predefinition of the short publication and citation windows, which are derived from convenience and cost-efficiency decisions made in the 1960s and 1970s (Martyn & Gilchrist, 1968; Garfield, 1972). Garfield (1972) found that the majority of citations are received 2 years after publication. For some disciplines two years are too short, because the citation peak is reached later and citations are more evenly distributed over the years (Moed & Van Leeuwen, 1995; Moed, 2005). Glänzel and Moed (2002) showed that changes in rankings occur when citation windows are altered. Bensman, Smolinsky, and Pudovkin (2010) concluded that the 2-year impact factor produces completely false rankings for mathematics journals. Although it was known in the early days of the impact factor that by limiting the citation count to two years, a large part of citations would be missed, computational limitations outweighed other considerations. Even though those reasons do no longer apply today, the calculation of the impact factor has not changed from its introduction in the 1970s (Archambault & Larivière, 2009). It is still based on the number of citations received one and two years after publication. Citations received in the same year of publication or after two years are not visible in the indicator (Moed, 2005). To make some amends, an additional 5-year version of the impact factor is provided since the 2007 edition of the JCR (Jacso, 2009; Franceschet, 2010a). It covers the citations in year y to documents published in the years $y-1$ to $y-5$ (Bensman & Leydesdorff, 2009).

Theoretically an impact factor can be computed for any time frame based on any database or document type (Rousseau, 2002). For those journals not included in the WoS a 'quasi' or 'external' impact factor can be computed based on the citations from covered journals. In contrast to the regular impact factors, the external version, however, undervalues the periodicals for not including journal self-citations (Christensen, Ingwersen, & Wormell, 1997; Leydesdorff, 2008). Schlögl and Stock (2004) computed regional impact factors from the reference lists of a set of German library and information science journals, which were not included in any citation database. Todorov and Glänzel (1988) propose a diachronous version of a 5-year impact factor. Rousseau (2002) underlines that although they suffer the same shortcomings than their synchronous counterparts, diachronous versions make it possible to compute impact factors for single volumes or issues of journals or for books and conference proceedings. Although numerous improvements and alternatives have been proposed, the 2-year impact factor listed in the JCR is still defined in the same manner as at the time of its inception as a database management tool. Although it can be shown that its two major technical shortcomings are based on ad hoc definitions dating back to the 1960s and rooted in computational limitations, which do no longer apply, the methodology has not been changed.

The third shortcoming of the impact factor calculation, which is rather a methodological but a technical problem, is most likely the most profound. The average citation impact of a journal is approached by its arithmetic mean, which is not a suitable indicator for a non-normal distribution:

> The great variability in citedness within a journal has important implications for the significance attached to the journal impact factor. [...] The skewness of the journal article distributions shows that this premise does not hold true: only a minor fraction of the articles are cited anywhere near the journal mean. (Seglen, 1992, p. 631)

Colquhoun (2003) blames the ISI for its "unsound statistical practice of characterizing a distribution by its mean only" (Colquhoun, 2003, p. 479). If the mean is used to describe the average citation impact of a set of documents cited in a non-normally distributed way, one should consider complementary indicators able to characterize the distribution such as the highly citedness and uncitedness factor. The impact factor has also been criticized for not listing a standard deviation (Todorov & Glänzel, 1988), although this could easily be done and would indicate the skewness of the distribution of citations per document to a certain extent, as can be seen for Act Cryst A in table 5.2.

As the impact factor became a popular tool of journal evaluation, so did its misuse. Misuse of the impact factor can be divided into two categories, namely attempts by journal editors to influence the outcome of the metric and misapplication by bibliometric laymen for research evaluation purposes. Of the latter, the most common and widely applied form of abuse is that of measuring citation impact on the level of single articles, authors and groups of authors through the impact factor of the journals the particular documents were published in. This approach is often applied in the biomedical fields, where grant committees demand cumulative impact factors of applicants and researchers list 'personal' impact factors in their CVs. It is even reported that in certain countries, financial bonuses are awarded for publications in 'high-impact journals' (Adam, 2002; Rogers, 2002; Jones, 2003; G. D. Lundberg, 2003; The PLoS Medicine editors, 2006). The idea behind cumulative and personal impact factors for a set of documents is that journal impact factors are supposed to serve as an expected citation rate for the articles they contain. However, due to the underlying skewed distributions, the impact factor is not a good representative and thus predictor of actual document citations (Seglen, 1997; Moed, 2002).

> It is important to realize that the IF of a journal represents the citation frequency of the average published article and not a specific article. Accordingly, even if an article appears in Nature or Science, which are journals with high impact factors, this does not necessarily mean the article in question is later highly cited. In short, the articles determine the journalÕs citation rate and not vice versa. (Jones, 2003, p. 6)

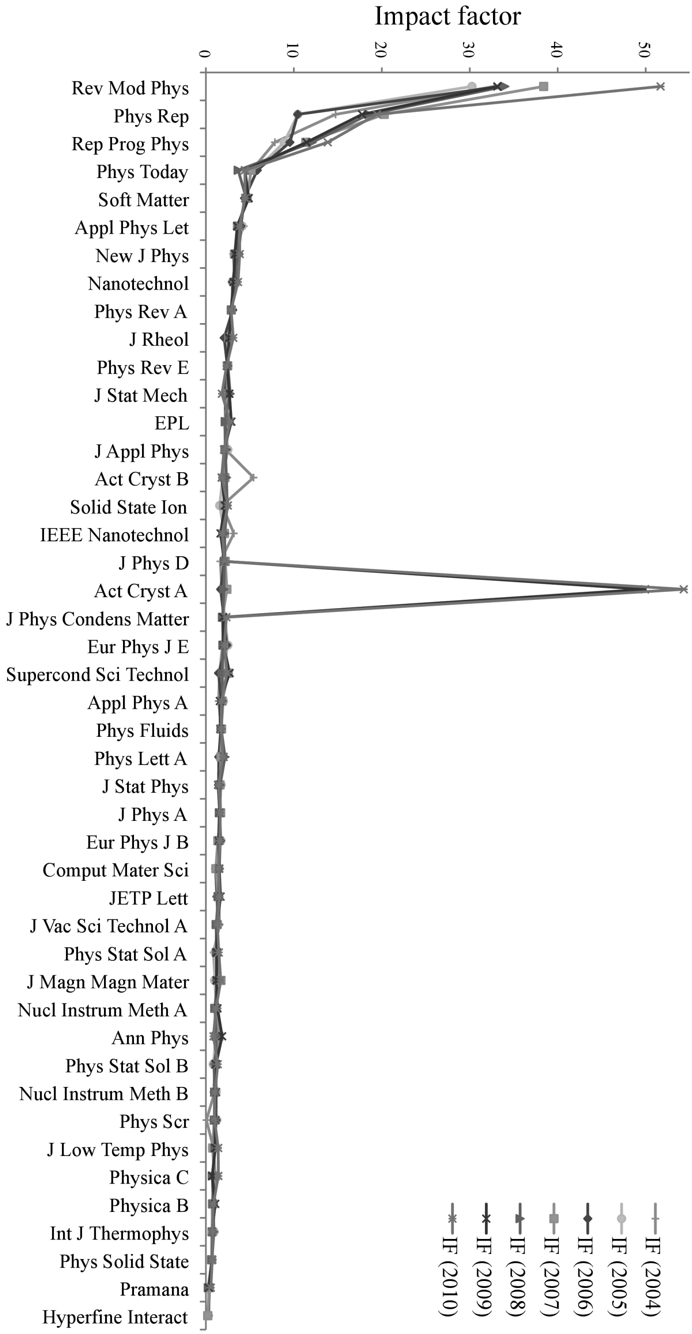

Figure 5.5 Impact factors (IF) for the years 2004 to 2010. Journals are ranked by the median value of all seven values.

For example, in the calculation of a cumulative impact factor, regardless of its actual citation rate, a publication in Act Cryst A would be assigned 49.926 impact points in 2009, although actual values between 0 and 6,653 occurred and only 0.6% of the papers had a citation rate above the impact factor (Opthof, 1997; Stock, 2009). An expected citation rate of 3 (median) would in fact be a more suitable predictor of citation impact for Act Cryst A papers.

> [T]he means may give a misleading impression of the citation performance of the bulk of each journal's papers because only a small minority of papers will reach or exceed the mean. (Calver & Bradley, 2009, p. 614)

Despite these deficiencies, the impact factor is still applied as a "cheap-and-cheerful" (Adam, 2002, p. 727) surrogate for actual citation rates of articles, authors and groups of authors because its is available at anytime – even at the time of publication, whereas actual citation can only be analyzed years after (Opthof, 1997) – and it is easily computable without any further knowledge of citation analysis (Adam, 2002). In a letter published in Nature, Colquhoun (2003) describes the misuse of impact factors in the evaluation of researchers as follows:

> Clearly it arises largely from laziness and poor homework on the part of senior scientists and bureaucrats (the dividing line is sometimes thin). It is amazing how unscientific some of them can be once outside their own narrow field. Eugene Garfield, who invented the wretched impact factor, himself said that it is not appropriate for ranking individuals. Astonishingly, these facts are not known (or are ignored) by some selection committees. (Colquhoun, 2003, 479)

As long as journals are judged by their impact factors, editors will try to manipulate them. Rogers (2002) calls it the 'numbers game', editors of PLoS Medicine refer to it as the 'impact factor game' (The PLoS Medicine editors, 2006) and Favaloro (2008) even call it the 'impact factor wars'. The abuse of the impact factor by journal editors appears in two forms, i.e. increasing the share of non-citable items on the one hand and the number of journal self-citations on the other (Seglen, 1997). As soon as the asymmetry caused by the discrepancy between citations received and items cited was known, editors started to cultivate the publication of documents regarded as non-citable items (Campanario & Gonzalez, 2006; Chew, Villanueva, & Van Der Weyden, 2007). By doing so, they increased the impact factor by decreasing the number of citable items in the denominator (Moed & Van Leeuwen, 1995). Another trend is to publish longer articles, especially reviews, to increase the average number of citations per document. The second kind of manipulation utilized by journal editors is boosting the number of journal self-citations (Yu & Wang, 2007). During peer review, authors are asked to enlarge their reference lists with publications from the journal (Hemmingsson, Mygind, Skjennald, & Edgren, 2002). Thus, the impact factor of the journal can be increased by increasing the numerator (Whitehouse, 2001; Rogers, 2002; The PLoS Medicine editors, 2006; Craig & Ferguson, 2009; Krell, 2010).

To some extent, the technical, methodological and abuse-related shortcomings can be observed in the impact factor values of the 45 journals which are described in the following. An extreme example of the methodological impracticability of the impact factor for representing the average citation impact of skewed citation distribution has already been provided above by Act Cryst A (figure 5.4). One extremely frequently cited article led to a 24-fold increase in the journal's impact factor. This is also reflected in the annual impact factor rankings shown in figure 5.5, which shows the annual impact factors from 2004 to 2010. Journals are ranked according to the median impact factor values of the seven years, so that the ranking represents the overall journal impact between 2004 and 2010. Large annual deviations affecting the particular rankings can be seen for Act Cryst A, Act Cryst B, Ann Phys, IEEE Nanotechnol and Supercond Sci Technol, where the highest and lowest rank differ at least by 15 positions. For example, Act Cryst A was ranked 23rd out of 45 in 2006 but first in 2009 and 2010, while Act Cryst B had the fourth highest impact factor in 2004 and was ranked 23rd in 2009.

Table 5.3 lists the particular impact factor values for the years 2004 to 2009 and the 5-year impact factor from 2009, which covers the citations received in 2009 by the documents under analysis published between 2004 and 2008. The impact factor was not available for all years for Hyperfine Interact, J Stat Mech and Soft Matter. While the latter two were only added to the JCR in 2005 and 2006 in accordance with their founding years (see figure 6.1) in section 6.1.1, Hyperfine Interact was excluded from the JCR due to its too low citation impact. The periodicals in table 5.3 are ranked in descending order according to their median impact factor values of the six years to obtain a ranking which reflects the overall journal impact between 2004 and 2009.

Table 5.3 Impact factors (IF) (2004 to 2009) and 5-year impact factor (2009) for the 45 journals. Journals are sorted in descending order according to the median of the annual impact factor values between 2004 and 2009.

Journal	IF_{2004}	IF_{2005}	IF_{2006}	IF_{2007}	IF_{2008}	IF_{2009}	5-year IF_{2009}
Rev Mod Phys	32.771	30.254	33.508	38.403	33.985	33.145	41.344
Phys Rep	14.742	10.458	10.438	20.263	18.522	17.752	17.334
Rep Prog Phys	7.842	8.893	9.549	11.366	12.090	11.444	13.355
Phys Today	5.211	5.685	5.839	5.133	3.674	4.437	4.876
Soft Matter	n/a	n/a	4.391	4.703	4.586	4.869	5.415
Appl Phys Let	4.308	4.127	3.977	3.596	3.726	3.554	3.780
New J Phys	3.095	3.585	3.754	3.264	3.440	3.312	3.438
Nanotechnol	3.322	2.993	3.037	3.310	3.446	3.137	3.574
Phys Rev A	2.902	2.997	3.047	2.893	2.908	2.866	2.895
J Rheol	2.525	2.423	2.082	2.602	2.676	2.646	2.973
Phys Rev E	2.352	2.418	2.438	2.483	2.508	2.400	2.603
J Stat Mech	n/a	2.273	2.185	2.418	2.758	2.670	2.782
J Appl Phys	2.255	2.498	2.316	2.171	2.201	2.072	2.278
EPL	2.120	2.237	2.229	2.206	2.203	2.893	2.463
Act Cryst B	5.418	1.910	2.172	2.163	2.341	1.801	2.033
IEEE Nanotechnol	3.176	2.112	1.909	2.110	2.154	1.671	2.190
Solid State Ion	1.862	1.571	2.190	2.012	2.425	2.162	2.741
J Phys D	1.642	1.957	2.077	2.200	2.104	2.083	2.305
Eur Phys J E	1.903	2.503	2.373	2.025	1.943	2.019	2.334
J Phys Condens Matter	2.049	2.145	2.038	1.886	1.900	1.964	2.024

continued on next page

Journal	IF_{2004}	IF_{2005}	IF_{2006}	IF_{2007}	IF_{2008}	IF_{2009}	5-year IF_{2009}
Act Cryst A	1.829	1.791	1.676	2.385	2.051	49.926	20.635
Supercond Sci Technol	1.556	1.896	1.440	2.547	1.847	2.694	1.828
Appl Phys A	1.452	1.990	1.739	1.857	1.884	1.595	1.813
Phys Fluids	1.761	1.728	1.697	1.780	1.738	1.638	2.056
Phys Lett A	1.454	1.550	1.468	1.711	2.174	2.009	2.013
J Stat Phys	1.747	1.729	1.437	1.605	1.621	1.390	1.574
J Phys A	1.504	1.566	1.577	1.680	1.540	1.577	1.572
Eur Phys J B	1.426	1.720	1.651	1.356	1.568	1.466	1.461
Comput Mater Sci	1.424	1.494	1.104	1.135	1.549	1.522	1.649
JETP Lett	1.455	1.446	1.251	1.378	1.418	1.662	1.339
J Vac Sci Technol A	1.557	1.399	1.394	1.278	1.173	1.297	1.338
Ann Phys	1.101	1.156	1.431	1.485	1.161	1.844	1.413
Phys Stat Sol A	0.880	1.041	1.221	1.214	1.205	1.228	1.246
J Magn Magn Mater	1.031	0.985	1.212	1.704	1.283	1.204	1.391
Nucl Instrum Meth A	1.349	1.224	1.185	1.114	1.019	1.317	1.228
Phys Scr	0.061	1.240	1.161	0.946	0.970	1.088	0.840
Phys Stat Sol B	0.982	0.836	0.967	1.071	1.166	1.150	1.134
Nucl Instrum Meth B	0.997	1.181	0.946	0.997	0.999	1.156	1.078
J Low Temp Phys	0.859	0.753	0.978	0.773	1.034	1.074	0.863
Physica C	1.072	0.948	0.792	1.079	0.740	0.723	0.662
Int J Thermophys	0.846	0.940	0.793	0.698	0.889	0.702	0.910
Physica B	0.679	0.796	0.872	0.751	0.822	1.056	0.932
Phys Solid State	0.724	0.699	0.690	0.650	0.682	0.721	0.658
Pramana	0.301	0.380	0.417	0.383	0.274	0.349	0.363
Hyperfine Interact	0.358	0.254	0.267	0.209	n/a	n/a	0.146

Effects caused by technical shortcomings can be discovered in the difference between the 5-year impact factor and the mean citation rate of articles, proceedings and reviews published between 2004 and 2008 (see table 5.2). As to be expected, Pearson's and Spearman's correlations of the two indicators for the 45 journals are extremely strong ($r = 0.967$, $\rho = 0.983$), since both indicators represent a mean citation rate. However, differences can be observed for individual journals. J Stat Mech is ranked seven ranks higher and Appl Phys Let five ranks lower by the 5-year impact factor than by the mean citation rate. This indicates that while Appl Phys Let's citation impact is well covered by the 2-year impact factor, J Stat Mech receives a significant number of citations after two years.

A great asymmetry between documents and citable items can be observed for Phys Today, of which only 218 of 1,780 publications are taken into account for the calculation of the 5-year impact factor. 20.5% of all citations included in the numerator of the 5-year impact factor are 'free citations'. The asymmetry caused by counting all citations on the one hand but only citable items on the other increases the impact factor by 25.8%.

The misuse by enlarging the number of journal self-citations to improve impact factor rankings is difficult to identify, since the share of journal self-citations depends on the degree of specialization of the journal. A value of $r = -0.379$ indicates that there is a low negative correlation between the percentage of self-citations and the

5-year impact factor. So in general, high impact factor values are not generated through journal self-citations but the citation impact comes from other sources. Journal self-citation rates are examined in section 5.1.5. Table 5.4 provides Pearson's r (lower half) and Spearman's ρ values (upper half of the matrix) for the impact factor, 5-year impact factor, number of documents (P) self-citation rate and the two distribution-based indicators uncitedness ($P_{uncited}$) and highly citedness ($P_{C\geq 25}$).

Table 5.4 Pearson correlation r (lower half) and Spearman rank order ρ (upper half) of number of articles, proceedings papers and reviews (P), mean citation rate (CPP), uncitedness ($P_{uncited}$), highly citedness ($P_{C\geq 25}$), self-citation rate, 5-year (5-year IF) and 2-year impact factor (IF).

	P	CPP	$P_{uncited}$	$P_{C\geq 25}$	self-citation	5-year IF_{2009}	IF_{2008}
P		−0.243	0.105	0.580**	0.571**	−0.239	−0.207
CPP	−0.145		−0.879**	0.578**	−0.288	0.983**	0.954**
$P_{uncited}$	−0.167	−0.401**		−0.638**	0.131	−0.861**	−0.870**
$P_{C\geq 25}$	0.875**	0.021	−0.304*		0.204	0.572**	0.608**
self citation	0.378*	−0.364*	0.068	0.204		−0.250	−0.234
5-year IF_{2009}	−0.163	0.967**	−0.388**	0.006	−0.379*		0.959**
IF_{2008}	−0.135	0.982**	−0.434**	0.037	−0.352*	0.913**	

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Immediacy Index

The immediacy index is a mean citation rate constructed in analogy to the impact factor with the only difference that the citation window is restricted to the year of publication. The immediacy index of journal j in year y is thus defined as:

$$II_{j,y} = \frac{C_{j,y}}{P_y} \tag{5.2}$$

where $C_{j,y}$ denotes the number of citations received by journal j in year y for all documents published in the same year and P_y stands for the number of articles and reviews published by journal j in year y. Through the one-sided restriction to citable items, the immediacy index suffers from the same asymmetry between the numerator and the denominator as the impact factor does. As an arithmetic mean, it is as unable to represent skewed citation distribution, which, in the year of publication, contains a particularly large share of uncited documents (Glänzel & Moed, 2002).

Since the immediacy index evaluates the number of citations received in the current year, the immediacy index is constructed and listed in the JCR as a supplement to the impact factor to measure the speed of citation impact or rapidity of a journal (Tomer, 1986; Todorov & Glänzel, 1988; Shin, 2004). In a study based on 39 journal indicators by Bollen, Van de Sompel, Hagberg, and Chute (2009) the immediacy index was the citation indicators, most closely related to usage-based metrics indicating their similarity in terms of rapidity. In scholarly communication, rapid transfer of information is crucial (Craig & Ferguson, 2009).

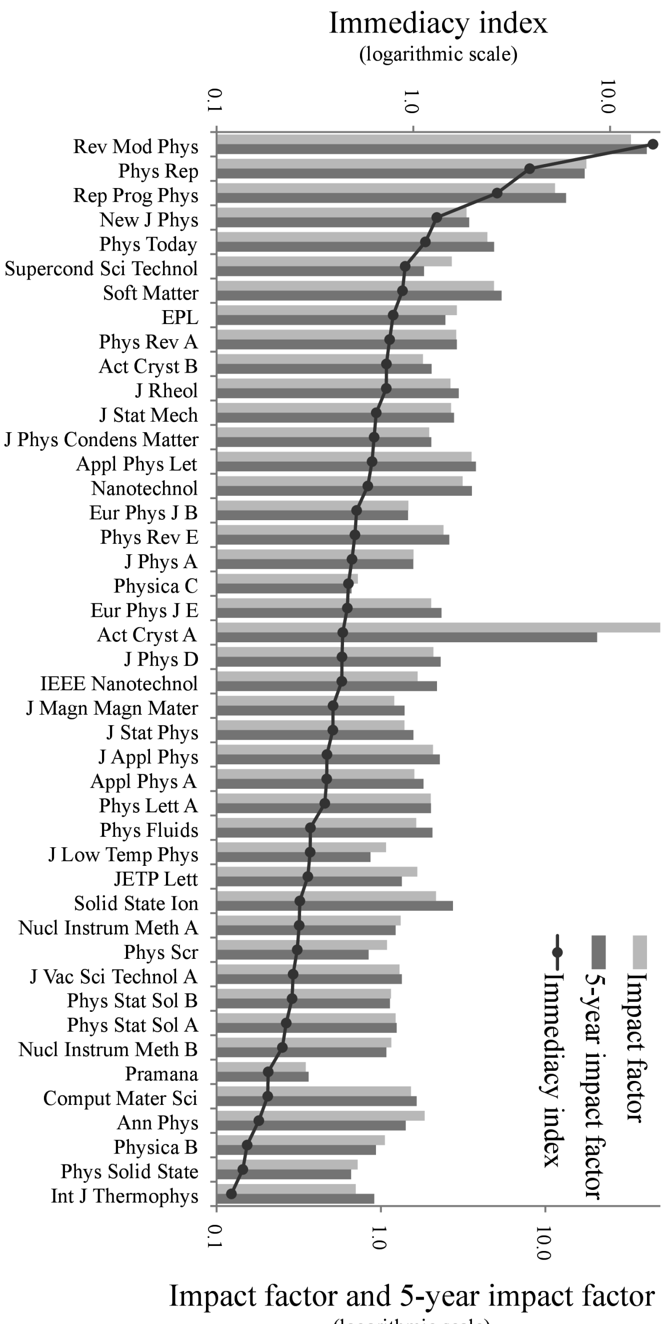

Figure 5.6 Immediacy index, impact factor and 5-year impact factor of 44 journals in 2009.

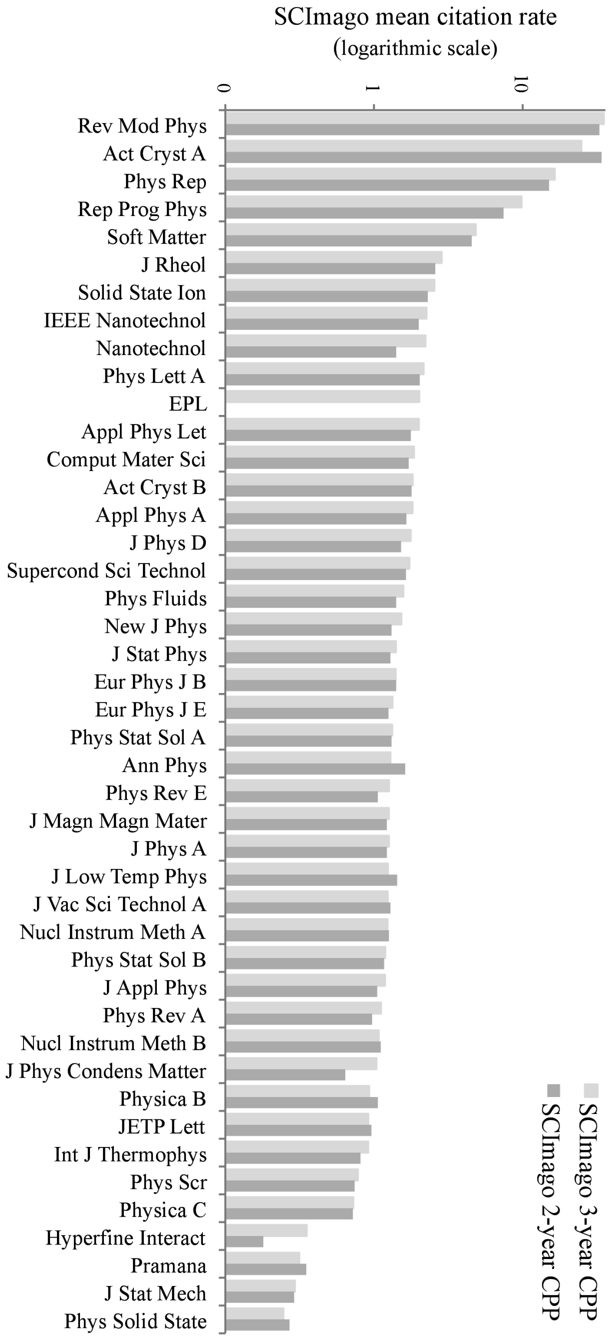

Figure 5.7 SCImago journal citation rate (*CPP*) for 44 journals in 2009 with a 2- and 3-year publication window.

The outcome of the immediacy index is, however, not only influenced by the rapidity of citation impact but also affected by the periodicity or publication frequency of scholarly journals (Todorov & Glänzel, 1988; Glänzel & Moed, 2002). Since the immediacy index does not measure how many citations are received within a year after publication but in the same calendar year, journals with weekly or monthly issues are able to collect a higher number of citations in the current year than a periodical that publishes only one or two issues annually (Tomer, 1986). Due to the publication lag (section 6.3.2), documents published in November or December are hardly ever cited in the current year. Those citation are not covered by the immediacy index (Andrés, 2009). Due to its additional shortcomings the indicator has not become as popular as the impact factor (Glänzel & Moed, 2002; Glänzel, 2009).

Shin (2004) explained an increase in the immediacy index values of educational journals between 1995 and 2003 through electronic publishing, which has sped up the process of scholarly publication. Articles are available online before actual publication so that the publication delay is shortened. Hence, the number of citations received by journals in the current year has increased. Schlögl and Gorraiz (2011) discovered the same trend for the immediacy indexes of pharmacology journals.

Figure 5.6 shows the immediacy index, impact factor and 5-year impact factor values for the 44 journals in 2009. Since the citing year is identical and only the publication windows differ, particular differences between the citation characteristics of the journals are revealed. Although Ann Phys has an impact factor and 5-year impact factor almost as high as Act Cryst B, its immediacy index is much lower. This indicates that documents published in Act Cryst B are more rapidly perceived by the scientific community.

SCImago Cites per Document

SCImago is a Spain-based research group responsible for the SCImago Journal and Country Rank portal[1] launched in December 2007. The SCImago portal provides a number of bibliometric indicators to rank the scholarly output and impact on the country and journal level based on Scopus publication and citation data (Butler, 2008). Like the JCR, the SCImago journal ranking lists a number of journal metrics and allows periodicals to be ranked by subject area. Besides the mean citation rate described in this section, the SCImago portal offers a weighted indicator, the SCImago journal rank described in section 5.2.3. Other than the WoS-based JCR, Scopus-based SCImago data can be accessed and downloaded free of charge.

The SCImago project computes a mean citation rate called SCImago cites per document. It is defined as

$$SCImago\ CPP_{j,y} = \frac{C_{P_{y-1},y} + C_{P_{y-2},y}}{P_{y-1} + P_{y-2}} \tag{5.3}$$

where $C_{P_{y-1},y}$ and $C_{P_{y-2},y}$ represent all citations of documents P (articles, conference papers and reviews) published in $y-1$ and $y-2$ received in y. The SCImago cites per document thus uses the same synchronous approach and publication and citation

1 http://www.scimagojr.com

windows as the impact factor but, since denominator and numerator are both limited to articles, proceedings and reviews, no asymmetry between citations and citable items occurs. Every citation that increases the numerator has a counterpart document in the denominator. Hence, so-called ‘free’ citations are avoided and manipulation of the indicator by editors through publication of non-citable items hindered. Besides the impact factor equivalent, the SCImago platform also lists the number of citable items published in the last three years and the total number of citations received in the current year. Thus it is also possible to compute a mean synchronous citation rate with a publication window of three years, which is used for the calculation of the SCImago journal rank as well.

Both the 2- and 3-year journal citation rates for the 44 journals[2] are shown in figure 5.7. Pearson’s r and Spearman’s ρ between the two metrics is 0.977 and 0.883, respectively. For most journals, the citation rate is higher with a longer publication window, indicating that a 2-year window does not suffice, since the peak of citations is reached later (Gonzalez-Pereira, Guerrero-Bote, & De Moya-Anegon, 2010). Large differences caused by choosing a different publication window can be observed for Act Cryst A, Nanotechnol, EPL, Ann Phys, J Phys Condens Matter and Hyperfine Interact.

5.1.2 Distribution-based Indicators

Another way to approach journal impact, other than by mean citation rates, is to compare the particular citation distributions. Aksnes (2004) suggests that the citation distribution should be analyzed instead of the average citation rate. Figure 5.8 shows a histogram of the percentage of documents per journal grouped into five categories of citation frequencies, i.e. uncited (0 citations), seldom (1–3), moderately (4–7), frequently (8–24) and highly cited (≥ 25) documents. The horizontal line marks the frequency distribution of the total of 163,131 articles, proceedings papers and reviews. Instead of reducing the number of citations received per article to a mean, the histogram provides information about the distribution of citations per document. It can be seen that the majority of papers published in Rev Mod Phys, Phys Rep and Rev Mod Phys are highly cited and that of Hyperfine Interact remain uncited. Phys Rep and Hyperfine Interact do, however, have the same percentage of documents with 4 to 7 citations. Act Cryst B remains below the average number of uncited and seldomly cited documents and has the largest share of moderately cited documents. This indicates that the articles published in Act Cryst B are reliable sources and play an important role in research.
The percentage of highly cited and the share of uncited papers are two indicators which provide information about the skewed citation distribution of the set of documents published in a journal (Seglen, 1992). Both metrics can serve as supplements to citation rates by identifying the share of journal articles that, on the one hand, receive a lot of attention and are cited frequently and those which are not visible at all, on the other (Todorov & Glänzel, 1988; Moed et al., 1999). A recent approach by Bornmann and Mutz (2011) does not only focus on the two extremes of the citation distribution but also tries to depict the whole citation curve through percentile ranks.

2 The SCImago platform does not include Phys Today.

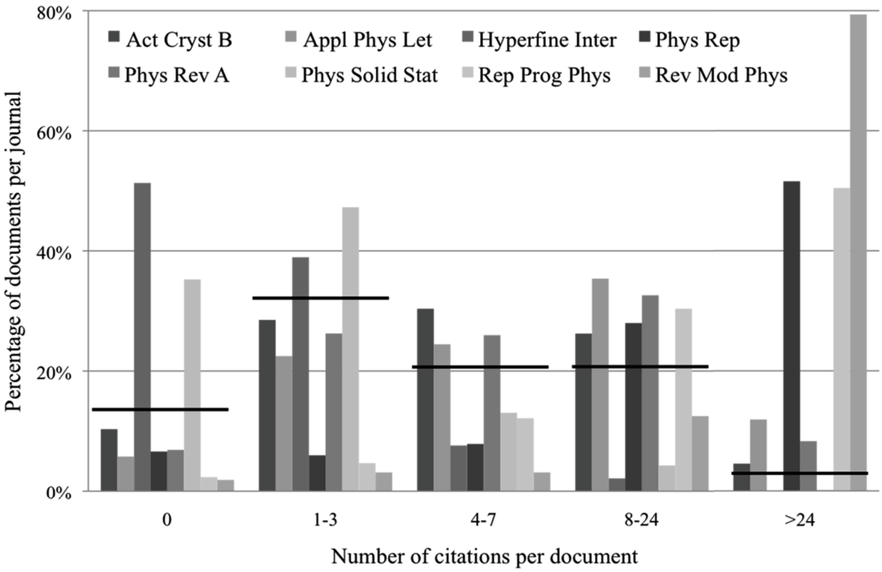

Figure 5.8 Different distributions of citations per document for eight journals. Documents are grouped into five classes, i.e. uncited (0 citations), seldom (1-3), moderately (4-7), frequently (8-24) and highly cited ($\geq$ 25) documents. The horizontal line marks the percentage distribution for all 163,131 articles, proceedings papers and reviews.

Highly Citedness

Another way to approach journal impact, other by mean citation rates, is its percentage of the most frequently cited papers. Since this identifies the most frequently cited documents published in a journal, highly citedness is rather a measure of excellence (Tijssen, Visser, & Van Leeuwen, 2002) than that of average citation impact and is able to identify reputable periodicals (Todorov & Glänzel, 1988). The indicator thus addresses a different aspect of journal citation frequency by focusing on the few most frequently cited documents rather than the average citation impact (Calver & Bradley, 2009).

> [S]cientific excellence ought to reveal itself in the upper tail of citation distribution functions, rather than the number of cited articles or average citation impact scores. (Tijssen et al., 2002, p. 386)

For a set of analyzed journals, all documents are ranked in descending order by number of citations. The top *n* papers are defined as highly cited. Van Leeuwen and Moed (2005) specify all papers with a citation rate above the mean, i.e. the journal's impact factor, as highly cited. Tijssen et al. (2002) uses the top 1% and top 10% of most frequently cited documents as an indicator of excellence. Due to the arbitrariness of the threshold, which separates highly cited publications from the rest, the percentage of highly cited publications suffers inconsistency problems similar to those of the h-index (Waltman & Van Eck, 2012), which are described in section 5.1.3. Other than the h-index, the percentage of highly cited papers is, however, independent of journal size due to normalization by the total number of documents published. Zitt, Ramanana-Rahary, and Bassecoulard (2005) showed that highly citedness depends on the definition of the benchmark of highly cited papers in terms of the breadth of the classification system. These issues are addressed in section 5.3

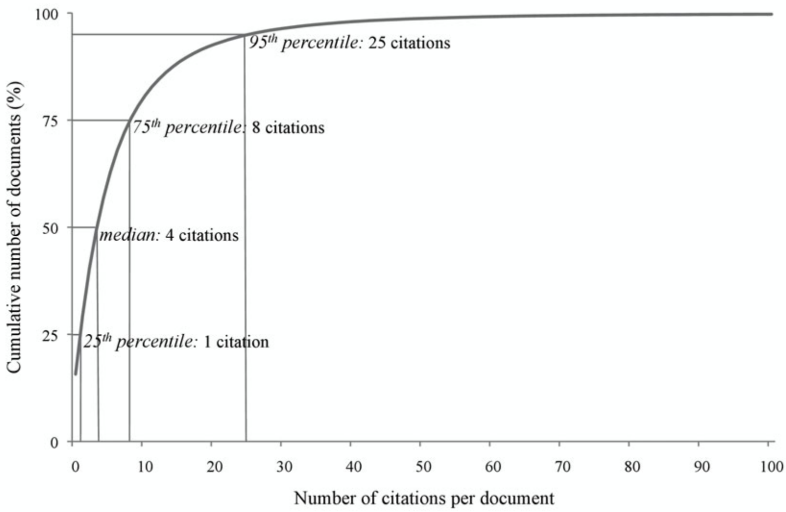

Figure 5.9 25th, 50th (median), 75th and 95th percentile of the cumulative distribution of the number of documents with a certain number of citations.

For the evaluation of the 45 journals, the 95th percentile of the citation distribution is used as a threshold to defining highly cited papers. For the 163,131 documents, the 95th percentile marks 25 citations per document, indicating that 5% of the documents were cited at least 25 times and 95% received citations below this value. In other words, all documents cited at least 25 times belong to the 5% most frequently cited papers. The distribution of number of citations per document and the distribution of the 25th, 50th, 75th and 95th percentile can be seen in figure 5.9. The highly citedness indicator is thus defined as

$$C_j^{max} = \frac{P_j^{C \geq 25}}{P_j} \tag{5.4}$$

where P_j are all documents published in journal j and $P_j^{C \geq 25}$ denotes the number of publications in journal j that received at least 25 citations. In order to determine the percentage of highly citedness of the 45 journals, the number of articles, proceedings papers and reviews with at least 25 citations is normalized by the total number documents published during the period under analysis. As to be expected, the three review journals, Rev Mod Phys, Phys Rep and Rep Prog Phys have the highest share of highly cited papers. Act Cryst A, which obtained the highest impact factor through one extremely frequently cited publication, is ranked 15th according to percentage of highly cited documents. This shows that this metric is not prone to extreme outliers as a mean citation rate is. It can thus provide additional information about the overall citation impact of the journal.

Table 5.5 Percentage of highly cited papers (C^{max}) among articles, proceedings papers and reviews for the 45 journals.

Journal	C^{max}	**Journal**	C^{max}
Rev Mod Phys	79.4%	J Phys Condens Matter	3.6%
Phys Rep	51.6%	J Phys A	2.9%
Rep Prog Phys	50.5%	Phys Fluids	2.6%
Soft Matter	13.5%	Eur Phys J B	2.5%
Phys Today	12.8%	J Stat Phys	2.4%
Appl Phys Let	11.9%	Ann Phys	1.9%
J Rheol	9.2%	Nucl Instrum Meth A	1.9%
New J Phys	8.7%	J Vac Sci Technol A	1.8%
Nanotechnol	8.6%	J Magn Magn Mater	1.7%
Phys Rev A	8.3%	Phys Stat Sol A	1.5%
Solid State Ion	6.9%	Comput Mater Sci	1.3%
Phys Rev E	6.0%	Phys Stat Sol B	1.3%
IEEE Nanotechnol	5.5%	JETP Lett	1.0%
EPL	5.1%	J Low Temp Phys	1.0%
Act Cryst A	5.1%	Nucl Instrum Meth B	0.7%
Eur Phys J E	5.0%	Phys Scr	0.7%
Appl Phys A	4.6%	Int J Thermophys	0.7%
Act Cryst B	4.5%	Physica B	0.6%
J Appl Phys	4.5%	Physica C	0.5%
Phys Lett A	4.3%	Phys Solid State	0.2%
J Phys D	4.2%	Pramana	0.1%
Supercond Sci Technol	4.1%	Hyperfine Interact	0.0%
J Stat Mech	4.1%		

Uncitedness

In the same way as the highly citedness indicator measures the excellence of a journal, the uncitedness or uncitedness factor (Van Leeuwen & Moed, 2005) is a metric representing the invisibility of a periodical. Uncitedness is the percentage of documents which have not received any citations during a certain period of time and measures overall citation response (Todorov & Glänzel, 1988; Van Leeuwen et al., 1999; Egghe, 2009). Moed et al. (1999) calculate the uncitedness factor with the same 2-year publication and 1-year citation window of the impact factor and found high negative correlations between the uncitedness and impact factor for 212 biochemical and molecular biology journals. Since the two indicators depend on one another, it is to be expected that, in general, high impact factor values imply low uncitedness and vice versa. There are, however, journals with a high share of uncited papers which have a high impact factor as well, due to the extreme high citation frequency of a limited number of documents (Moed et al., 1999). In these cases, distribution-based indicators, such as the percentage of highly cited and uncited documents, can be helpful supplementary metrics.

Although not being cited does not necessarily mean not being used (compare chapter 4), a high share of uncited papers indicates low visibility of the journal in terms of citation impact. Garfield (1998) found that among the world's leading scholarly journals, uncitedness is close to 0 and that it increases for low impact journals. Wallace, Larivière, and Gingras (2009) proved that the share of uncited publications has generally decreased over the last century for all disciplines due to publication growth and an increasing number of references per paper.

Table 5.6 Uncitedness ($P_{uncited}$) of articles, proceedings papers and reviews for the 45 journals.

Journal	$P_{uncited}$	**Journal**	$P_{uncited}$
Rev Mod Phys	1.9%	J Phys Condens Matter	17.1%
Rep Prog Phys	2.3%	J Vac Sci Technol A	17.8%
Soft Matter	3.2%	Phys Lett A	17.8%
J Rheol	4.5%	J Phys A	18.6%
Appl Phys Let	5.8%	Comput Mater Sci	18.6%
Nanotechnol	6.2%	J Stat Phys	18.8%
Phys Rep	6.6%	Nucl Instrum Meth B	19.7%
Phys Rev A	6.9%	Ann Phys	22.3%
Eur Phys J E	7.2%	Phys Stat Sol A	23.5%
New J Phys	7.4%	JETP Lett	24.6%
Solid State Ion	8.3%	Nucl Instrum Meth A	24.6%
Phys Rev E	8.4%	Phys Stat Sol B	25.0%
Act Cryst B	10.3%	J Magn Magn Mater	27.4%
EPL	10.6%	Physica B	28.1%
IEEE Nanotechnol	12.5%	J Low Temp Phys	29.4%
Appl Phys A	12.9%	Phys Today	30.7%
J Appl Phys	13.0%	Int J Thermophys	31.7%
J Stat Mech	13.7%	Physica C	33.0%
Phys Fluids	14.2%	Phys Solid State	35.3%
J Phys D	14.6%	Phys Scr	36.3%
Supercond Sci Technol	15.3%	Hyperfine Interact	51.3%
Eur Phys J B	16.4%	Pramana	52.0%
Act Cryst A	16.5%		
		all journals	15.7%

Uncitedness does not only differ between types of documents as described above, but varies from one journal to another as well. Van Leeuwen and Moed (2005) found that uncitedness was higher for journals publishing a comparably small number of publications. They found a high negative correlation ($r = -0.63$) between uncitedness and impact factors, which is to be expected, since a large number of uncited papers increase the denominator without adding to the numerator. Van Leeuwen et al. (1999)

found that a high negative correlation between impact factor and uncitedness remains even if uncited documents are removed from the set on which the impact factor is calculated. As shown in table 5.4, for the 45 journals analyzed, a low negative correlation was found between uncitedness and number of documents ($r = -0.167$) and a negative Pearson's value of uncitedness and 5-year impact factors ($r = -0.861$). Uncitedness values in 2010 for the articles, proceedings papers and reviews published between 2004 and 2008 are listed in table 5.6.

Although those types of documents not cited frequently were excluded from the citation analysis in this section, table 5.6 shows that 15.7% of all articles, proceedings papers and reviews still remain uncited. This is caused by the skewness of the citation distribution.

> The skewness implies that there will always be a large faction of uncited publications, the size of the fraction depending on the citation practices (such as the number of references per publication) within the field in question. (Seglen, 1992, p. 628)

As can be seen in table 5.6, the skewness of the distribution does not only vary between fields but also from one journal to another. While uncitedness is below 5% for Rev Mod Phys, Rep Prog Phys, Soft Matter and J Rheol, more than one third of Phys Solid State and Phys Scr papers and more than half of all documents published in Hyperfine Interact and Pramana are never cited. Since the latter four also have very low values of highly citedness, they can be regarded as journals of low scientific visibility. As a consequence of its low visibility and a continuous decrease of the impact factor, Hyperfine Interact was excluded from the JCR in 2008 and the WoS in 2009 after 32 years of being covered by the SCI.

Percentile Ranks

Bornmann and Mutz (2011) recently proposed using percentile ranks to indicate the citation distribution of a set of documents. In fact, highly citedness and uncitedness described above represent two particular percentiles, i.e. the 95th and 16th percentile. Thus they focus on the two extreme ends of the citation curve, while the approach by Bornmann and Mutz (2011) evaluates the whole citation distribution. It can be regarded as a kind of cited-side normalization (see section 5.3.1) because the actual number of documents per percentile are compared with the expected distribution. Leydesdorff, Bornmann, Mutz, and Opthof (2011) state that the number of percentiles chosen is normative. They propose using 6 or 100 percentiles. Figure 5.8 shows a similar approach. Documents are assigned to five pre-defined percentile ranks as well. Bornmann and Mutz (2011) and Leydesdorff et al. (2011) weight the publications according to their percentile rank instead of limiting themselves to a graphical method. If six percentiles are chosen, the publications in the lowest group are weighted with 1 and those in the most frequently cited group with 6. The highest score of 6 is reached if all the documents in the set belong to the percentile covering the highest number of citations per document. Rousseau (2005) introduced median and percentile impact factors as a normalized version of the impact factor.

5.1.3 H-index

The h-index, introduced by physicist Jorge E. Hirsch as a parameter to "quantify an individual's scientific research output" (Hirsch, 2005), has had an enormous impact on the scholarly community (Waltman & Van Eck, 2012) due to its attempt to reflect an author's publication output and citation impact with one simple metric. Hirsch (2005) defined the h-index of an author as follows:

> A scientist has index h if h of his or her N_p papers have at least h citations each and the other $(N_p - h)$ papers have $\leq h$ citations each. (Hirsch, 2005, p. 16569)

In other words, for the set of documents published by author *A*, ranked in descending order by number of citations received, h indicates the number of papers for which the number of citations is still higher or at least as high as the corresponding ranking position. This means that if author *A* has an h-index of 10, 10 of his papers were each cited at least 10 times. The set of documents from the first to the h^{th} position are called h-core documents. The h-index specifies neither the number of total publications nor citations, thus two authors with a completely different numbers of publications, citations and citation rates can have the same h-index. An extreme example is given in table 5.7.

Since this simple method of calculation can be applied to any set of papers, numerous variants of the h-index have been introduced. Bornmann, Mutz, Hug, and Daniel (2011) compiled a total of 37 variants. Braun, Glänzel, and Schubert (2005, 2006) applied the h-index to scientific journals:

> We suggest that an h-type index would be a useful supplement to journal impact factors. First, it is robust, i.ýe., insensitive to an accidental excess of uncited papers and also to one or several outstandingly highly cited papers. Second, it combines the effect of ÒquantityÓ (number of publications) and ÒqualityÓ (citation rate) in a rather specific, balanced way that should reduce the apparent ÒoverratingÓ of some small review journals. (Braun et al., 2006, p. 170)

According to Braun et al. (2006) the journal h-index should be limited to a definite period. For the 45 journals, the set of documents was limited to the five years under analysis and to articles, proceedings papers and reviews.

The particular advantage of the h-index as a journal metric is that it is, on the one hand, not influenced by outliers such as the Act Cryst A paper described above and, on the other hand, does not overestimate small review journals. For example, both Act Cryst A and JETP Lett have an h-index of 21, although the respective citation rates are 27.9 and 3.6. Due to the large number of papers published, Appl Phys Let has an h-index of 109, which is by far the highest value, although its mean citation rate is only 12.0. Differences of mean citation rates and h-index for the 45 journals are shown in figure 5.10, where *CPP* is plotted against and the h-index.

Table 5.7 Fictitious example of two authors *A* and *B* with an h-index of 5.

Author *A*		**Author** *B*	
P	20	*P*	10
C	323	*C*	25
CPP	16.15	*CPP*	2.5
h	5	*h*	5

Document	**Citations**	**Document**	**Citations**
Document 1	120	Document 1	7
Document 2	90	Document 2	7
Document 3	50	Document 3	6
Document 4	12	Document 4	5
Document 5	10	Document 5	5
Document 6	5	Document 6	0
Document 7	5	Document 7	0
Document 8	5	Document 8	0
Document 9	4	Document 9	0
Document 10	4	Document 10	0
Document 11	3		
Document 12	3		
Document 13	3		
Document 14	3		
Document 15	3		
Document 16	2		
Document 17	2		
Document 18	0		
Document 19	0		
Document 20	0		

The biggest drawback of this indicator is its dependence on size, i.e. a larger journal will have greater chances of a obtaining a large h-index, and above all its abnormal statistical behavior (Schubert & Glänzel, 2007). In a principal component analysis of several journal impact metrics, Leydesdorff (2009) found that the journal h-index combines the two components of output size and impact. Similar results were found by Bollen et al. (2009). He concluded that this has led to the popularity of the metric. However, exactly the combination of two factors is what makes the h-index so problematic.

> [T]he H-index may oversimplify the complexities involved because it tries to capture both orthogonal dimensions (size and impact) in a single indicator. (Leydesdorff, 2009, p. 117)

If one citation is added, the metric does not necessary increase. The h-index increases if, and only if, the particular document is cited that with additional citations will increase the h-core. In the fictitious example of table 5.7, document 6 of author A has to be cited once to increase the h-index from 5 to 6, while author B has to obtain at least one additional citation for documents 4 and 5 and six for document 6 to achieve the same increase of *h*. Thus, the h-index is inconsistent: if two entities gain the same number of citations, their h-index does not increase equally. Waltman and Van Eck (2012) summarize the inconsistency of the metric by proving that the h-index violates the following properties:

> If two scientists achieve the same relative performance improvement, their ranking relative to each other should remain unchanged. (Waltman & Van Eck, 2012)

> If two scientists achieve the same absolute performance improvement, their ranking relative to each other should remain unchanged. (Waltman & Van Eck, 2012)

> If scientist X_1 is ranked higher than scientist Y_1 and scientist X_2 is ranked higher than scientist Y_2, then a research group consisting of scientists X_1 and X_2 should be ranked higher than a research group consisting of scientists Y_1 and Y_2. (Waltman & Van Eck, 2012)

The same inconsistencies apply to the h-index if used as a journal indicator. For this reason, the h-index should be handled with care and is never to be used as a single metric to represent citation impact. Since it is size-dependent, the h-index favors periodicals with a large publication output.

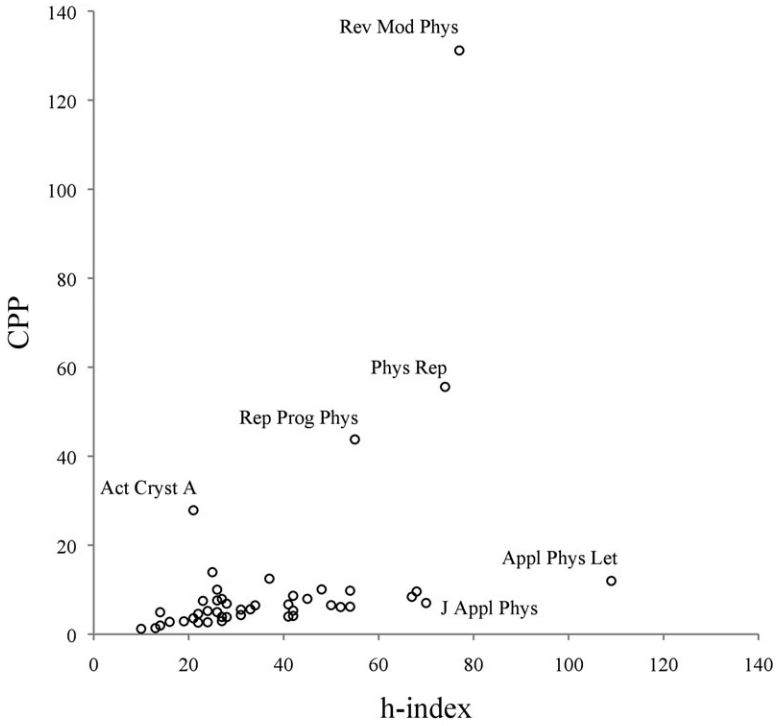

Figure 5.10 Correlation between citation rate (*CPP*) and h-index values for the 45 journals.

5.1.4 Time-based Indicators

The basic citation indicators described above examine the number of citations received by a set of documents at a certain point in time. The problem of choosing a suitable citation window has been addressed above. Time-based citation indicators analyze the distribution of citations received over a period time. They determine specific aging characteristics by examining the time when or for how long documents are used, i.e. cited.

> The distribution of citations over time is an indicator of the (percentage) change of information usage in time. Therefore, ageing processes (i.ýe. obsolescence) of scientific literature is assumed to be reflected by the change of information usage over time. (Glänzel & Schöpflin, 1995, p. 38 f.)

The time structure of citations received by a set of documents usually peaks some years after publication, after which usage steadily decreases indicating the obsolescence of the published content (Seglen, 1992). These structures do not only differ between scholarly fields but vary also from one journal to another (Moed, Van Leeuwen, & Reedijk, 1998). Through an analysis of such decay processes, particular characteristics and differences between the validity of journal content can be discovered (Glänzel & Schöpflin, 1995).

In analogy to the citing half-life introduced in section 2.1.5, the cited half-life analyzes the median age of citations received. The mean response time measures the average time between publication and first citation and thus the timeliness of journal reception (Glänzel & Moed, 2002). Time-based journal indicators can be divided into synchronous, such as citing half-life, and diachronous approaches, such as mean response time. While the former considers one citing year and analyzes the age distribution of the cited documents (constant user population), the latter is restricted to one year of publication and examines the citing documents (varying user population) (Moed et al., 1998).

Glänzel and Schöpflin (1995) differentiate between four types of aging structures reflecting the maturing and obsolescence patterns of journal content. Maturing and obsolescence patterns can be visualized in the form of so-called life-time curves of citations as shown in figure 5.11 and figure 5.12, where citations for documents published in 2004 are distributed by year. Type I is characterized by a short period of maturing, while the literature quickly becomes obsolete. The life-time curve of citations has a steep increasing slope, which peaks shortly after publication and is followed by a steep decline. J Low Temp Phys is an example of a type I journal. 5.6% of all citations of 2004 publications are obtained during the year of publication, an additional 18.4% in the first and 24.5% in the second year after publication. After that, the number of citations received decreases. Hyperfine Interact is a representative of type II indicating a long period of maturing followed by a short period of decline. The majority of citations are received in the fifth year after publication (22.0%). The type I and II distribution curves are generally more skewed because the rapid aging is indicated by a steep negative slope (Glänzel & Schöpflin, 1995). Type III describes a short period of maturing and a long decay. Phys Scr is an example of such an aging structure. Type IV indicates that both periods of maturing and decline stretch across a long period as can be observed in figure 5.12 for Phys Stat Sol A. Citations gradually increase up to the third year after publication, after which the number of citations received by 2004 documents steadily declines. Moed et al. (1998) define four additional types of aging structure in order to differentiate between very fast, fast, slow and very slow maturing and very fast, fast, slow and no decline.

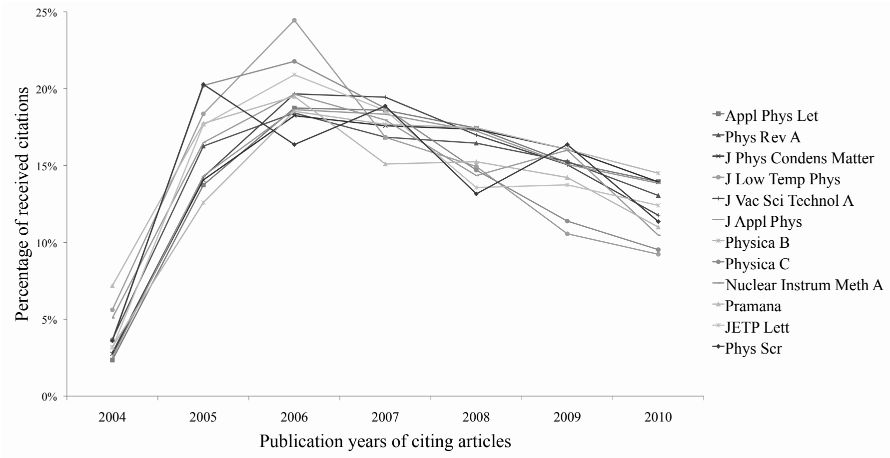

Figure 5.11 Annual distribution of publication years of citations to articles, proceedings papers and reviews published in 12 journals in 2004.

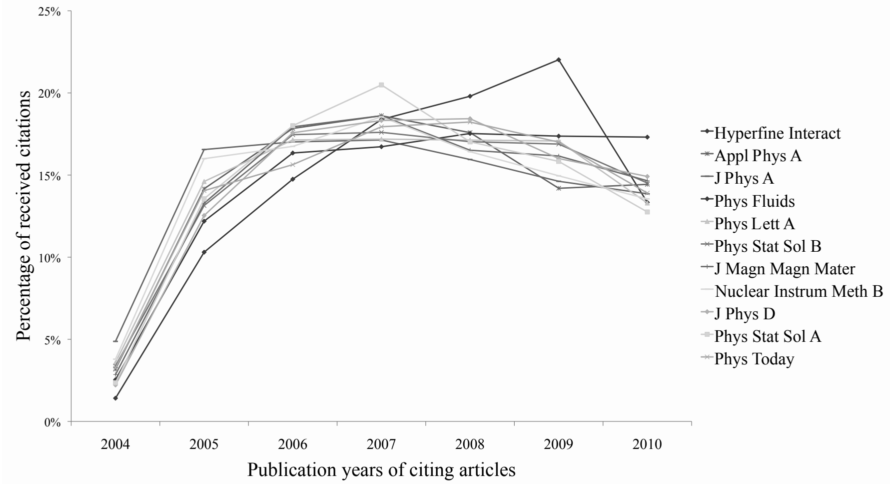

Figure 5.12 Annual distribution of publication years of citations to articles, proceedings papers and reviews published in 11 journals in 2004.

Cited Half-life

Literature half-life was introduced by Burton and Kebler (1960) in analogy to radioactive half-life (compare section 2.1.5). Cited half-life synchronously examines the age distribution of journal publications cited in a particular year. The indicator thus analyzes for how long the content of the particular journal is used.

Cited half-life is the median age of the cited articles and hence analyzes the time after which half of the journal content has become obsolete (Stock, 1980; Todorov & Glänzel, 1988). A long cited half-life indicates that documents published in a journal remain valid for a long time, a short half-life shows that they are quickly replaced by other content. Of course, cited half-life values are influenced by discipline-specific publication and citation behavior (Burton & Kebler, 1960; Craig & Ferguson, 2009). As mentioned by Stock (1980) and described in section 2.1.5, the decay process is not necessarily steady so that obsolescence patterns can be examined in greater detail by additionally determining the time after which 25%, 12.5% or 6.25% of the documents are still used.

Cited half-life values are listed in the JCR[3] as a supplement to the impact factor accounting for the differences in citation age distributions, i.e. indicating the extent to which the 2-year citation window of the impact factor is suitable (Moed, 2005).

The cited half-life $T_{\frac{1}{2}}^{\text{cited}}$ of journal j in the year t is thus defined as

$$T_{\frac{1}{2}}^{\text{cited}}(j,t) = y + \frac{(a-b)}{(c-b)} \tag{5.5}$$

where a is half of the number of citations received in year t, y is the number of years from t to the subcritical year, the year before the critical year, up to which half of all citations (a) were published. b is the accumulated number of citations published between t and the subcritical year and c is the accumulated number of citations published between t and the critical year.

Table 5.8 Cited half-life in 2010 and founding year of 45 journals.

Journal	Cited half-life	Founding year
J Low Temp Phys	>10	1969
J Stat Phys	>10	1969
JETP Lett	>10	1965
Phys Solid State	>10	1959
Phys Fluids	>10	1958
Act Cryst A	>10	1948
Act Cryst B	>10	1948
J Rheol	>10	1929
Rev Mod Phys	>10	1929
Ann Phys	>10	1790
J Vac Sci Technol A	9.9	1964
Phys Today	9.8	1948

continued on next page

3 http://admin-apps.isiknowledge.com/JCR/help/h_ctghl.htm#jcrnlc

Journal	Cited half-life	Founding year
Phys Scr	9.7	1970
Hyperfine Interact	9.4	1975
Phys Rep	9.4	1971
Solid State Ion	9.3	1980
Rep Prog Phys	8.9	1934
J Appl Phys	8.4	1931
Phys Rev A	8.4	1893
Int J Thermophys	8.3	1980
Phys Stat Sol A	8.3	1961
Phys Stat Sol B	8.0	1961
Phys Lett A	7.6	1962
J Phys A	7.5	1968
Physica C	7.3	1934
J Magn Magn Mater	6.9	1976
Pramana	6.9	1973
Nucl Instrum Meth B	6.8	1957
Physica B	6.8	1934
Phys Rev E	6.7	1993
Comput Mater Sci	6.6	1993
Nucl Instrum Meth A	6.5	1957
Eur Phys J B	6.3	1963
J Phys Condens Matter	6.2	1968
Appl Phys A	6.1	1973
EPL	5.8	1969
J Phys D	5.7	1968
Eur Phys J E	5.6	1963
Appl Phys Let	5.6	1962
IEEE Nanotechnol	4.3	2002
Supercond Sci Technol	3.8	1988
Nanotechnol	3.3	1990
J Stat Mech	2.9	2004
New J Phys	2.7	1999
Soft Matter	2.1	2005

Table 5.8 shows the 2010 cited half-life values for the 45 journals, i.e. the median age of documents cited in 2010. Since the JCR includes only the age distribution of the cited documents for ten years, a cited half-life of more than ten years cannot be determined based on this data. For 10 journals, i.e. Act Cryst A, Act Cryst B, Ann Phys, J Low Temp Phys, J Rheol, J Stat Phys, JETP Lett, Phys Fluids, Phys Solid State and Rev Mod Phys, the cited half-lives are longer than 10 years, indicating that their published contents remain relevant and valid for a long period of time. Since cited half-life values depend on the particular journal publication, the founding years of the journals are provided. The cited half-life does not correct for age differences of journals (Moed, 2005). Soft Matter has the lowest cited half-life of 2.1, but it was only founded in 2005, so that the oldest citable documents were no older than five years in 2010.

Todorov and Glänzel (1988) proposed to provide additional values such as a cited quarter-life to obtain further information about the aging patterns of journals. Moed et al. (1998) criticized the cited half-life because the metric does not consider the size of citable items. Since the number of past documents influences the number of citations analyzed by the cited half-life, it should normalize for the density of citable items published by the journal in past years. This is done in what Moed et al. (1998) introduce as corrected citation half life. Similar criticism has been expressed by Line (1970) and Abt (1998), who both argued that half-lives depend on the growth rate of the particular fields. Abt (1998) showed that high cited half-lives in astronomy can be explained by the extreme growth of the field because the chance of being cited has increased over the years. Egghe and Rousseau (2000) proved that literature obsolescence is influenced but not caused by the growth rates of scientific fields.

Mean Response Time

The mean response time is an indicator introduced by Schubert and Glänzel (1986) to reflect the speed of reception of journal content. It measures the length of the period between the publication of a document and the first citation received (Schubert & Glänzel, 1986; Todorov & Glänzel, 1988). In contrast to the cited half-life, the mean response time is a diachronous not a synchronous approach. This means that journal publications from one year are analyzed in terms of the annual distributions of citations obtained.

Figure 5.11 and figure 5.12 show these distributions for all articles, proceedings papers and reviews published in 2004 for the 23 of the 45 journals which were already part of Schubert and Glänzel's study. While figure 5.11 shows all journals that receive the most citations one (Phys Scr) or two (Appl Phys Let, J Appl Phys, JETP Lett, J Low Temp Phys, J Phys Condens Matter, J Vac Sci Technol A, Nucl Instrum Meth A, Physica B & C, Phys Rev A and Pramana) years after publication, figure 5.12 includes those where the peak of annual citations is reached three years after publication (Appl Phys A, J Magn Magn Mater, J Phys A, Phys Lett A, Phys Scr, Phys Stat Sol A & B and Nucl Instrum Meth B) or later (Hyperfine Interact, J Phys D, Phys Fluids and Phys Today).

Schubert and Glänzel (1986) calculated the mean response time for 109 physics journals, 22 of which match 23 of the periodicals included in the test set. Nucl Instrum Meth corresponds to today's Nucl Instrum Meth A & B, Appl Phys is the predecessor of Appl Phys A, J Phys C that of J Phys Condens Matter and J Vac Sci Technol that of J Vac Sci Technol A. For an overview of the journals' publication histories see section 6.1.1.

In Schubert and Glänzel's study, the publication year was 1979 and citations were limited to a 5-year window (1979–1983), arguing that papers that were not cited within 5 years after their publication would most likely not be cited at all. This is confirmed by the distribution of first citations of 2004 publications. For the 23 journals, the median percentage of first citations received in the same year is 19.0%. 38.5% received their first citation one, 15.1% two, 6.9% three and 4.0% four years after publication. In 2009 and 2010, i.e. five and six years after publication, only 2.0% and 1.3% of the 2004 documents received their initial citation.

The mean response time represents the average response time in years of all articles in a journal, taking into account the share of uncited papers, which have an infinite response time. In general, the mean response time is defined as an exponential average:

$$MRT_j = -\ln(n^{-1} \sum_{i-1}^{n} e^{-t_i}) \tag{5.6}$$

Schubert and Glänzel (1986) limited the citation window to five years, since each document not being cited after five years is expected not to be cited at all. For a citation window of five years, i.e. the year of publication and four subsequent years, the mean response time MRT of journal j is defined as

$$MRT_j = -\ln(f_0 + f_1\mathrm{e}^{-1} + f_2\mathrm{e}^{-2} + f_3\mathrm{e}^{-3} + f_4\mathrm{e}^{-4}) \tag{5.7}$$

where f_i is the share of documents that receive their first citation in the i^{th} year after publication. Documents which have not been cited after five years are regarded as uncited. As the negative logarithm $-\ln$ is the inverse function of e it balances the exponential weighting, so that the indicator is an exponential average. The lowest value of the indicator is 0 and it is reached if all documents are cited in the same year they were published. It is 1, if all documents are cited one year after publication, 2 if all documents are cited in the second year after publication and so on. Uncited papers increase the mean response time accordingly. Schubert and Glänzel (1986) defined journals with a mean response time below 1 as fast, those above as slow.

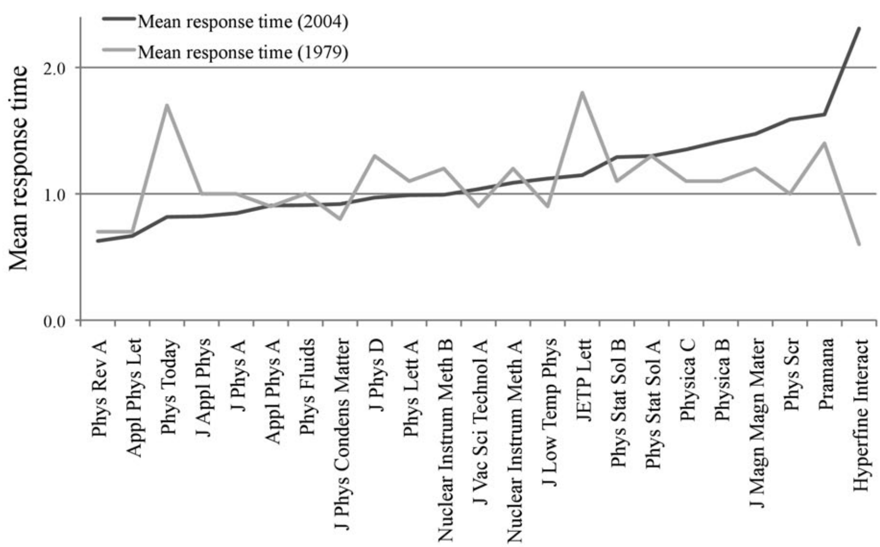

Figure 5.13 Annual distribution of publication years of citations of articles, proceedings papers and reviews published in 11 journals in 2004.

Due to the negative exponential weighting and the low fractions of documents receiving first citations after five years, the differences between a 5-year (2004–2008) and 7-year (2004–2010) citation window for the 23 journals can be disregarded, as can be seen in the mean response time calculation of Phys Rev A. Mean response time of Phys Rev A documents published in 2004 with a 5-year citation window:

$$\begin{aligned} MRT_{PhysRevA} &= -\ln(0.342+0.481\mathrm{e}^{-1}+0.098\mathrm{e}^{-2}+0.028\mathrm{e}^{-3}+0.012\mathrm{e}^{-4}) \\ &= 0.62683 \end{aligned} \tag{5.8}$$

Mean response time of Phys Rev A documents published in 2004 with a 7-year citation window:

$$\begin{aligned} MRT_{PhysRevA} &= -\ln(0.342+0.481\mathrm{e}^{-1}+0.098\mathrm{e}^{-2}+0.028\mathrm{e}^{-3}+0.012\mathrm{e}^{-4} \\ &\quad +0.005\mathrm{e}^{-5}+0\mathrm{e}^{-6}) \\ &= 0.62676 \end{aligned} \tag{5.9}$$

Figure 5.13 shows the particular mean response times for the 23 journals in 2004 and 1979. Large differences can be observed between Schubert and Glänzel's values and those 35 years later (Pearson's $r = -0.019$). Hyperfine Interact, which used to have the lowest response time of 0.6 in 1979, now has the highest value of 2.3, which is mostly due to a large percentage of documents (48.8%) that were never cited during the 5-year period. Phys Today and JETP Lett have notably improved their mean response time from 1979 to 2004. According to Schubert and Glänzel's rule of thumb, Phys Rev A, Appl Phys Let, Phys Today, J Appl Phys, Appl Phys A, Phys Fluids, J Phys Condens Matter, J Phys D, Phys Lett A and Nucl Instrum Meth B can be regarded as journals which are cited fast.

5.1.5 Citing Sources

Besides counting the number of citations, citation analysis can provide information about the recipients of journal content. A serial's citation image is shaped by the authors citing it (Bonnevie-Nebelong, 2006). In the same way that reference analysis examines a journal's knowledge import (section 2.1.5), citation analysis is able to shed light on knowledge export on the basis of citing authors (given that synonymy and homonymy problems are solved, compare section 2.2.1) and, if aggregated on higher levels, citing journals, countries and disciplines (Christensen & Ingwersen, 1996; Wormell, 1998; Bonnevie, 2003; Yue & Wilson, 2004). In the following, citations are analyzed in detail on the level of citing journals.

On the journal level, the citing journals and the distribution of citations among them can be examined. Citations received in 2008 are analyzed in detail for the 45 periodicals. Citation data is extracted from the 2008 edition of the JCR. For that reason, citation results in this section are not limited to articles, proceedings papers and reviews but count all citations as listed in the JCR. The number of different citing journals are listed in table 5.9 as J_{citing}. At 10,517 unique serials, Phys Rev A is the journal with the largest number of citing journals in 2008, which is partly due to the high number of citations and publications and the broad scope of the journal (section 6.1.3). J Stat

Mech, which is focused on a more specific topic, exports its knowledge to only 216 journals.

The self-citation rate of a journal analyzes the share of citations from articles published in the journal itself (Bonnevie, 2003). Although journal self-citations are part of the scholarly communication process, a high self-citation rate mirrors a certain degree of isolation of the journal in its citation environment, which indicates low visibility either due to specialization or unimportance (Rousseau, 2002; Bonnevie-Nebelong, 2006).

Table 5.9 Number of citing journals J_{citing}, self-citation rate and journal diffusion factor (JDF) for the 45 journals in 2008. (Data is based on the 2008 edition of the JCR. Since Hyperfine Interact was excluded from the database in 2008, data from the 2007 edition was used instead.)

Journal	J_{citing}	**Self-citation rate**	JDF
Rev Mod Phys	1540	0.4%	0.06
Rep Prog Phys	987	0.5%	0.13
Phys Rep	983	0.8%	0.06
Phys Today	843	1.0%	0.25
Ann Phys	519	2.5%	0.23
Act Cryst A	688	2.9%	0.06
Phys Stat Sol A	713	3.0%	0.09
Act Cryst B	678	3.4%	0.07
IEEE Nanotechnol	323	3.7%	0.22
EPL	1046	3.8%	0.07
Phys Stat Sol B	641	4.5%	0.09
Eur Phys J B	832	4.6%	0.14
Appl Phys A	952	5.1%	0.10
Physica B	840	5.2%	0.08
J Vac Sci Technol A	672	5.3%	0.09
New J Phys	619	5.6%	0.10
Eur Phys J E	418	5.7%	0.16
JETP Lett	467	5.9%	0.08
Comput Mater Sci	619	6.6%	0.15
Pramana	325	7.3%	0.31
Hyperfine Interact*	295	7.3%	0.20
J Stat Phys	687	7.5%	0.11
Phys Scr	628	7.7%	0.13
J Phys Condens Matter	902	8.4%	0.03
Soft Matter	328	9.2%	0.18
Phys Lett A	2266	9.4%	0.09
J Magn Magn Mater	943	9.6%	0.05
Nanotechnol	1152	9.7%	0.07
Phys Fluids	990	10.2%	0.06
J Rheol	464	10.5%	0.11
J Appl Phys	2106	10.8%	0.02
Appl Phys Let	1362	11.0%	0.01
J Phys D	1351	11.4%	0.07

continued on next page

Journal	J_{citing}	**Self-citation rate**	JDF
Solid State Ion	702	12.1%	0.04
Int J Thermophys	354	12.7%	0.21
J Low Temp Phys	290	13.1%	0.10
J Stat Mech	217	13.6%	0.11
J Phys A	1038	15.1%	0.06
Phys Solid State	457	16.4%	0.09
Physica C	395	16.6%	0.05
Nucl Instrum Meth A	868	16.7%	0.05
Phys Rev E	2286	17.0%	0.04
Nucl Instrum Meth B	1078	19.4%	0.07
Phys Rev A	10517	23.7%	0.14
Supercond Sci Technol	267	23.9%	0.07

2008 journal self-citation rates are listed in table 5.9. For the 45 periodicals, median and mean self-citation rate are 7.7% and 8.9%, respectively. The lowest self-citation rates, and thus high visibility, are obtained by the review journals Rev Mod Phys, Rep Prog Phys and Phys Rep, which is to be expected, since review journals frequently cite research articles and not the review papers they publish themselves. Todorov and Glänzel (1988) stated that self-citation rates of review journals are negligible. The highest self-citation value of 23.9% is reached by Supercond Sci Technol, which indicates a certain degree of isolation. Phys Rev A represents an exception since it has a high rejection rate of 23.7% but at the same time reaches a large number of periodicals.

The Pearson correlation between the number of unique citing journals and number of citations received is 0.448. This shows that a high number of citations does not necessarily imply a wide diffusion of knowledge into the scientific community, and vice versa low citation counts do not mean that the journal cannot be received by a relatively large audience (Rowlands, 2002). For example, Appl Phys Let and J Phys D are cited by 1,362 and 1,351 unique journals in 2008, respectively, although J Phys D received only one tenth the number of citations. The ratio of citing journals and received citations is described by the journal diffusion factor, which, similar to the citations/citee-ratio described in section 2.1.5, measures the breadth of a journal's knowledge export (Rowlands, 2002). The journal diffusion factor JDF of journal j is defined as

$$JDF_j = \frac{J_{citing}}{C_j} \tag{5.10}$$

where J_{citing} denotes the number of unique journals citing journal j and C_j represents the number of citations received by j. Theoretically, the highest value of the journal diffusion factor is 1, which is reached if each citation comes from another journal (Rowlands, 2002).

According to the journal diffusion factor, J Phys D reaches out further into the community than Appl Phys Let, which, at 0.01, has the lowest value of all 45 journals. The highest journal diffusion factor of 0.31 is reached by Pramana, which is cited 1,050 times by 325 journals. This shows that the journal diffusion factor is an indicator measuring the journal's reach into the community, but due to its size independence, i.e. a high diffusion value can be reached with a low number of citations, it should be used together with the number of citing journals or citations. The calculation of the journal diffusion factor can, of course, involve citation and publication windows of several years and can be constructed synchronously or diachronously (Frandsen, 2004). Frandsen, Rousseau, and Rowlands (2006) altered the diffusion factor by counting only new citing journals, i.e. journals that have not cited the particular periodical earlier in the citation window under analysis, and Frandsen (2004) used division by number of publications instead of citations.

Figure 5.14 Citation network of 45 journals and most frequently citing journals in 2008. Includes those journals which account for more than 3% of all citations received in 2008. The 45 cited journals are represented by the darker nodes.

Figure 5.14 shows a 2-mode network graph of the journals citing the 45 journals most frequently in 2008. Included are all periodicals which contribute at least 3% of the total number of citations received by the particular journal in 2008. Self-citations are indicated by loops. Of course, all journals cite themselves to a certain extent, however, only self-citation rates above 3% are shown. The 45 journals are represented by the dark nodes.

Differences between knowledge import and export of the 45 journals can be observed, if figure 5.14 is compared to figure 2.7 in section 2.1.5. While the reference network is more centralized around Phys Rev Lett and Phys Rev B, the citation network is less dense. Phys Rev B has a central position in both networks, indicating that it is not only cited by but also cites the 45 journals frequently. It can thus be regarded as a central node within the scholarly communication network.

Phys Rev Lett is the most important knowledge importer but does not cite the 45 journals that often. The network also shows a larger number of separate components than the reference network. In the former, Act Cryst A and B were connected through the largest component, whereas in the latter they are isolated in a cluster containing their sister journals Act Cryst C and E and Inorg Chem. 30.2% of all citations Act Cryst A received in 2008 come from Act Cryst E, which is a rapidly publishing open-access journal. Each of Int J Thermophys, Solid State Ion and Nucl Instrum Meth A and B are isolated as well: they are not frequently cited by any of the other 45 journals. Nucl Instrum Meth B is especially isolated. Although it is cited by 1,078 unique periodicals in 2008, none of these reaches the 3% threshold applied in figure 5.14. Its isolation is confirmed by a high self-citation rate of 19.4%. Phys Rev E is the most important citing source among the 45 journals. However, the isolation of Solid State Ion indicated by a self-citation rate of 23.9% is not confirmed by the network structure, because the journal is frequently cited by Physica C, Phys Rev B, J Appl Phys and IEEE T Appl Supercon as well.

5.2 Weighted Indicators

In contrast to the basic journal indicators described above, weighted metrics factor in the importance of citing sources instead of limiting citation impact to the sheer number of citations received. Bollen, Rodriguez, and Van de Sompel (2006) introduced Googles PageRank (Brin & Page, 1998) into journal evaluation by proposing to calculate weighted impact factors based on the search engine algorithm, so that citations from more prestigous journals weigh more than those from unimportant sources. The Eigenfactor metrics (West, 2010) and the SCImago journal rank (Gonzalez-Pereira et al., 2010) use similar weighting methods.

Although these iteratively weighted indicators are often attributed to the PageRank algorithm, the groundwork in weighted journal indicators was established by Pinski and Narin (1976) in the form of the influence weight (Leydesdorff, 2009). All these metrics are based on the eigenvector centrality developed by Bonacich (1972). Bonacich aimed at identifying the importance of a person's social status in a circle of friends by analyzing their reciprocal connections in the network. In an iterative process, the eigenvector centrality determines the influence of a node through its ingoing connections to all other nodes in the network. Bonacich (1972) described the idea behind the iterative weighting algorithm as follows:

> A simple measure of the popularity is just the number of friends each person has. It might be desired to create second order indices of popularity by weighting each person's choice of others by the number of choices he receives. But there is no reason to stop at this point. If the second order indices are better than the first order indices (the number of friends), then third order indices in which each person's choice of others is weighted by his second order measure of popularity should be even better. (Bonacich, 1972, p. 114)

While in the calculation of unweighted measures, a citation from a low-impact journal counts as much as that from a prestigious one and a citation from a highly-cited article weighs the same as being cited by a document which has never been cited by anyone, weighted measurements try to solve this injustice by allocating different weights to citations (Bollen, Van de Sompel, & Rodriguez, 2008; Craig & Ferguson, 2009; Franceschet, 2010a). Weighted journal indicators based on eigenvector centrality do not rely on simple citation counts as the basic indicators described in section 5.1, but weight citations according to the prestige of the citing sources through a recursive weighting process (Gonzalez-Pereira et al., 2010; Waltman & Van Eck, 2010b).

The first weighted journal indicator was introduced by Pinski and Narin (1976). Their influence weight, the Eigenfactor measures and the SCImago journal rank are described in the following. Besides these eigenvector-based metrics, traditional social network measures such as degree, closeness and betweenness centrality, which determine the prestige of an actor through his connectedness in the network structure have been proposed to determine journal impact. For example, Leydesdorff (2007), Bollen et al. (2008) and Leydesdorff (2009) used indegree, outdegree, closeness and betweenness centrality in terms of citing and cited journals to measure journal impact. Bollen et al. (2006) applied the PageRank algorithm and proposed the Y-factor which is the product of a journal's PageRank and impact factor to determine 'journal status'.

5.2.1 Influence Weight and Influence per Publication

Pinski and Narin (1976) were the first ones to transfer the eigenvector centrality approach to journal impact measures. They addressed the problem of previous journal indicators, which count each citation equally and disregard differences between citing sources. Their influence weight and influence per publication indicators aimed at assigning weights to citations based on the citation impact of the citing journal. With respect to the citation network in figure 5.14, being cited by Solid State Ion has less weight than being cited by Phys Rev B. In a recursive manner based on the eigenvector approach, citations from important sources which themselves have been cited frequently by important sources, carry more weight than citations from sources with less citation impact (Glänzel & Moed, 2002; Moed, 2005).

In line with Bonacich (1972), Pinski and Narin (1976) argue:

> It seems more reasonable to give higher weight to a citation from a prestigious journal than to a citation from a peripheral one. (Pinski & Narin, 1976, p. 298)

They define the influence weight IW of journal i ($i = 1, \ldots, n$) as follows:

$$IW_i = \frac{\sum_j IW_j C_{ji}}{S_i} \tag{5.11}$$

where C_{ji} is the number of citations from journal j to journal i which are weighted by the influence weight of journal j. To accommodate for differences in the length of reference lists, the sum of the weighted citations is normalized by all referenced S by i to all other journals in the network. The influence weight is thus a kind of input-output indicator. The influence weights are normalized to equal 1 in a

> self-consistent 'bootstrap' set of relations, in which each unit plays a role in determining the weights of every other unit. (Pinski & Narin, 1976, p. 300)

As a sum of all weighted received citations divided by the number of cited references, the influence weight is thus an average of weights per citation not per article (Waltman & Van Eck, 2010b). To obtain a size-independent journal indicator, the influence per publication measure is introduced as the influence weight divided by the number of published articles. Geller (1978) proposed further improvements (Todorov, 1984).

Table 5.10 Influence weight and influence per publication for 16 of the 45 journals in 1973. Source: Pinski and Narin (1976, p. 305 ff.)

Journal	**Influence weight**	**Influence per publication**
Rev Mod Phys	2.10	245.8
Rep Prog Phys	0.27	31.6
Phys Rev	1.42	26.4
Ann Phys	1.95	17.2
Phys Fluids	1.39	13.9
J Appl Phys	1.23	13.9
Appl Phys Let	1.89	13.6
JETP Lett	1.25	12.2
Physica	0.85	11.1
J Phys	0.59	7.7
Phys Today	0.41	7.0
Nucl Instrum	0.65	5.7
J Vac Sci Technol	0.42	5.7
J Low Temp Phys	0.22	4.0
Phys Stat Sol	0.31	3.7
Phys Scr	0.17	2.8

The values of influence weight and its variant, the influence per publication indicator from Pinski and Narin (1976), are shown in table 5.10. It can be seen that the review journals, Rev Mod Phys and Rep Prog Phys, have the highest score in the output-normalized ranking.

5.2.2 Eigenfactor and Article Influence Score

The Eigenfactor metrics were developed by Jenvin D. West and Carl T. Bergstrom in 2007 (Bergstrom, 2007; Bergstrom & West, 2008). 'Eigenfactor' is an amalgamation of the two words eigenvector centrality, i.e. the computational method it is based on, and impact factor, the indicator it seeks to improve (West, 2010). Since 2009, Eigenfactor and article influence score have been listed in the JCR (Franceschet, 2010b; Jacso, 2010).

Inspired by the success of Google's PageRank (Brin & Page, 1998; Bergstrom, 2007; Craig & Ferguson, 2009), they took up the approach of Bonacich (1972) and Pinski and Narin (1976) and, in a recursive method, weight citations received by a journal according to the citation impact of the citing journal (Bollen et al., 2009).

While the Eigenfactor score represents the absolute weighted impact and is thus a measurement depending on the size of the journal, the article influence score normalizes by the number of documents published by the journal and is hence a size-independent indicator (Bergstrom, 2007; Franceschet, 2010b).

The Eigenfactor metrics are based on a citation window of one year and a publication window of five years (West, Bergstrom, & Bergstrom, 2010b). Citations in year y of documents published during the five previous years $y-1$ to $y-5$ are analyzed. Eigenfactor and article influence are thus synchronous journal indicators with the same citation and publication window of a 5-year impact factor except that journal self-citations are omitted for methodological and practical reasons:

> We ignore self-citations for several reasons. First, we want to avoid over-inflating journals that engage in the practice of opportunistic self-citation and to minimize the incentive that our measure provides for such practice. Second, we do not have self-citation information for the journals not listed in the JCR. Considering self-citations for JCR-listed but not non-listed journals would systematically overvalue the journals in the former set relative to the latter. Third, if self-citations are included, some small journals with unusual citation patterns appear as nearly-dangling nodes, and this can bias their Eigenfactor scores upward.[4]

Like the PageRank algorithm used by Google, the Eigenfactor uses a parameter, a so-called damping factor, of $\alpha = 0.85$ to weight citations in an iterative manner. For a citation network containing n journals, the Eigenfactor EF of journal i ($i = 1, \ldots, n$) is defined as

$$EF_i(\alpha) = 100 \sum_j \frac{p_j C_{ji}}{S_j} \tag{5.12}$$

where C_{ji} is the number of citation from j to i, S_j stands for the total number of cited references of i and p_i ($p_1, \ldots, p_n$) is a weighting factor obtained for each journal i defined as

$$p_i = \alpha \sum_j \frac{p_j C_{ji}}{S_j} + (1-\alpha) \frac{P_i}{\sum_j P_j} \tag{5.13}$$

where C_{ji} is the number of citations from journal j to i, which are multiplied by the weight p of j and divided by the total number of cited references S_j. P_i denotes all documents published by journal i during the years $y-1$ to $y-5$, which is normalized by the total number of documents published by all n journals in the network during the 5-year period. In accordance to the random walker or random surfer model of PageRank (Brin & Page, 1998), the Eigenfactor score can be regarded as an estimate of the time spent with a journal by a reader, who starts reading a random paper and continuously selects the new papers from the reference list of the previous one (Stock, 2009). The Eigenfactor is thus the time the random researcher spents with a particular journal based on the probability of being accessed through the reference lists of other documents (Bergstrom, 2007). The journal's prestige is hence based on the connectedness of its articles in the entire citation network (Bergstrom, West, & Wiseman, 2008; West, 2010; West et al., 2010b).

4 http://Eigenfactor.org/methods.pdf

As the influence per publication ratio by Pinski and Narin (1976) accounts for journal size in contrast to the influence weight, the article influence score was developed to define an average Eigenfactor per article. It is hence defined as the sum of all weighted citations received in year y divided by the number of documents published in journal i between $y-1$ and $y-5$:

$$AI_i(\alpha) = 0.01 \frac{EF_i(\alpha)}{P_i} \tag{5.14}$$

Waltman and Van Eck (2010b) prove that if the parameter α is 1, it is proportional, and thus the same as the influence per publication indicator, i.e. the size-independent variant of Pinski's and Narin's influence weight. If α equals 0, the article influence score is proportional to the audience factor described in section 5.3.2.

Figure 5.15 shows the 5-year impact factor and article influence score of the journals, which are both based on the citations received in 2009 by documents published between 2004 and 2008. Except for the difference that the article influence score excludes journal self-citation, the two metrics are based on exactly the same data and Pearson correlation is strong ($r = 0.983$).

A Spearman correlation of $\rho = 0.96$ was found between 5-year impact factor and article influence for 6,598 journals listed in the 2007 science and 1,980 in the social science edition of the JCR (Franceschet, 2010a). Jacso (2010) compared 52 library and information science journals in terms of impact factor and Eigenfactor metrics and discovered significant differences in the ranking position of individual periodicals. He also discovered some errors in the Eigenfactor data. Elkins, Maher, Herbert, Moseley, and Sherrington (2010) found strong correlations between article influence and impact factor as well, although the ranking differed extremely for individual journals. In a visualization of the differences between article influence and impact factor and Eigenfactor and total number of citations for medical journals, West, Bergstrom, and Bergstrom (2010a) showed that despite a high correlation coefficient ($\rho = 0.955$), these can be extreme, especially for low to medium-ranked journals. West et al. (2010b) visualize the same differences for economic journals. The same can also be observed for individual titles in the set of 45 periodicals: Act Cryst A is ranked much lower by the article influence score than by the 5-year impact factor. This means that citations received by Act Cryst A carry less weight than those by Phys Rep and Rep Prog Phys. A large proportion of Act Cryst A's citations in 2009 come from Act Cryst E, which has a rather low Eigenfactor score of 0.01583, while the serials contributing most citations to Phys Rep's and Rep Prog Phys's 5-year impact factors in 2009 score higher (Phys Rep: $EF_{PhysRevD} = 0.33534$, $EF_{PhysRevE} = 0.24890$; Rep Prog Phys: $EF_{PhysRevB} = 0.76892$, $EF_{PhysRevA} = 0.23892$). J Stat Phys's citation impact is relatively high based on article influence in comparison to the 5-year impact factor. In the particular rankings of the 44 journals, it is ranked 15$^{\text{th}}$ and 27$^{\text{th}}$, respectively.

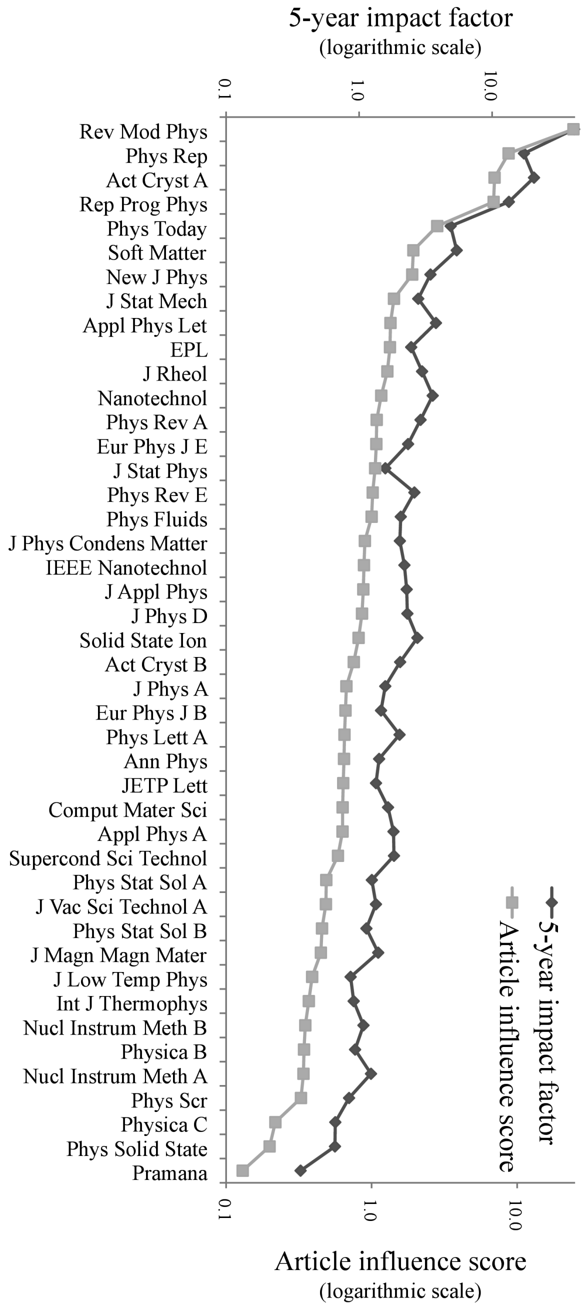

Figure 5.15 Logarithmic representation of the 2009 values of 5-year impact factor and article influence score for 44 journals. Hyperfine Interact is not included in the 2009 edition of the JCR.

5.2.3 SCImago Journal Rank

As described in section 5.1.1, SCImago is a journal portal[5] similar to the JCR based on Scopus (Craig & Ferguson, 2009). It is hosted by a Spanish bibliometrics research group and since December 2007 has provided annual journal rankings from 1999 free of charge (Butler, 2008). In addition to basic metrics such as the SCImago cites per document and journal h-index, the platform provides the SCImago journal rank indicator (SCImago Research Group, 2007; Falagas, Kouranos, Arencibia-Jorge, & Karageorgopoulos, 2008; Jain, 2008).

As the impact factor and Eigenfactor metrics, the SCImago journal rank is a synchronous citation rate with a 3-year publication and one year citation window. Three years were chosen as the best compromise between the obsolescence patterns of various fields. SCImago journal rank is based on citations received in year y of documents published in the three previous years $y-1$, $y-2$ and $y-3$. As the influence weight and Eigenfactor metrics, the SCImago journal rank weighting is based on eigenvector centrality and thus takes into account the prestige of the citing sources (Falagas et al., 2008; Siebelt et al., 2010). Citing sources are assigned a specific score, thus the value of a citation is based on the prestige of the citing source:

> The essential idea underlying the application of these arguments to the evaluation of scholarly journals is to assign weights to bibliographic citations based on the importance of the journals that issued them, so that citations issued by more important journals will be more valuable than those issued by less important ones. This "importance" will be computed recursively, i.ýe., the important journals will be those which in turn receive many citations from other important journals. (Gonzalez-Pereira et al., 2010, p. 379 f.)

Other than the Eigenfactor metrics, the SCImago journal rank is limited to specific document types, namely articles, proceedings papers and reviews (i.e. those identified above as the most frequently cited ones) and to a certain extent allows journal self-citations. The self-citation rate is limited to 33%, "so that excessive self-citation will not involve artificially inflating a journals value, but without touching the normal process of self-citation" (Gonzalez-Pereira et al., 2010, p. 390). Since the document type limitation applies to citing and cited documents alike, an asymmetry between numerator and denominator, such as that affecting the impact factor, is prevented. This particular framework makes the SCImago journal rank a more mature weighted journal indicator than the Eigenfactor and article influence metrics.

In an iterative process, prestige values are calculated by taking the whole citation network into account. Three factors influence the calculation of the impact weight *PSJR*, namely a constant depending on the size of the database, the share of documents published by the particular journal in contrast to the total number of documents and, most profoundly, the weighted citations. The iterative weighting process of the *PSJR* results in a total weight of citations received in year y, which is divided by the number of documents published in the years $y-1$ to $y-3$. The SCImago journal rank is a size-independent indicator normalizing the weighted *PSJR* value by the publication output of the journal. The *PSJR* can be compared to the size-dependent influence

5 http://www.scimagojr.com

weight and Eigenfactor while the *SJR* applies the same normalization as the influence per publication indicator and the article influence score.

The SCImago journal rank of journal i is defined as:

$$SJR_i = c\frac{PSJR_i}{P_i} \tag{5.15}$$

where P_i denotes the number of articles, proceedings papers and reviews published in journal i in the three years $y-1$ to $y-3$, c is a constant increasing the value to "obtain an easy-to-use SJR indicator value"[6] and the *PSJR* of i represents the weighted citations received by these documents in year y. It is defined as follows:

$$PSJR_i = \frac{1-d-e}{n} + e\frac{P_i}{\sum_{j=1}^{n} P_j} + d(\sum_{j=1}^{n} C_{ji}\frac{PSJR}{C_j}CF + \frac{P_i}{\sum_{j=1}^{n} P_j} + \sum_{K\in DN} PSJR_k) \tag{5.16}$$

PSJR is a citation weight indicator, which can be divided into three parts, each representing different aspects of journal prestige. In the first step of the calculations, the same value of $\frac{1-d-e}{n}$ is assigned to each journal i in the database. n simply represents the number of different journals included and d and e are constants used to weigh the specific influence of the three parts of the indicator. These constants can thus be regarded as the damping factor applied in the PageRank and the Eigenfactor metrics ($\alpha = 0.85$). The second fraction is based on the specific weight of publication output of journal i in comparison to the whole database. P_i denotes the number of articles, proceedings papers and reviews published in journal i in the three years $y-1$ to $y-3$, while $\sum_{j=1}^{n} P_j$ represents the number of documents published by all journals in the database in the same period. Since the first two fractions of the equation depend only on the number of journals and documents in the database, their values remain constant in each step of the iterative calculation process (Gonzalez-Pereira et al., 2010).

In the calculation of *PSJR*, the constants are set to $d = 0.9$ and $e = 0.0999$, so that together the first two parts of the indicator account for 10% of the value, while the third part makes up 90%. The latter defines the weight of the citations received by journal i in year y. For each citation C_{ji} from journal j to journal i a particular weight is assigned. This weight is based on the SCImago journal rank of journal j divided by the number of total citations from journal j. This indicates that the weight transferred from journal j to journal i depends on the number of journals to which the prestige of journal j is transferred. *CF* represents a correction factor which accounts for the number of citations from journal j that went to documents outside the analyzed publication window of $y-1$ to $y-3$ so that the entire citation weight of journal j can be assigned and no prestige is lost. The second half of the third part of the *PSJR*, which is the numerator of the *SJR*, takes into account so-called 'dangling nodes'. Dangling nodes are journals which during the period analyzed do not cite any other journals and thus have only incoming and no outgoing connections. $\sum_{K\in DN} PSJR_k$ accounts for these journals and distributes their prestige values among the other journals in the database in proportion to their number of documents through multiplying by $\frac{P_i}{\sum_{j=1}^{N} P_j}$.

6 http://arxiv.org/ftp/arxiv/papers/0912/0912.4141.pdf

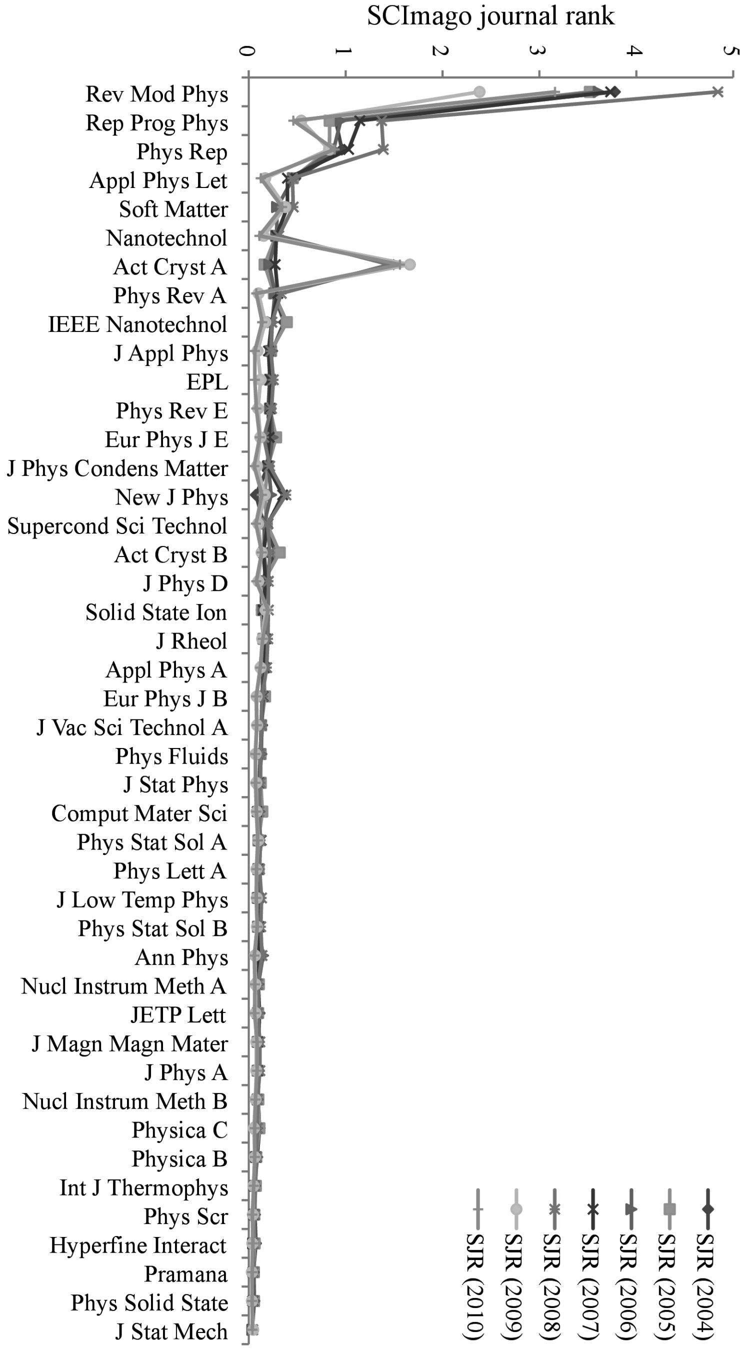

Figure 5.16 SCImago journal rank (*SJR*) for the years 2004 to 2010. Journals are ranked by the median value of all seven values.

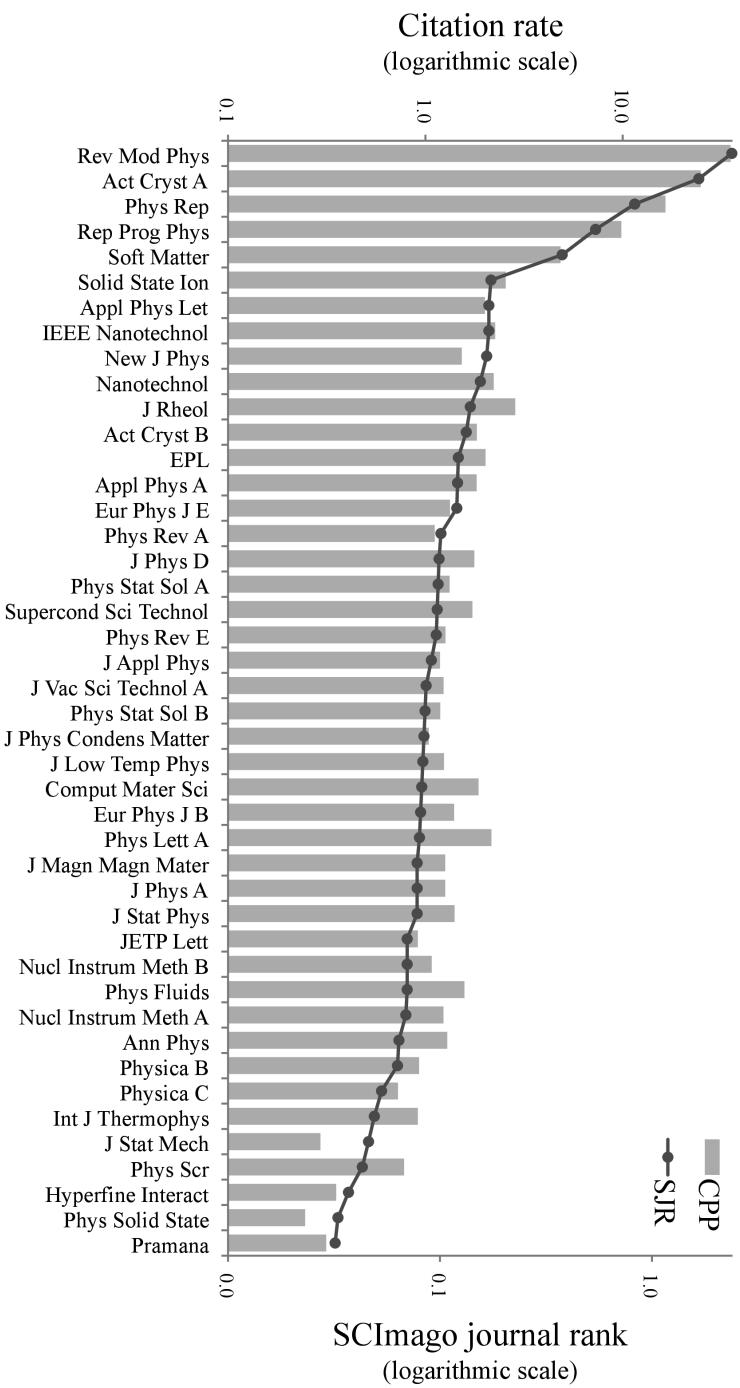

Figure 5.17 SCImago journal rank and mean citation rate (*CPP*) in 2009 of citable items published between 2006 and 2008.

Table 5.11 Statistics of the SCImago journal rank values for the journal between 2004 and 2010 and Pearson (r) and Spearman (ρ) correlations with the mean citations rate (CPP) in Scopus covering the same publication and citation windows.

Statistics	SJR_{2004}	SJR_{2005}	SJR_{2006}	SJR_{2007}	SJR_{2008}	SJR_{2009}	SJR_{2010}
N	42	42	44	44	44	44	44
Mean	0.273	0.269	0.266	0.278	0.358	0.213	0.219
Std. dev.	0.585	0.542	0.547	0.576	0.767	0.430	0.523
Min.	0.409	0.053	0.037	0.038	0.038	0.032	0.035
Max.	3.778	3.521	3.612	3.735	4.842	2.382	3.160
Median	0.128	0.138	0.142	0.140	0.138	0.086	0.078
Correlations with respective CPP_{2004} to CPP_{2010} values							
r	0.987**	0.992**	0.994**	0.994**	0.961**	0.993**	0.988**
ρ	0.951**	0.952**	0.961**	0.946**	0.939**	0.859**	0.867**

** Correlation is significant at the 0.01 level (2-tailed).

In each step of the iterative calculation process of $PSJR$, the sum of the particular values for all journals equals 1. The calculations are repeated until only minor value changes occur, i.e. the sum of the absolute changes do not exceed 0.001% (Gonzalez-Pereira et al., 2010). Since $PSJR_i$, like the Eigenfactor, is a metric depending on the size of the journal, the SJR_i is calculated in a final step of dividing the $PSJR_i$ by the number of documents published.

As figure 5.5 shows for the impact factor, figure 5.16 plots the annual SCImago journal rank from 2004 to 2010. The strong increase of the indicator can be seen for Act Cryst A here as well. However, it is not as extreme as for the impact factor, because, as mentioned above, a large share of the citations received by Act Cryst A come from Act Cryst E, which has low SCImago journal rank values (e.g., $SJR_{2010} = 0.038$). Thus these citations count less in the SCImago journal rank than they do in the impact factor. The same tendency was discovered for the article influence score. Even though article influence and SCImago journal rank are based on a similar weighting algorithm which assigns prestige weights on the citing sources, Elkins et al. (2010) found a higher rank order between SCImago journal rank and the unweighted impact factor ($\rho = 0.89$, 5,503 journals) than between SCImago journal rank and article influence ($\rho = 0.61$, 6,508 journals).

To avoid biases caused by database coverage and citation and publication windows, rankings of the 44 journals are compared based on the SCImago journal rank and a mean synchronous citation rate (CPP) in Scopus with the same particular publication and citation frame (figure 5.17). The journal citation rate is calculated on the basis of all citations received in 2009 by citable items published from 2006 to 2008. In contrast to the impact factor, the relation between received citations and cited documents, i.e. between numerator and denominator, is symmetrical. This mean citation rate and the SCImago journal rank hence only differ in methodology but cover the same data.

For the 44 journals, SCImago journal rank and mean citation rates (CPP) produce very similar results. As shown in table 5.11, Pearson and Spearman correlations are strong. According to both measures, Rev Mod Phys, Act Cryst A, Phys Rep, Rep Prog Phys and Soft Matter can be identified as the five journals with the highest citation impact, weighted or unweighted, in 2009. Changes occur in the lower ranks. For example, New J Phys is ranked higher by the weighted than by the unweighted impact measure, while for Phys Lett A, Phys Fluids and J Rheol it is vice versa. Although J Rheol's unweighted citation rate is almost twice as high as that of New J Phys in 2009 ($CPP_{JRheol} = 2.857$, $CPP_{NewJPhys} = 1.529$), the latter scores a higher SCImago journal rank ($SJR_{NewJPhys} = 0.166$, $SJR_{JRheol} = 0.139$). As noted above for the differences between article influence and impact factor, this can be explained by the higher prestige of the sources citing New J Phys compared to those citing J Rheol.

While Pinski and Narin's influence measures, the Eigenfactor metrics and the SCImago journal rank approach the issue of the different importance of citing sources and base journal impact not only on the number of citations as the basic indicators described in section 5.1 but factor in the prestige of citations, they do not solve the problem of field-specific differences. For example, the top ten of all Scopus journals ranked by SCImago journal rank are from the most frequently cited area of life sciences and a ranking of the computer science subject category is led by computational biology serials (Gonzalez-Pereira et al., 2010). Indicators aiming at the normalization of field-specific citation characteristics in order to enable comparison of journals from different disciplines are described in the following section.

5.3 Normalized Indicators

Although the weighted journal indicators described above improve journal evaluation due to the fact that they allocate different weights to citations based on the impact or prestige of the citing source, they are not able to account for discipline-specific and document-type induced biases (Glänzel, Schubert, Thijs, & Debackere, 2011).

> [R]ankings of journals according to the number of citations received [...] are only meaningful as long as fluctuations reflect a real rise or drop in the importance of influence of the journal, and is not only the results of noise or of a purely random process. (Rousseau, 2002, p. 428)

Normalized journal metrics focus on removing any noise and randomness, which most often appears in the form of biases caused by the subject area, publication growth and speed, different document types, time frames and/or database coverage. One method that tries to account for these biases is the comparison of the actual or observed citation values of a journal with the expected citation rate of its field (Schubert & Braun, 1996). Normalized journal impact measures calculate a citation rate relative to the discipline-specific world average (Moed et al., 1999).

In the early years of journal evaluation studies, attention focused on specific scholarly fields. Journals were compared in order to identify the most important journals in a discipline or to compile core journals in a particular research field. For example, Gross and Gross (1927) analyzed chemistry journals and Allen (1929) ranked serials in mathematics. It was hence not necessary to account for particular discipline-specific differences (Archambault & Larivière, 2009). With an increasing level of inter- and multidisciplinarity and the request for research evaluation studies to compare countries, institutions and authors of various subject areas, journals from different disciplines are compared with each other. Due to differences in publication and citation behavior between fields and subfields, journal indicators need to be normalized in order to "enable cross-comparisons of journals among disciplines" (Moed, 2005, p. 100).

The basic aim of normalized journal metrics is that the average mathematical journal scores as high as the average biomedical journal. A successfully normalized journal metric is able to counterbalance all artificial biases so that they do not affect indicator results but differences in ranking solely imply differences in citation impact (Rousseau, 2002; Glänzel et al., 2011). Due to the complexity of scholarly communication, a full normalization of biases is a difficult task which so far has not been entirely successful. This section describes those journal metrics which have taken up the challenge of facilitating the comparison of periodicals among various disciplines.

Normalization approaches usually consists of four basic steps. In a first step, the average number of citation per document of a journal is computed. Secondly, the journals subject field has to be deliminated to be able to determine the particular benchmark in a third step and to compute the normalized journal impact in a fourth step (Moed, 2010). Two approaches can be differentiated, namely cited-side and citing-side normalization.

The former method is also called a posteriori (Glänzel et al., 2011) or ex post facto normalization (Zitt & Small, 2008; Zitt, 2010) because normalization is applied after computation of the journal indicator on the side of the cited journal. Whereas the latter approach attempts to counterbalance biases before the construction of the indicator on the citing side and is thus referred to as a priori, ex ante or source normalization (Glänzel et al., 2011; Zitt, 2011). While the cited-side method usually involves a classification system for defining the field and using its expected citation rate as a benchmark, the citing-side is free from any preconditioned classification because it defines the 'citation potential' (Garfield, 1979) of the field through the sources directly citing the journal analyzed (Moed, 2010). Examples of both cited- and citing-side normalized indicators are described in the following.

5.3.1 Cited-side Normalization

Cited-side or a posteriori methods first calculate the citation impact of a journal and then try to account for differences in the citation characteristics of scholarly fields. Most of the time the actual indicator value of a journal is compared to an expected average of the particular subject area. The normalized metric thus indicates whether the particular journal performed above or below field average. This normalization makes it possible to compare relative journal performance across fields (Zitt, 2011).

The major disadvantage of cited-side normalization is that a classification of the particular journal is necessary in order to determine a field average that can be used for normalization. The indicator value of a journal thus depends on the group of journals it is compared to. A change in subject classification can lead to different results (Zitt et al., 2005).

The rank-normalized impact factor by Pudovkin and Garfield (2004) and the mean normalized journal score constructed at CWTS represent two variants of cited-side normalization.

Normalized impact factors

There are several a posteriori methods for normalizing the impact factor in comparison to impact factors of the same subject area. Most of them are based upon the subject category classification system of the JCR. Pudovkin and Garfield (2004) introduced a straightforward normalization of the impact factor the so-called rank-normalized impact factor. The method involves a normalization by the relative ranking position of a journal according to the impact factor in a subject category previously suggested by Schubert and Braun (1996). By comparing the rank to the total number of journals in a category, cross-category comparison becomes possible. The rank-normalized impact factor $rnIF$ of journal j is thus defined as

$$rnIF_j = \frac{n - r_j + 1}{n} \tag{5.17}$$

where n is the number of journals in a subject category and r_j denotes the ranking position of journal j in that category according to its impact factor score. The journals with the highest impact factor of each category have a rank-normalized impact factor of 1, those ranked last, obtain an $rnIF$ close to 0 (Pudovkin & Garfield, 2004). As $1 - rnIF$ indicates the percentage of journals in the category that have a higher impact factor than the journal analyzed, the normalized ranking is easy to interpret. If a journal is classified in more than one subject category, the arithmetic mean of its category-specific rank normalized impact factors is used (Pudovkin & Garfield, 2004).

Sen (1992) proposed normalizing impact factors by the highest impact factor score in the particular subject category of the journal. The normalized impact factor nIF of journal j is defined as

$$nIF_j = \frac{10IF_j}{IF_{top}} \tag{5.18}$$

where IF_j is the impact factor of journal j and IF_{top} is the highest impact factor in the same category. Just like the impact factor, the normalized and rank-normalized impact factors are comprehensible and easily available through the data provided in the JCR. In addition they allow a comparison of journals of different fields. However, the normalized indicators suffer from all the shortcomings of the impact factor, such as the asymmetry between citations and citable items, the short citation window, the overestimation of review journals etc. Additionally, normalized impact factors depend on the definition of the ISI subject categories. Problems associated with this particular classification system are described in section 3.2.1. Moreover, journals assigned to a small subject category have a higher probability of obtaining a high rank-normalized impact factor than those classified in a category containing a large number of periodicals. Since values are replaced by ranks in the rank-normalized impact factor, small and large distances between rank orders are treated equally.

Mean Normalized Journal Score (MNJS)

The field-normalized journal impact metric used at the CWTS is the mean normalized journal score (*MNJS*)[7], which normalizes the actual citations of a journal by the average number of expected citations of a pre-defined subject field that the particular journal is classified in. The *MNJS* has recently replaced the old CWTS journal indicator $JCSm/FCSm$ (Moed, De Bruin, & Van Leeuwen, 1995; Van Raan, 2004). The old field-normalized journal impact score used at the CWTS is defined as

$$JCSm/FCSm = \frac{\sum C_j}{\sum C_f} \tag{5.19}$$

where C_j are the citations received by journal j and C_f are the expected citations, i.e. the average number of citations received by the whole subject field to which j is assigned. The expected citations are the average number of citations received by documents of the same type (article, letter or review), published in the same pre-defined subject field during the same year (Moed et al., 1995; Waltman, Van Eck, Van Leeuwen, Visser, & Van Raan, 2011a, 2011b). Actually received and expected citations are compared at the group level instead of comparing them separately on the level of single documents (Larivière & Gingras, 2011). At ECOOM Leuven the normalized mean citation rate (NMCR) is computed in a similar way, i.e. by dividing the mean observed citation rate of a journal by the expected citation rate of the field (Glänzel, Thijs, Schubert, & Debackere, 2009; Waltman et al., 2011b).

Since the old method underlying the field-normalized journal indicator transgresses the order of operations by calculating a ratio of averages and thus works in favor of papers from frequently cited fields, it has been criticized by Opthof and Leydesdorff (2010) and earlier by J. Lundberg (2007). Hence, the CWTS has recently replaced the old calculation method by a new one which involves calculating an average of ratios by normalizing at document level (Van Raan, Van Leeuwen, Visser, Van Eck, & Waltman, 2010; Van Raan, Van Eck, Van Leeuwen, Visser, & Waltman, 2010; Waltman et al., 2011b, 2011a). In the calculation of the old indicator, all citations received by the journal are summed up first and divided by the sum of expected citations, i.e. citations received by the subject field of the journal. The new method involves a comparison of received and expected citations of each document separately (Van Raan, Van Eck, et al., 2010; Van Raan, Van Leeuwen, et al., 2010). For a set of n papers published in journal j the mean normalized journal score *MNJS* is defined as

$$MNJS = \frac{1}{n}\sum \frac{C_j}{C_f} \tag{5.20}$$

As it is an average of ratios, this calculation ensures that each citation is weighted equally and compared directly with expected citation rates of similar documents. For each document, a normalized value of citation performance is computed. If it is below 1, the document has not been cited as frequently as the average document of the same type, published in the same subject area and year. If it is exactly 1, the document received the

7 It should be noted that the *MNJS* is calculated in the same way as the mean normalized citation score *MNCS* with the only difference that it is specifically defined for the evaluation of journals.

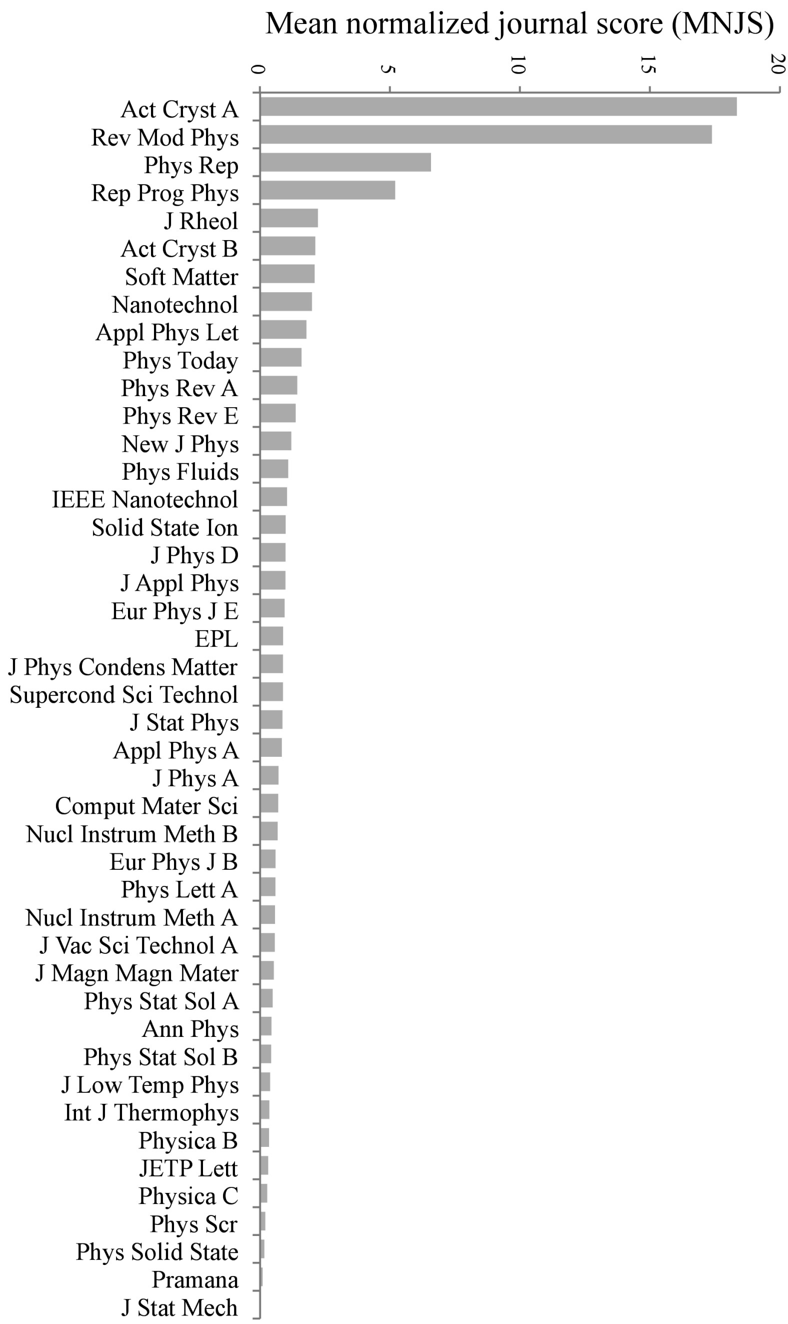

Figure 5.18 Mean normalized journal score (MNJS) for 44 journals.

expected number of citation, and if it is above 1, it has exceeded the average number of citations. All n ratios are summed up and then divided by n to obtain an average of ratios as the mean normalized journal score *MNJS* of journal j. Due to the new method of calculation, which is the standard a posteriori normalization in other bibliometric groups (Gingras & Larivière, 2011), the normalized indicator is consistent, allows for statistical analysis of significance and adds up to unity at world level (Larivière & Gingras, 2011; Waltman et al., 2011b).

Although Waltman et al. (2011a) argue that the differences in the ranking are only small at high levels of aggregation, Larivière and Gingras (2011) show that these difference are significant and that the method based on a ratio of averages produces inconsistent results. The mean normalized journal scores of the 45 journals are listed in figure 5.18.

Although the mean normalized journal score allows for a comparison of journals of different research areas and counterbalance biases caused by document types, like any other a posteriori normalization approach it stands and falls with the definition and classification of subject fields (Leydesdorff & Opthof, 2010a; Zitt, 2010).

> Strong points of the normalised measures are that to some extent they enable cross-comparisons among disciplines and that they are not biased in favour of review journals. But there are some points that should be kept in mind as well. First, it is difficult for multi-disciplinary journals such as Science or Nature to calculate normalised measures that cover a broad range of disciplines. Secondly, their values depend upon how journals are aggregated into (sub-)disciplines. (Moed, 2005, p. 105)

Depending on the expected citations that serve as a benchmark, one and the same journal can be ranked quite differently in a different classification system. Citing-side normalizations do not suffer from these problems since they are independent of pre-defined classification systems (Leydesdorff & Opthof, 2010a).

5.3.2 Citing-side Normalization

Through normalization of the citing instead of the cited side, a priori or source-normalized metrics are independent of a classification of journals according to research fields (Waltman & Van Eck, 2010b). Citing-side normalization aims at counterbalancing field-specific differences through the number of references and age of the citing source.

> The ratio of citable to citing literature, which determines the inequality of average citation rates among fields, depends on several factors. In a model configuration of isolated fields, the citing propensity of the field depends on the average length of bibliographies; growth of the area; and the obsolescence rate of citations. (Zitt, 2010, p. 393)

Since normalization is applied to single documents before the construction of the journal indicator, a priori metrics are not tied to any subject classification system (Leydesdorff & Opthof, 2010a). The audience factor (Zitt & Small, 2008), SNIP (Moed, 2010) and the fractionally counted impact factor (Leydesdorff & Opthof, 2010a, 2010b) are a priori metrics normalizing citations by the length of the reference lists of the citing sources, which is regarded as the field's citation potential. They are based on fractional citation counts which has long been applied but not been implemented with respect to citing-side normalization of journals (Small & Sweeney, 1985). While the audience factor and SNIP are normalized on the journal level, the fractional impact factor normalizes citation counts on the level of single articles. Due to its independence of an artificial classification of journals, source normalization seems to be the most natural way to account for field biases (Leydesdorff & Opthof, 2010a; Zitt, 2011).

Audience Factor

The audience factor is a journal indicator introduced by Zitt and Small (2008) including a field normalization of the citing side through the average number of references. This method has previously been applied by Small and Sweeney (1985) in a co-citation context. They explained the normalization as follows:

> In fractional citation counting, each citing item has a total voting strength of one, but divides that single vote equally among all references it cites. If an item contains ten references, each citation has a fractional weight of 1/10. This procedure has the generally desirable effect of giving papers with short reference lists greater weight, and papers with long reference lists, such as review papers, less weight per reference. (Small & Sweeney, 1985, p. 393 f.)

The audience factor represents a journal's mean citation impact per article based on this kind of normalization of citation potential, i.e. through weighting citations according to the average length of the citing journal's reference lists.

> The propensity to cite, and to cite in a given time frame (the citation window, say 5 years), can be approximated by the average number of references per article in citing journals to cited articles 5 years old or less (deemed “active" references). This propensity depends both on general field features, such as the degree of specialization and social norms, and on particular features of the citing journal. (Zitt & Small, 2008, p. 1856)

Normalization applies in so far that a citation from a journal with on average 10 references per article counts five times as much as a that from a serial, where on average 50 sources are listed in the reference lists. The idea behind this kind of normalization is that citations received from fields of high citation density, such as the life sciences have less weight, while citations from fields with low citation rates, such as mathematics have greater weight, so that field differences are compensated (Zitt & Small, 2008; Zitt, 2010).

In Zitt and Small (2008) the audience factor of journal j was initially defined as

$$AF_j = \frac{\sum_i w_i C_{ij}}{P_j} \tag{5.21}$$

where C_{ji} denotes the number of citations from i to j in year y, P_j represents all documents published in j between $y-1$ and $y-5$ and w_i is the citation weight of journal i defined as

$$w_i = \frac{m_s}{m_i} \tag{5.22}$$

where m_s stands for the average number of (active) references in the database and m_i denotes the average number of references of journal i. Thus the weight w_i of the citation from i to j is larger than 1 if the journal's average reference list is shorter than the database average and it is smaller if the citation density is higher than average. To avoid under- or overweighting of citations from reviews or journals with extremely short reference lists, the minimum and maximum values of the weight were limited (Zitt & Small, 2008).

If w_i equals 1 the audience factor equals a 5-year mean synchronous journal citation rate, it is thus a weighted version of the 5-year impact factor, where the weight does not account for the prestige of the citing journal (as the weighted indicators described in section 5.2), but the particular journal's propensity to cite (Zitt & Small, 2008).

In Zitt (2010) the weighting indicator w_i was further modified. It is now not based on the average length of the reference lists of the citing journal but of the journals neighborhood, i.e. the journals similar to journal i. The weight w_i is now defined as

$$w_i = k\frac{x_s}{x_i} \tag{5.23}$$

where k is a correcting factor and x_s and x_i denote the average number of active references of the whole database and of those journals cited by journal i, respectively (Zitt, 2010). In contrast to the earlier indicator, where the weighting denominator was based on the citing behavior of one, i.e. the citing, journal, the modified method is more robust, because it is based on the average length of references of the field. Since the field is defined through citation relations of journal i, the method is independent of a classification-based definition of research fields (Zitt, 2010).

The advantage of the audience factor method is thus that there is no need for a journal classification scheme because normalization is directly defined through the citation behavior of journals. This solves the difficulties related to inter- and multidisciplinary journals. Based on 5,284 journals included the JCR 2006 edition, Zitt and Small (2008) found that in contrast to the 5-year impact factor the 5-year audience factor produces a less skewed distribution of values.[8] Hence, the dominance of high impact medical journals is reduced in favor of periodicals from engineering, mathematics and physics. In fact, Rev Mod Phys ranked first of all 5,284 JCR journals based on the modified audience factor. The results of those 42 of the 45 included in the ranking can be found in figure 5.19.

A disadvantage of the audience factor is that the weight used to normalize field differences is that the number of references are computed on the journal not the document level. All citations issued by the same journal thus receive the same weight. SNIP and fractional impact factor try to solve this by computing weights on article level. Waltman and Van Eck (2010b) point to another shortcoming of the audience factor, namely its dependence on the database coverage of a field. The journal indicator decreases the less citing journals are covered by the database.

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8 Results can be downloaded from http://www.obs-ost.fr/en/know-how/etudes-en-ligne/travaux-2010/note-de-presentation-le-facteur-d-audience-des-periodiques-scientifiques/experimental-measure-of-the-audience-factor-of-scientific-journals.html.

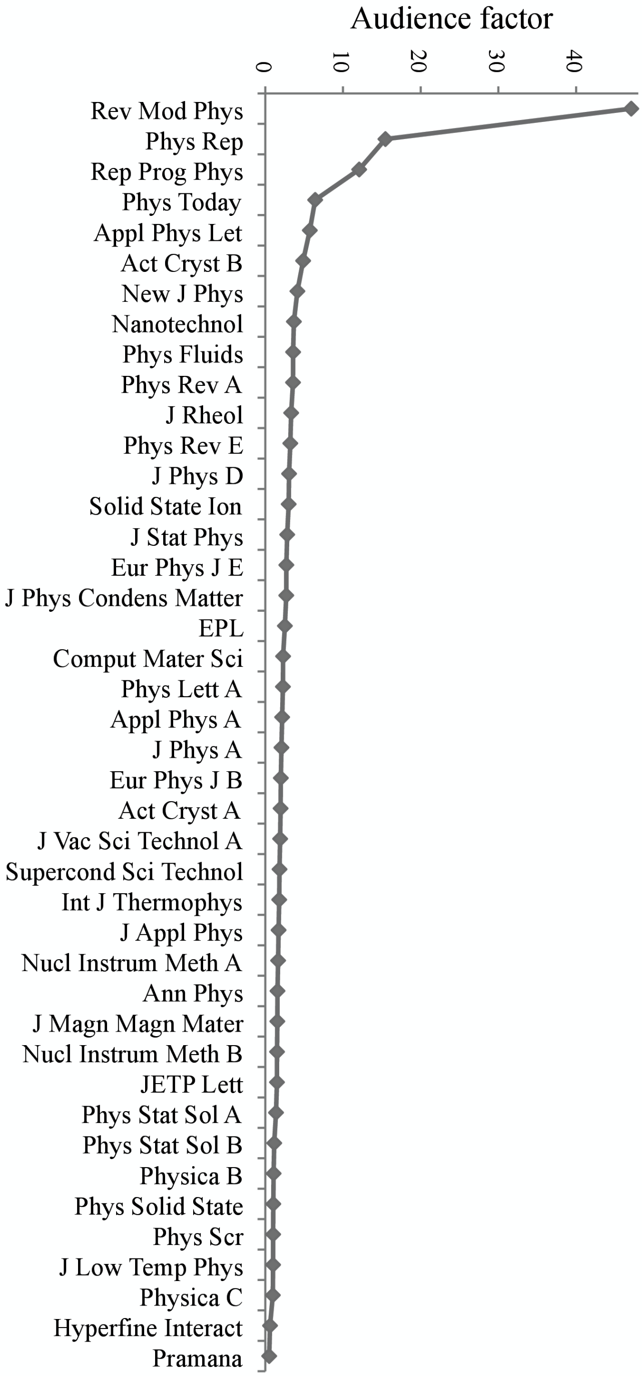

Figure 5.19 Audience factor for 42 journals in 2006.

> If the bibliographic database one uses covers relatively more infrequently cited journals in one field than in another, journals in the former field have an advantage over journals in the latter field. (Waltman & Van Eck, 2010b, p. 1478)

The property of the audience factor of being sensible to insignificant journals may be problematic, when comparing journals of various field with different levels of coverage (Waltman & Van Eck, 2010b). Since citation databases are far from complete and some fields are covered to a greater extent than others, this will almost always be the case. SNIP tries to account for database coverage by incorporating the database citation potential.

Source Normalized Impact per Paper (SNIP)

The source normalized impact per paper (SNIP) indicator was introduced by Moed (2010) and has been listed in Scopus since the beginning of 2010. It aims to account for field differences through the number of references of the citing documents and the database coverage of the particular field. Moed (2010) describes the objectives of SNIP as follows:

> It measures a journal's contextual citation impact, taking into account characteristics of its subject field, especially the frequency at which authors cite other papers in their reference lists, the rapidity of maturing of citation impact, and the extent to which the database used for the assessment covers the field's literature. (Moed, 2010, p. 266)

SNIP is calculated as a ratio of a journal's mean citation rate and the field's citation potential and as the SCImago journal rank it is limited to articles, proceedings papers and reviews published during three years and cited in the following year. It is defined as

$$SNIP_j = \frac{RIP_j}{RDCP} \tag{5.24}$$

where RIP_j denotes the raw impact per paper of journal j and is thus a mean citation rate with a 3-year publication ($y-1$ to $y-3$) and 1-year citation window (y). RIP_j is thus the 3-year mean citation rate used by the SCImago group described in section 5.1.1. *RDCP* stands for the relative database citation potential and is defined as

$$RDCP = \frac{R_j^d}{M^d} \tag{5.25}$$

where M^d is the median of the database citation potentials R_j^d, i.e. the median of the n (n = all journals in the database) journal citation potentials, which again is defined as the mean number of references of the documents citing the particular journal. Thus, R_j^d is defined as the arithmetic mean of references of documents in the database that directly cite journal j:

$$R_j^d = \frac{\sum_{i=1}^{m} {}^{i}r_j^d}{m} \tag{5.26}$$

SNIP is thus a mean journal citation rate normalized by a factor that compares the citation potential of the field to that of the database. The denominator of SNIP (*RDCP*), which is a median of means, is greater than 1, if the average number of references in the journal's field is above database average, which decreases the unnormalized citation rate of the journal (RIP_j). If the field's citation potential (R_j^d) is below average, the factor is below 1 and SNIP increases.

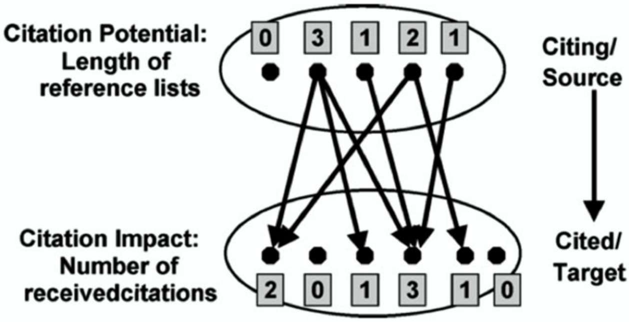

Figure 5.20 Scheme of citation potential and citation impact covered by SNIP. Source: Moed (2010, p. 267)

Similar to the audience factor, the advantage of SNIP is that the citation potential of the field is delimited as the average number of references of the papers that directly cite the particular journal and is thus independent of a classification system. In contrast to the audience factor, SNIP is not influenced by the coverage of the field, according to Waltman et al. (2011b) it is hence insensitive to insignificant journals. This property is achieved through counting not all references of citing papers but only those targeting journals covered by the database:

> [C]itation potential must take into account the extent to which the database covers a subject field. A new parameter is defined, denoted as database citation potential. It does not count the total number of cited references in a fieldÕs papers, but the number of cited references published in journals processed for the database. (Moed, 2010, p. 268)

SNIP aims to normalize for large differences in the coverage of different subject fields. Thus the average number of references per paper does not reflect the actual citation propensity of the field but is limited to the citation potential that is reflected in the database (Moed, 2010).

Figure 5.21 shows SNIP values for the 45 journals between 2004 and 2009. Data is available for download on SNIP website[9]. In contrast to the impact factor (figure 5.5) and SCImago journal rank (figure 5.16), the annual rankings of the journal according to SNIP are less homogeneous indicating that the metric is less robust. Especially the values for 2008 and 2009 differ from the rest. Pearson correlation between 2007 and 2008 is $r = 0.573$.

9 http://www.journalmetrics.com

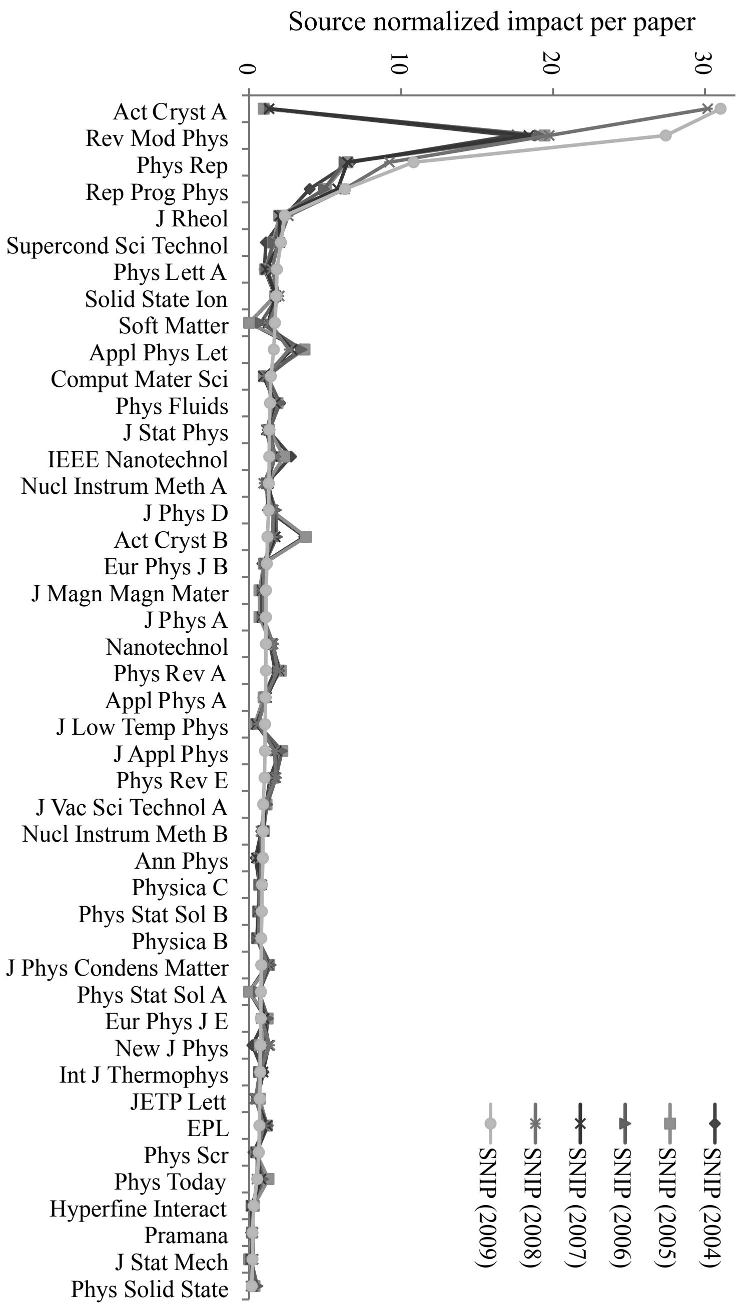

Figure 5.21 Annual source normalized impact per paper (SNIP) for the 45 journals from 2004 to 2009.

SNIP was criticized by Leydesdorff and Opthof (2010b) since it used the same method of calculation as other field-normalized metrics at CWTS (see section 5.3.1), which involves a transgression of the order of operations by dividing averages instead of averaging ratios causing erroneous results (Opthof & Leydesdorff, 2010; Leydesdorff & Opthof, 2010b). They argue that "the original idea behind the SNIP indicator is a good one, but the elaboration is problematic" (Leydesdorff & Opthof, 2010b, p. 2365). Leydesdorff and Opthof (2010b) improved the mathematical shortcomings of SNIP in the so-called fractional-counted impact factor, which is described in the following section.

Fractional-counted Impact Factor

Leydesdorff and Opthof (2010b) aimed to improve the shortcomings of SNIP and the audience factor through the introduction of a journal impact factor based on fractional counts of citations. Just like the audience factor and SNIP, the fractional impact factor is independent of any classification system "because the citing paper positions itself in terms of the relevant fields and, thus, in terms of citation behavior" (Leydesdorff & Opthof, 2010b, p. 2367), as shown in figure 5.20. In contrast to the other source normalized metrics, the fractional-counted impact factor, however, normalizes on the article instead of the journal level. It does not divide averages but represents an average of ratios (Leydesdorff & Opthof, 2010a, 2010b). The fractional impact factor is defined as

$$fractional\ IF_j = \frac{\sum\limits_p \frac{1}{r_p}}{P_j} \tag{5.27}$$

where for each citation received by journal j from any document p, the citation is weighted as a fraction of the number of references of p. The fractional citation count is added up and divided by the number of documents P_j published in the journal in order to obtain a size-independent measure of the fractional-counted citation impact of journal j. In other words, on a document level each citation received weighs exactly $\frac{1}{r}$ of the r references contained in the citing paper p. A citation from a biomedical paper with 30 references thus weighs $\frac{1}{30}$ while a publication in mathematics with a list of 5 cited references weighs $\frac{1}{5}$.

Just like SNIP and the audience factor, the fractional impact factor thus tries to counterbalance discipline-specific differences in the citation potential. Since normalization is performed separately for each document and is not based on journal or database averages, it allows statistical testing of the distributions. The definition of a world average as a benchmark is no longer necessary since fractional citation counting can be applied to any set of documents. It is, however, possible to determine any kind of benchmark for comparison. The statistical significance between various sets can be determined (Leydesdorff & Opthof, 2010a, 2010b; Leydesdorff & Bornmann, 2011; Leydesdorff & Opthof, 2011).

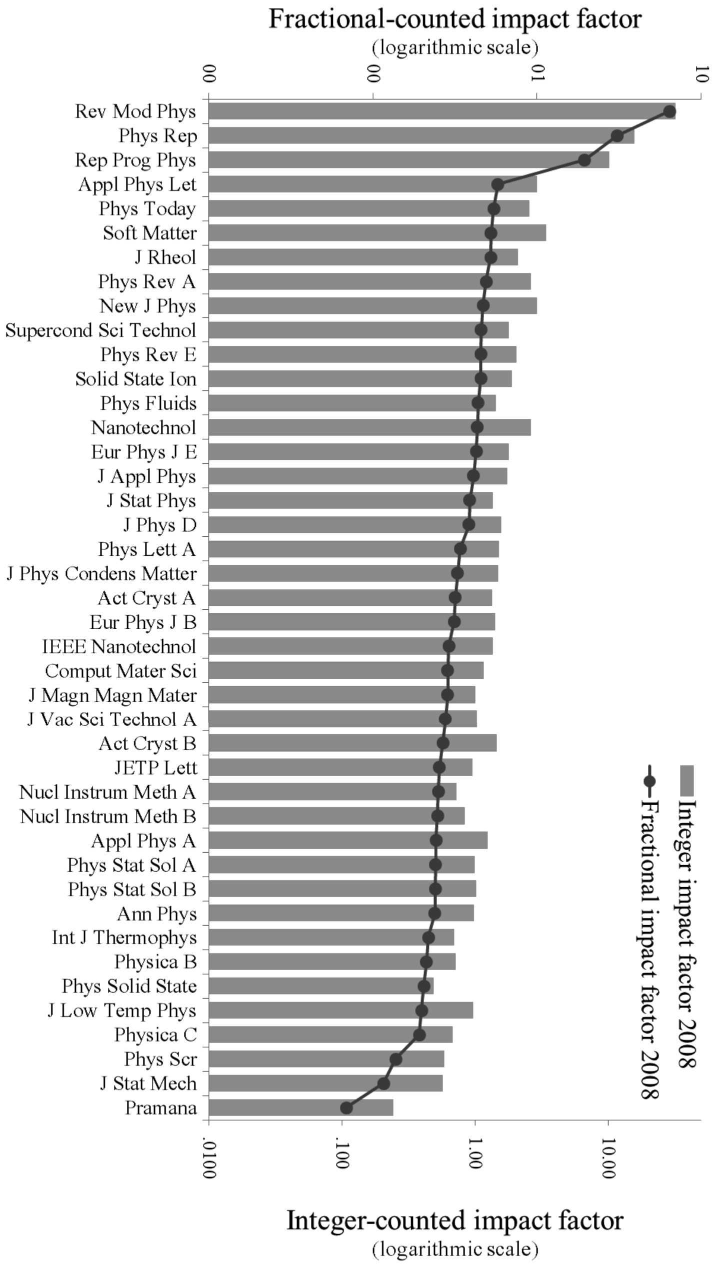

Figure 5.22 Fractional-counted impact factor and impact factor based on integer counts for 42 journals. The latter is called 'quasi' impact factor, since it is computed from the JCR CD-ROM version.

Figure 5.22 shows the fractional 2-year impact factor for the 42 of the 45 journals included in an analysis of 5,742 journals based on the 2008 JCR edition. The data is freely available for download[10]. Besides the fractional impact factor, figure 5.22 includes a 'quasi' impact factor calculated on integer values of the same citation data. It is called a 'quasi' impact factor, since it is a 2-year mean synchronous citation rate based on the JCR CD-ROM version of the 2008 edition of the JCR and is not identical with the impact factor computed by Thomson Reuters. See Leydesdorff and Bornmann (2011) for details of the differences. It can be seen in figure 5.22 that for this set of journals the differences between the two rankings are generally small. For more than half of the journals, the ranking position did not change by more than 2 positions. Seven journals obtained exactly the same rank including the periodicals ranked as first three. This was to be expected since the set represents a more or less homogeneous collection of journals in terms of citation potential, which "varies with fields of science, but not among specialties within fields" (Leydesdorff & Bornmann, 2011, p. 219). The largest differences between integer and fractional citation counts can be observed for Act Cryst B, which drops from 19th position in the former to 27th in the latter. This indicates that Act Cryst B is cited by sources with comparably long references lists. The opposite is the case for Phys Fluids, which improves by seven ranks based on the fractional-counted impact factor. Sources citing Phys Fluids have fewer references, so that citations received by Phys Fluids count relatively more.

Although Leydesdorff and Opthof (2010b) and Leydesdorff and Bornmann (2011) show that differences between fields are no longer significant – variance between fields can be reduced by 81% – the fractional-counted impact factor is not able to entirely counterbalance particular biases.

Moed (2011) criticized the fractional impact factor for lacking a limitation of references in terms of age and database coverage. He argues that Leydesdorff and Opthof's approach undervalues disciplines with long reference lists, i.e. high citation potential, but long periods of maturing, and underestimates fields with low database coverage. Moreover, he argues in favor of field-level and against article-level normalization (Moed, 2011). Zitt (2011) summarizes an obvious problem of fractional citation counts with regards to overestimation of sources with extremely short references lists such as trade journals:

> The correction provided in favor of sources with short bibliographical lists must take notice that bibliographies may be short for bad reasons. Translating the scarce bibliographies of trade journal articles into an overweight for each individual reference is an obvious trap likely to spuriously enhance the impact of these journals. It would be abnormal that an article cited three times in trade journals receive a larger score than an article cited ten times in good scientific journals. (Zitt, 2011, p. 342)

Waltman and Van Eck (2010a) and Glänzel et al. (2011) have proposed further improvements of source normalization based on fractional counting. Waltman and Van Eck (2010a) introduced the mean source normalized citation score (MSNCS) to complement the set of CWTS indicators by a source-normalized approach. It is calculated

10 http://www.leydesdorff.net/weighted_if/weighted_if.xls

exactly like the fractional impact factor by Leydesdorff and Opthof (2010b) with additional correction for the publication year of the cited document. In contrast to the audience factor, SNIP and the fractional impact factor, the MSNCS is not restricted to a certain citation and publication frame but takes into account all received citations normalized by age. Waltman and Van Eck (2010a) describe the normalization attempt of the indicator as follows:

> Assuming fields to be in a steady state and assuming the absence of inter-field citation traffic, the average MSNCS value of a publication is the same for all fields and all publication years. This property provides a strong justification for the way in which the MSNCS indicator normalizes citation counts. (Waltman & Van Eck, 2010a, p. 299)

Of course, actual citation relations are not as simple as assumed in the quote. Citations are frequently exchanged between journals of different fields and they are anything but steady. The MSNCS is therefore not able to correct for all field biases either. It should be noted that both the MSNCS and the fractional impact factor are not limited to journal evaluation but they can be applied to any set of documents.

The approach of Glänzel et al. (2011) takes into account only the references which are indexed in the database to normalize on the article level so that the indicator results are consistent for the whole database. Glänzel et al. (2011) claim that their indicator

> compensates for the "surplus" of citations received from both review articles which have by nature long reference lists and the "hard sciences" where most of the references are most recently published journal articles. (Glänzel et al., 2011, p. 420)

They improve normalization if the fractionally counted indicator is only computed for cited documents and the uncitedness (section 5.1.2) functions as a supplementary indicator. Although the method is able to reduce biases to some extent, it does not fully normalize all field differences, however.

Summary

This chapter focused on the dimension of journal citations which reflect the scholarly impact of journal content. Three major categories of citation-based journal metrics were identified, namely basic, weighted and normalized journal indicators.

Basic indicators are based on simple citation counts and do not differentiate between discipline-specific differences so that they should only be applied to periodicals of the same research field. Basic journal measures can be subdivided into mean citation rates, distribution-based indicators such as the percentage of highly or uncited documents, the journal h-index, time-based indicators analyzing obsolescence patterns and an analysis of citing sources.

Weighted indicators try to account for the citing source by weighting citations from prestigious journals higher than those from peripheral periodicals. The influence weights, Eigenfactor metrics and the SCImago journal rank are all based on an iterative algorithm factoring in citation weights determined by the eigenvector centrality of the citing journal.

Normalized journal metrics try to account for subject-specific biases to allow comparisons of journals across scholarly fields. Normalization is achieved either a posteriori through a comparison of actual to field-specific observed citation rates constructed on the basis of a classification system or a priori on the citing side. The latter determines the citation potential of the field independent of a pre-defined classification scheme through the reference lists of the citing sources. A perfect normalization method able to remove all noise and biases has, however, not been constructed yet. This shows that it is a difficult, if not impossible, task to account for all biases involved in journal citation impact.

The complex structures of formal scholarly communication prove to be extraordinarily difficult to capture in one indicator of citation impact. Even if all artificial biases were to be normalized and an iterative algorithm incorporated, weights based on the prestige of the citing source, editors and publishers would find ways to manipulate this indicator in their favor. Moreover, the skewed distribution limits the informative value of mean citation rates. Distribution-based metrics may be helpful to provide a more complete picture. This demonstrates that it is best not to rely on one metric but to consult a set of citation metrics to evaluate journal citation impact.

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Chapter 6
Journal Management

This chapter focuses on the factors influencing the prestige and selection of periodicals by authors, readers and librarians which can be attributed to journal management.

> Prospective authors in the field of library and information science face a nearly overwhelming array of journals to which they might consider submitting manuscripts. However, information on these journals – their aims and scope, their quality and their manuscript review processes – sometimes is difficult to ascertain. Because promotion and tenure decisions in academic libraries are often based partly on the perceived quality of the journal in which articles are published, it is important that academic librarians be well informed about the publication policies and practices of journals in the field. (Via, 1996, p. 365)

What Via (1996) expresses with regard to authors in the field of library and information science, applies equally to researchers in most other scholarly disciplines. Various factors in journal management, i.e. editorial and publishing policies, influence a journal's prestige but are hardly generally known nor widely considered in journal evaluation (Vastag & Montabon, 2002). These aspects include a journal's publication history (section 6.1.1), publisher affiliation (section 6.1.2) and thematic scope (section 6.1.3), the size and composition of the editorial board (section 6.2), the review process including rejection rates (section 6.3.3) and publication delay (section 6.3.2), and subscription prices (section 6.4.3).

6.1 General Journal Characteristics

General characteristics of journals include journal age and publishing tradition, publisher affiliation, coverage by abstracting and indexing services, the placement of advertisements, circulation and type of publication and appearance (Vastag and Montabon (2002); Schlögl and Petschnig (2005); Juchem, Schlögl, and Stock (2006); Schlögl and Stock (2008)).

Much has been written about the transfer from print to online journals, the benefits, challenges and acceptance of the new medium and changes in reading behavior. Visions of the future of e-only journals included tapping the full potential of the new medium comprising interactive and dynamic articles, video and three-dimensional sequences. On the other hand, it has also been predicted that scholarly journals will die out in the digital age. These extreme predictions have, however, not come true (Odlyzko, 1995; Meier, 2002). Although the transition from print to e-only journals has taken place, the concept of scholarly journal publishing has not changed a great deal: there is basically no difference between the print and online version of a periodical (Keller, 2005). Although access and searchability of journal content have, to a great extent, been improved through electronic publishing, the concept of the academic journal has not been altered through the digital revolution (Kling & Callahan, 2003). The PDF is the established format of electronic articles because it mimics the print format (Mierzejewska, 2008). Although the electronic format allows convenient navigation within and between documents, e.g. through hyperlinks and direct linking of cited references, the structure of a scholarly article remains the same (Odlyzko, 2002; Keller, 2005).

Most of today's scholarly e-journals have predecessors or parallel versions in print. Keller (2005) found that 90% of all journal titles in EZB have or have had counterparts in print. Many scholarly libraries and journals have switched to e-only, new titles are born electronically. From an economic perspective, e-only enables a new business model called 'long tail business', where a publisher can offer a large number of small specialized journals with fairly low subscription rates (Linde & Stock, 2011).

Since scientific communication and publishing in STM has successfully negotiated the transition from print to online, the issue of print vs. online will not be further discussed at this point. For an overview of this aspect refer to Tenopir and King (2000) or Kling and Callahan (2003). In the following, publication history (section 6.1.1), publisher affiliation (section 6.1.2) and scope (section 6.1.3) of the 45 journals are examined more closely.

6.1.1 Age and Publication History

A journal's publication history and tradition can be crucial to its standing within the scholarly community. When describing journal publication history, demographic terms like age, birth, death, marriage, divorce and sibling are often used. Journal age is defined as the number of years since its first publication regardless of title changes (Yue & Wilson, 2004). The median age of the analyzed journals is 46, indicating that in general, these physics journals have a long publication history. With a publication history of over 200 years, Ann Phys is the oldest of the analyzed periodicals. Its current publisher Wiley describes Ann Phys's tradition on the website:

> Founded in 1790, Annalen der Physik is one of the world's oldest and most renowned physics journals with an over 200 year tradition of excellence. Annalen der Physik has always been the home of innovative papers from the best and brightest minds in the field, such as Albert Einstein, Max Planck, and many others.[1]

Soft Matter is the youngest of the analyzed journal. It 'was born' in 2005. Figure 6.1 displays a time line of the journals' publication history. Different colors indicate journal title changes, which were usually caused by twigging ('divorce') and merging ('marriage') of periodicals. Changes in subtitles were not considered as title changes. Information about founding years and predecessors were collected from ZDB and the journals' websites.

1 http://www.wiley-vch.de/publish/en/journals/alphabeticIndex/2257

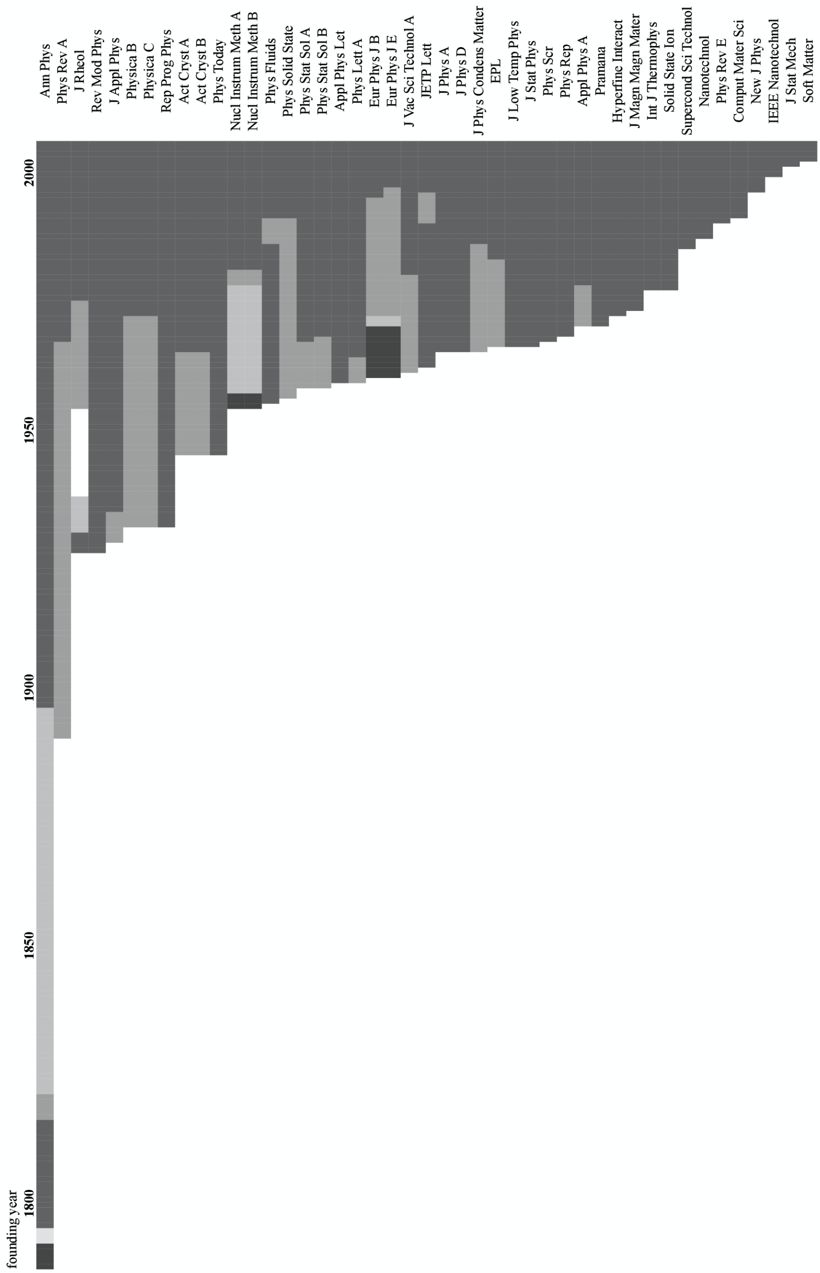

Figure 6.1 Publication history of the 45 journals. Different shades of gray indicate journal title changes caused by merging and splitting. Changes of subtitles were not considered title changes.

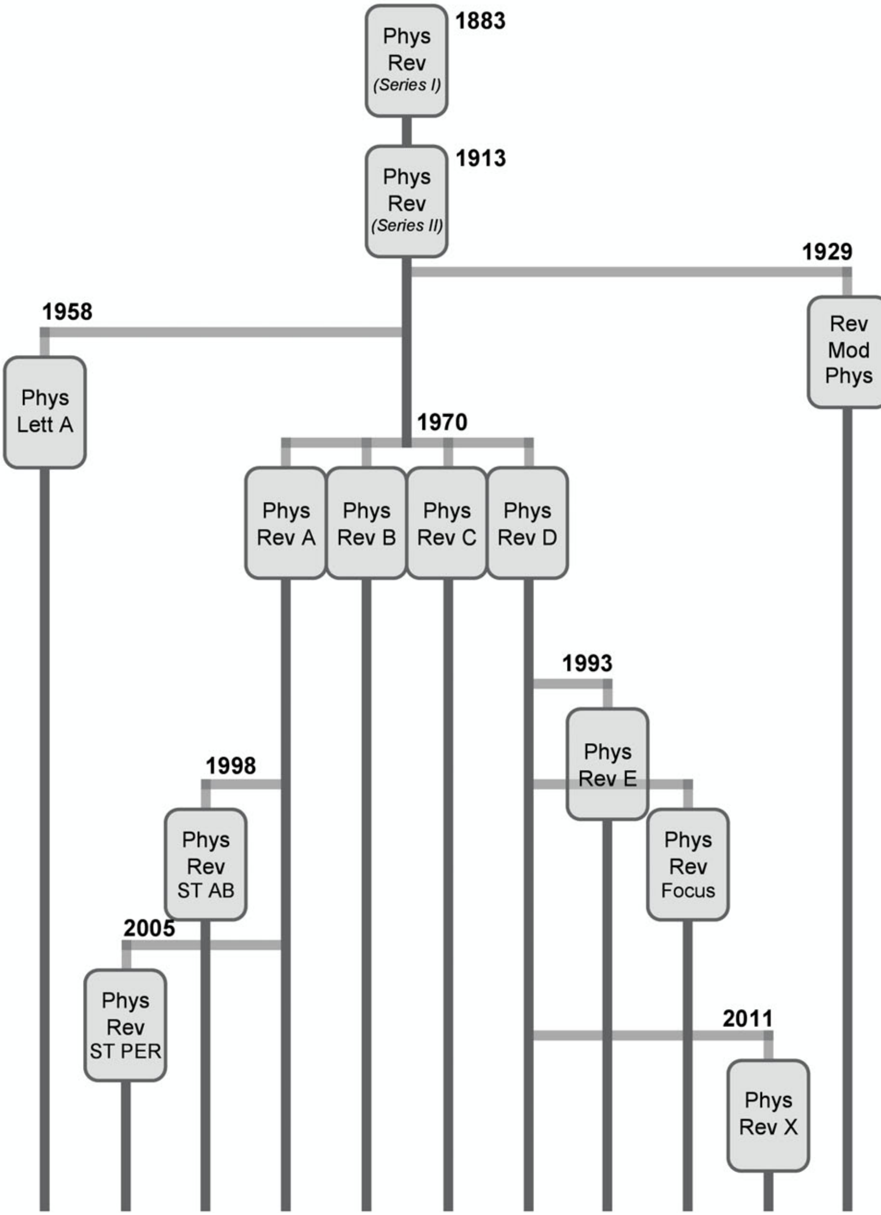

Figure 6.2 'Family tree' of the Physical Review journals.

The complexity of some publication histories is illustrated by the following examples. Ann Phys emerged from Journal der Physik (1790–1794) and Neues Journal der Physik (1795–1797) and appeared under the name Ann Phys for the first time in 1799. Between 1819 and 1824 it operated under the title of Annalen der Physik und der physikalischen

Chemie and of Annalen der Physik und Chemie from 1824 to 1899. Under its editor Paul Drude it returned to its original name in 1900.[2] Phys Fluids, which was founded in 1958, was split into sections A and B between 1989 and 1993, which were then again merged under the original name in 1994. J Rheol was initially launched in 1929 and published under its name until 1932/33, when it was incorporated and published as a section in the journal Physics, which in 1937 became J Appl Phys. After 1939, publication of J Rheol was completely discontinued until 1957, when it started again as Transactions of the Society of Rheology. The original and current name was reclaimed in 1978.[3]

As can be seen in figure 6.1, most, i.e. 38 of the 45 journals, were founded after World War II, when scientific publishing became economically interesting. Big publishing houses entered the market and added to the growth of science, technology and the scholarly economy (Keller, 2005; Mierzejewska, 2008). Today the scholarly publishing market has a revenue of US$16.1 billion, over half of which is earned by ten publishing houses. This market concentration on big global players like Elsevier, Wiley-Blackwell, Wolters-Kluwer and Springer has lead to monopolistic conditions, which encourage annual increases in subscription rates (compare section 6.4; McCabe (2002); Mierzejewska (2008); Cope and Kalantzis (2009)).

Developments in science and technology influence journal scope, which often leads to title changes. Increasing specialization leads to splitting one serial into new 'sibling' journals like Phys Stat Sol A and Phys Stat Sol B, Act Cryst A and Act Cryst B, Nucl Instrum Meth A and Nucl Instrum Meth B, and so on. For example, Physica Status Solidi was split into sections A and B in 1970 and 1971 to focus on applied and basic research, respectively (Marx & Hoffmann, 2011).

Figure 6.2 displays the complicated structure of the Physical Review journal family. Phys Rev was founded in 1893 at Cornell University as a general physics journal. Until 1912, 33 volumes were published under its editor Edward Nichols, referred to as Series I. When the journal was taken over by APS in 1913, it started over with Volume 1. This second phase is called Series II. In 1929, Rev Mod Phys, originally called Physical Review Supplements, was founded to publish extensive review articles (Lustig, 2000). The minutes of the APS meeting in December 1928 read:

> That the Society authorize the publication of supplements to the Physical Review, these to contain resumés, discussions of topics of unusual interest and, in a broad sense, material that will give valuable aid to productive work in physics and yet that cannot appropriately be published in the Physical Review. (Webb, 1929, p. 276)

The foundation of Phys Rev Lett, which Lustig (2000) appraised as "undoubtedly the most important development in post-war physics journal publishing" (Lustig, 2000, p. 604), followed in 1958 and aimed at publishing short articles and letters of significance and immediate impact in physics research. In 1970, the original Phys Rev was split up into four more specialized sections: Phys Rev A with a focus on 'atomic, molecular, and optical physics', Phys Rev B on 'condensed matter and materials physics', Phys

2 http://www.physik.uni.augsburg.de/annalen/history/history.html
3 http://www.journalofrheology.org/about/publication_history

Rev C on ‘nuclear physics’ and Phys Rev D on ‘particles, fields, gravitation, and cosmology’. Phys Rev E followed in 1993 to cover ‘statistical, nonlinear, and soft matter physics’. In 1998, the first special topics journal focusing on ‘accelerators and beams’ was launched, as was Phys Rev Focus. The latter publishes selections from the other Phys Rev journals and explains them to students and non-specialists (Lustig, 2000). Phys Rev ST PER was founded in 2005 to cover physics education. The latest edition to the Physical Review family is Phys Rev X, which attaches special importance to rapid publication. Phys Rev X, Focus, ST AB and ST PER are open access.[4]

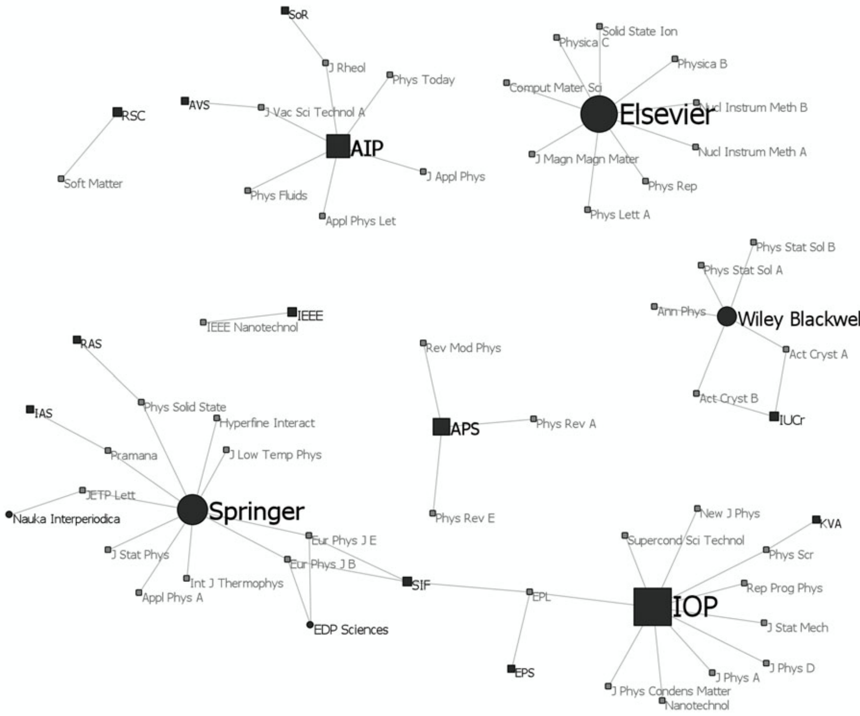

Figure 6.3 2-mode network of 45 journals and affiliated publishers.

6.1.2 Publisher Affiliation

Another characteristic of journal management that influences a journal’s prestige is its publisher affiliation. In academic publishing, a distinction can be made between commercial publishing houses and non-profit academic societies (McCabe, 2002). As mentioned above and described in section 6.4, the global market for scholarly journal publishing is concentrated more and more on large commercial publishing houses. As can be seen in figure 6.3, Elsevier, Springer and Wiley-Blackwell control large parts of the market of the 45 journals. However, IOP is the strongest publisher. Among the

4 http://publish.aps.org/about

18 actors, 13 are scholarly societies like IOP, AIP and APS, which publish a large number of titles, but also specialized societies like the American Vacuum Society (AVS), the Society of Rheology (SoR) or the International Union of Crystallography (IUCr), who publish one or a few journals, which function as the central communication channel of the particular community. Many of the small publishing societies distribute their journals through larger ones (e.g., SoR and AVS through AIP) or commercial publishers (e.g., Russian Academy of Sciences (RAS) through Springer). This is why journals in figure 6.3 are connected to more than one publisher. Commercial publishers are indicated by a circle, non-profit societies by a square. The size of the vertices represents the number of affiliated journals per publisher.

6.1.3 Scope

With the number of periodicals still growing, it is crucial for authors to select a suitable publication venue. In order to do so they "need to have a clear idea of the scope of the journals in the field" (Via, 1996, p. 366). A journal's scope is the self-portrait of the periodical, which can generally be found in a central position on the periodical's homepage. It emphasizes topics covered, publishing tradition and level of excellence, the up-to-dateness of its contents or the size of readership. Within a short paragraph the journal usually aims to attract potential authors and readers. An example can be found in figure 6.4, which displays the particular section of the website of J Magn Magn Mater.

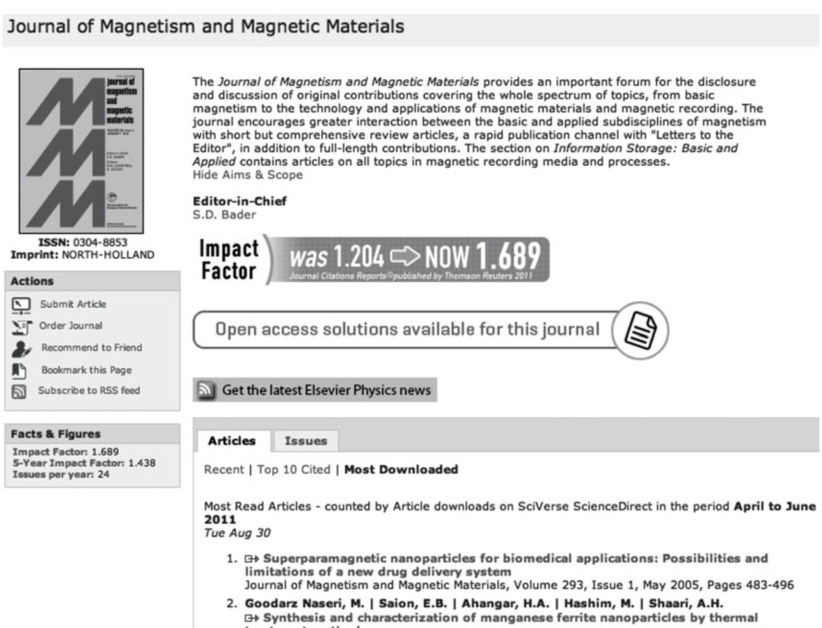

Figure 6.4 Scope of J Magn Magn Mater. Source: http://www.elsevier.com/wps/find/journaldescription.cws_home/505704/description

The websites of the 45 journals were examined in terms of their scopes. The major point highlighted in a journal's scope was thematic coverage (sometimes specified as broad or specific) and whether the periodical was theoretical, experimental or oriented towards application. Topics covered mentioned in the scope were grouped in eight fields of research. These classes are neither hierarchical nor exclusive, they simply aim to group those topics which were listed most frequently. Figure 6.5 depicts a 2-mode network graph of these eight topics (circles) and the mentioned orientation, i.e. experimental, theoretical and applied (triangles). It can be seen that five general physics journals did not specify any orientation towards application or theory. Three of those, Rep Prog Phys, Rev Mod Phys and Phys Rep are review journals. On the lower right of the graph, a cluster of journals can be identified that emphasize their orientation towards applications, especially those covering the field of materials science, surfaces and nanotechnology. In the upper left, periodicals are grouped around an experimental and theoretical orientation. This structure occurs because most of the journals emphasize that they publish both experimental and theoretical approaches: while 17 journals claimed both, Act Cryst B and J Phys D highlighted their experimental orientation and J Phys A, J Stat Phys, Phys Stat Sol A, Phys Stat Sol B and Physica C stressed their focus on theory. However, the latter three also claimed to publish application-oriented research.

Besides the thematic orientation, various 'unique selling points' were addressed in the scope section. Grouped in different categories, an overview can be found in table 6.1. Most of the journals emphasized their position in citation rankings or simply listed their impact factor scores. Only 7 of the 45 serials did not refer to their citation performance. The second most frequently emphasized aspect was journal usage: 26 periodicals gave information on article downloads. All Elsevier titles list the 10 most downloaded documents "counted by Article downloads on SciVerse ScienceDirect in the period April to June 2011"[5] (see figure 6.4) and Springer displays the five most frequently used documents and a detailed diagram (an example is shown in figure 4.10 in section 4.2.2) of daily downloads based on realtime data of the last 7, 30 or 90 days.[6]

Table 6.1 Aspects emphasized in journal scope: editorial board (EB), open access (OA), rapid publication (rapid), citation indicators (citation), usage, internationality (int.), abstracting & indexing services (A&I) and excellence (exc.).

Journal	**EB**	**OA**	**rapid**	**citations**	**usage**	**int.**	**A&I**	**exc.**
Act Cryst A				✓				
Act Cryst B				✓				
Ann Phys								✓
Appl Phys A	✓		✓	✓	✓	✓	✓	
Appl Phys Let			✓	✓				
Comput Mater Sci		✓		✓	✓			
EPL	✓	✓	✓	✓		✓	✓	
Eur Phys J B								

continued on next page

5 http://www.elsevier.com/wps/find/journaldescription.cws_home/523412/description#description
6 http://www.springer.com/materials/journal/10909

Journal	EB	OA	rapid	citations	usage	int.	A&I	exc.
Eur Phys J E								
Hyperfine Interact				✓	✓		✓	
IEEE Nanotechnol								✓
Int J Thermophys				✓	✓	✓	✓	✓
J Appl Phys			✓	✓				
J Low Temp Phys			✓	✓	✓	✓	✓	
J Magn Magn Mater		✓	✓	✓	✓			
J Phys A				✓	✓			
J Phys Condens Matter		✓	✓	✓	✓			✓
J Phys D				✓	✓	✓		✓
J Rheol				✓	✓			
J Stat Mech				✓	✓			
J Stat Phys			✓	✓	✓		✓	
J Vac Sci Technol A								
JETP Lett			✓	✓	✓			
Nanotechnol				✓	✓			✓
New J Phys		✓		✓	✓			✓
Nucl Instrum Meth A		✓		✓	✓			
Nucl Instrum Meth B		✓		✓	✓			
Phys Fluids			✓	✓				
Phys Lett A		✓	✓		✓			✓
Phys Rep				✓	✓			✓
Phys Rev A		✓		✓			✓	
Phys Rev E		✓		✓			✓	
Phys Scr			✓	✓	✓	✓		
Phys Solid State				✓	✓	Russia	✓	✓
Phys Stat Sol A			✓	✓		✓		✓
Phys Stat Sol B			✓	✓				✓
Phys Today								
Physica B		✓		✓	✓			✓
Physica C		✓	✓	✓	✓			
Pramana				✓	✓	India	✓	
Rep Prog Phys				✓		✓		✓
Rev Mod Phys			✓	✓			✓	
Soft Matter				✓		✓		
Solid State Ion				✓	✓			
Supercond Sci Technol				✓	✓	✓		✓
total	2	12	16	38	26	12	11	16

Excellence was a central point emphasized by 16 periodicals. Ann Phys and Int J Thermophys highlighted a tradition of excellence, while 14 other journals emphasized their reputation by requesting “highest scientific quality standards”[7] and claiming to publish only “novel and frontier physics”[8]. 16 journals emphasized rapidity of publication and the up-to-dateness of their published contents. While only New J Phys can be regarded as a true open-access journal, eleven other periodicals offered

7 http://iopscience.iop.org/0957-4484/page/Scope

8 http://www.elsevier.com/wps/find/journaldescription.cws_home/505705/description#description

open access solutions (see Springer's 'Open Choice' model described in section 6.4.2), which they highlighted on their scope webpage. The particular coverage by abstracting and indexing services was listed by 11 journals. Ten emphasized their internationality, while Pramana and Phys Solid State stated their national focuses on India and Russia, respectively. Appl Phys A and EPL mention the excellent composition of their editorial boards, which is examined more closely in the following.

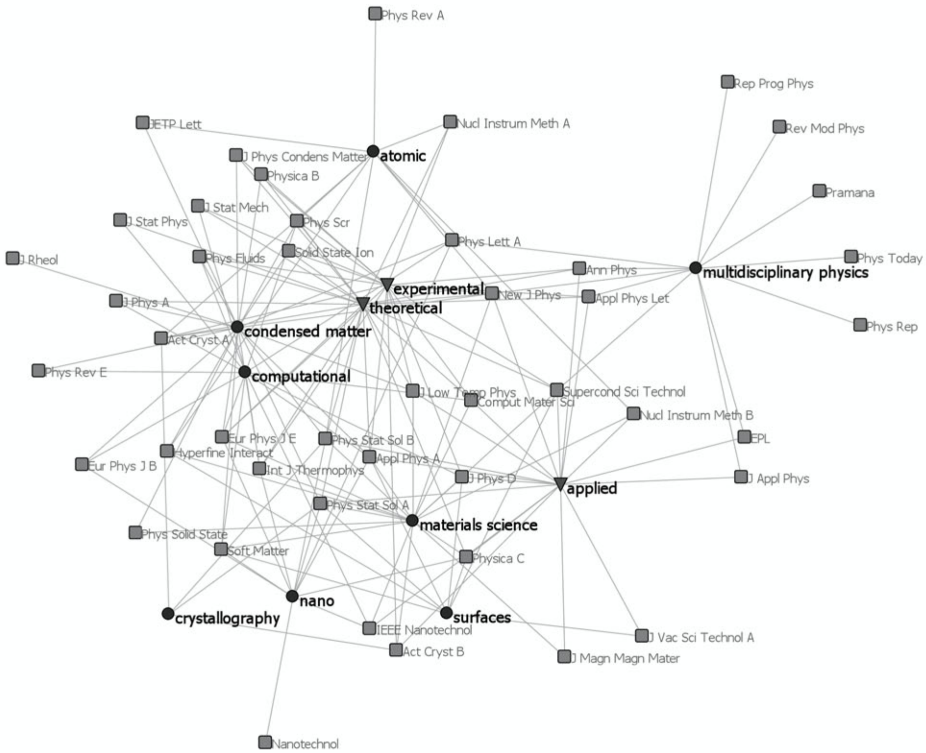

Figure 6.5 2-mode network of journals and covered subjects (circles) and orientation (triangle) highlighted in journal scope.

6.2 Composition of the Editorial Board

The editorial board functions as the gatekeeper of the journal and tries to maintain its function as a platform for scholarly communication. Shaping journal content, which represents the most important form of formal scholarly communication, journal editors occupy a powerful role in the scientific community (Nord & Nord, 1995; Braun, 2004; Braun, Zsindely, Diospatonyi, & Zador, 2007).

> For the satisfactory operation of the stratified system of science, the information screening activity of journal editorial boards - which designate the professional profile of those journals - is of paramount significance. (Zsindely, Schubert, & Braun, 1982b, p. 58)

> [T]he critical mentality and decisions of journal editors have so far protected and will also warrant in the future the social and intellectual integrity of science. The members of the editorial and advisory boards of science journals are rightly considered the gatekeepers of the science journals. (Braun, 2004, p. 96)

Editorial board membership represents an outstanding recognition of a scholar's scientific achievements, and can thus often be found in CVs for promotional purposes (Braun, 2004). Zsindely et al. (1982b) went as far as to propose measuring the scholarly impact of countries by the number of editors affiliated with it. Braun (2004) evaluated the citation rates of editors-in-chief and editorial board members and found a strong correlation with the journals' impact factors. In Braun et al. (2007), the mean citation rate of editors was introduced as a measure to evaluate the quality of the editorial board. Defined as the average number of citations received in a particular year for publications by the journal's editors of the two previous years, the so-called gatekeeping indicator of a journal is constructed in analogy to the citation-based impact factor (see section 5.1.1). Due to the problems associated with determining the correct number of publications per person described in section 2.2.1, the gatekeeping indicator is not computed at this point.

The composition of its editorial board is crucial to journal selection. A study among 5,513 authors by Rowlands and Nicholas (2005) identifies the reputation of the editorial board as the fifth most important reason for journal selection after journal reputation, readership, impact factor and speed of publication (compare figure 4.2 in section 4.1.1). Editorial board composition can be analyzed to evaluate the management of editorial processes. Its size (section 6.2.1) and the internationality of its members (section 6.2.2) can be assessed to gain insight into gatekeeping structures (Uzun, 2004). For the 45 journals, board membership data was collected from the journal's websites. Included were all current editors-in-chief and members of editorial and advisory boards together with the country of their affiliated institutions. Number of editors and country representation might have not been the same during the five years analyzed. However, board structures are not subject to extreme changes, so these limitations should not affect the general results (Nisonger, 2002). Technical staff was excluded. This information was collected for all journals except Phys Today, which did not provided any specific information on the editorial board when the data was collected in early 2011.[9] Phys Today is hence omitted from all evaluations concerning the editorial board.

6.2.1 Size

As editors are responsible for the selection of suitable referees and have to make the final decision regarding acceptance or rejection of a manuscript, a large number of editors can be beneficial, so each thematic specialty can be represented by its own expert. Of course, the size of the journal influences the number of submissions and the level of specialty so that the number of publications seems an appropriate measure to normalize editorial board size. Based on the assumption that the more editors are available per submission, the higher the level of expertise and intensity devoted to editorial decisions, the editor-publication ratio is proposed as an indication of gatekeeping quality.

9 It should be noted that after a website relaunch editorial board members were listed in August 2011 under http://www.physicstoday.org/about_us/our_people.

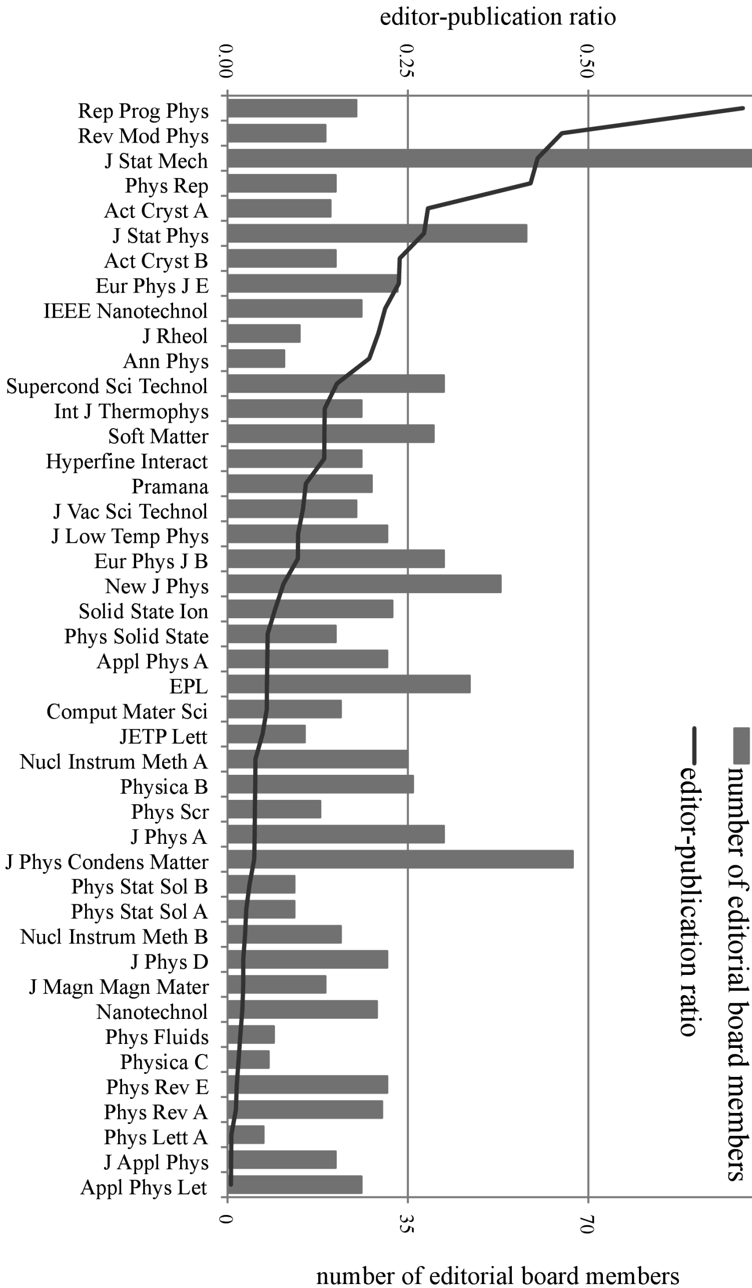

Figure 6.6 Number of editorial board members and editor-publication ratio for 44 journals. Phys Today is not included because it does not specify board members.

Figure 6.6 depicts the number of editorial board members and the editor-publication ratio, which is the number of members divided by the number of journal publications in 2008. The numbers show that the number of board members and journal output is not at all correlated. Pearson's r of the number of editors of a periodical and documents published in 2008 equals 0.018. Of the 44 journals, the median-sized board has 26 members. Values ranged from 7 (Phys Lett A) to 104 (J Stat Mech) people. The editor-publication ratio, i.e. editors normalized by journal output, was highest for the review journals Rep Prog Phys, Rev Mod Phys and Phys Rep. For every ten documents released in 2008, there were at least four editors to choose from to manage their publication. Due to the enormous size of its board, J Stat Mech scored a high editor-publication ratio of 0.430 as well. The smallest number of editors per publication were available at Appl Phys Let, J Appl Phys and Phys Lett A. Each member of their editorial boards had to manage 186.4, 200.7 and 213.8 publications on average, respectively. This equals an editor-publication ratio of 0.005 each.

Table 6.2 Statistics for the number of members and countries represented on the editorial board, editor-publication ratio and internationality of the editorial board.

	Mean	**Std. Deviation**	**Median**	**Min.**	**Max.**
Editorial board members	29.3	17.37	26	7.0	104.0
Editor-publication ratio	0.1	0.15	0	0.0	0.7
Represented countries	10.3	5.57	10	1.0	21.0
Internationality	66.8%	32.90%	79%	0.1%	100.0%

6.2.2 *Internationality*

Since international collaboration is associated with improvement of scholarly quality and international visibility in the sciences, the international composition of a journal's editorial board can be used as one indicator to reflect its international influence (Braun, 2004; Yue & Wilson, 2004). Evaluating the composition can provide information on gatekeepers and hence the quality of journal management (Gutierrez & Lopez-Nieva, 2001).

> [T]he editorial bodies of international journals are true "gatekeepers" and their professional status is positively correlated with the scientific quality of the international journals [. . .]. (Zsindely, Schubert, & Braun, 1982a, p. 76)

By evaluating editorial board members one can gain insights as to whether the periodical is able to attract renowned scientists representing an international community or if the board members are limited to one nationality or even one institution. Zsindely et al. (1982b) declared a periodical to be international if a minimum of five countries were represented by members of its editorial board. In the same ways that a serial's international attraction power can be analyzed based on the number of foreign authors (see section 2.2.3) it is able to attract, a journal's internationality can be examined in terms of its editors. Both metrics do, however, have the same problem of determining what is foreign and what is not. As described in section 2.2.3, it is problematic to define the country the journal is "usually associated" (Diodato, 1994) with. Following Nisonger (2002) and what was discussed before with regard to publishing authors (section 2.2.3), the internationality of the editorial board is examined through a set of metrics. These are listed in table 6.3 and include the number of different countries represented by editorial board members, the publishing country, the internationality of the editorial board, i.e. the the proportion of editors from countries other than the publishing country, and the distribution of editors per country on the board.

Table 6.3 Editorial board: Number of represented countries (*N*), publishing country (Publ.), internationality (Int.) and number of editors per country (top 3). Italics indicate that publishing and strongest country are identical.

Journal	*N*	**Publ.**	**Int.**	**Representation of top 3 countries**		
Act Cryst A	13	DNK	100%	CHE (4)	DEU (3)	USA (3)
Act Cryst B	13	DNK	100%	AUS (4)	USA (3)	*3 others (2)*
Ann Phys	2	*DEU*	9.1%	DEU (10)	CHE (1)	
Appl Phys A	11	*DEU*	61.3%	DEU (12)	AUT (5)	USA (5)
Appl Phys Let	6	*USA*	34.6%	USA (17)	CHN (3)	FRA/JPN (2)
Comput Mater Sci	9	NLD	95.5%	USA (13)	JPN (2)	*6 others (1)*
EPL	19	*FRA*	85.1%	FRA (7)	USA (7)	DEU (6)
Eur Phys J B	12	*DEU*	69.0%	DEU (13)	ITA (7)	USA (4)
Eur Phys J E	12	DEU	75.8%	FRA (8)	DEU (8)	GBR (4)
Hyperfine Interact	17	NLD	96.2%	JPN (4)	USA (4)	*3 others (2)*
IEEE Nanotechnol	7	*USA*	23.1%	USA (20)	*6 others (1)*	
Int J Thermophys	15	*USA*	65.4%	USA (9)	GBR (3)	JPN (2)
J Appl Phys	5	*USA*	38.1%	USA (13)	CHN (2)	FRA/JPN (2)
J Low Temp Phys	14	*USA*	67.7%	USA (10)	JPN (3)	*6 others (2)*
J Magn Magn Mater	11	NLD	94.7%	USA (8)	FRA (2)	*9 others (1)*
J Phys A	17	GBR	85.7%	USA (8)	DEU (7)	GBR (6)
J Phys Condens Matter	17	GBR	85.1%	USA (18)	GBR (10)	JPN (6)
J Phys D	14	GBR	90.3%	USA (6)	*4 others (3)*	
J Rheol	5	GBR	100%	USA(10)	*5 others (1)*	
J Stat Mech	21	GBR	91.3%	USA (20)	FRA (18)	DEU (12)
J Stat Phys	10	*USA*	56.9%	USA (25)	FRA (13)	DEU/ITA (5)
J Vac Sci Technol A	4	*USA*	12.0%	USA (22)	*3 others (1)*	
JETP Lett	1	*RUS*	0.0%	RUS (15)		
Nanotechnol	10	GBR	89.7%	USA (12)	*3 others (3)*	
New J Phys	20	GBR	90.6%	USA (16)	DEU (9)	GBR (5)
Nucl Instrum Meth A	16	NLD	97.1%	USA (11)	DEU (5)	CHE 3)
Nucl Instrum Meth B	15	NLD	100%	USA (4)	*4 others (2)*	
Phys Fluids	2	*USA*	11.1%	USA (8)	GBR (1)	
Phys Lett A	3	NLD	100%	USA (4)	GBR (2)	ITA (1)
Phys Rep	7	NLD	95.2%	USA (10)	DEU (2)	ISR (2)
Phys Rev A	8	*USA*	30.0%	USA (21)	FRA (2)	ITA (2)
Phys Rev E	8	*USA*	32.3%	USA (21)	DEU (3)	FRA (2)
Phys Scr	9	SWE	77.8%	NOR (5)	SWE (4)	FIN/USA (2)

*c*ontinued on next page

Journal	*N*	Publ.	Int.	Representation of top 3 countries		
Phys Solid State	1	*RUS*	0.0%	RUS (21)		
Phys Stat Sol A	6	*DEU*	61.5%	DEU (5)	USA (4)	*4 others (1)*
Phys Stat Sol B	7	*DEU*	53.8%	DEU (6)	USA (2)	*5 others (1)*
Physica B	16	*NLD*	75.0%	NDL (9)	JPN (6)	CHE/FRA (3)
Physica C	6	NLD	100%	JPN (2)	USA (2)	*4 others (1)*
Pramana	2	*IND*	3.6%	IND (27)	USA (1)	
Rep Prog Phys	9	GBR	88.0%	USA (14)	GBR (3)	DEU (2)
Rev Mod Phys	6	*USA*	31.6%	USA (13)	DEU (2)	*4 others (1)*
Soft Matter	18	GBR	90.0%	USA (7)	GBR (4)	*5 others (3)*
Solid State Ion	17	NLD	93.8%	JPN (5)	*3 others (4)*	
Supercond Sci Technol	11	GBR	81.0%	USA (12)	GBR (8)	JPN (7)

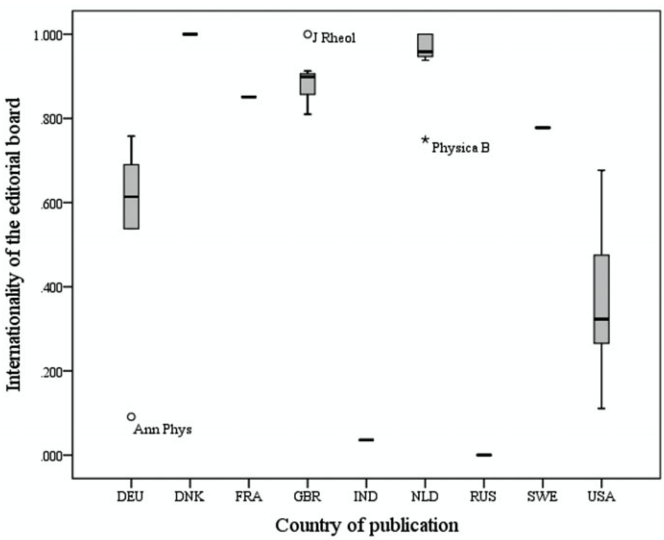

Figure 6.7 Boxplot displaying internationality of the editorial board per publishing country.

As can be seen in table 6.2, the average number of countries represented on the editorial board is 10, values vary between 1 and 21. With just one nation involved, JETP Lett and Phys Solid State can be identified as truely domestic Russian journals (table 6.3). According to Zsindely et al.'s (1982b) definition, Ann Phys, Pramana, Phys Fluids, Phys Lett A and J Vac Sci Technol A have a national focus regarding editorial board composition as well, because their editors represent less than five countries. For Ann Phys a restriction to the German-speaking area in terms of journal management is confirmed through the country of publication, low internationality and binational composition of the editorial board. The same applies to Pramana, which is published in India and 27 of 28 editors are affiliated with Indian institutions. Phys Fluids and J Vac Sci Technol A are both published in the US and 88.9% and 88.0% of board members are American. For Phys Lett A the domestic categorization by number of represented countries does not hold true, however. Published in the Netherlands, the internationality value amounts to 100%. With four US American, two British and one Italian member on the editorial board, Phys Lett A can be regarded as international. With 21 different nations represented in editorial management and an internationality score of 91.3% J Stat Mech can be regarded as highly internationalized, too. With 104 members, it had also the largest editorial board and the third highest editor-publication ratio.

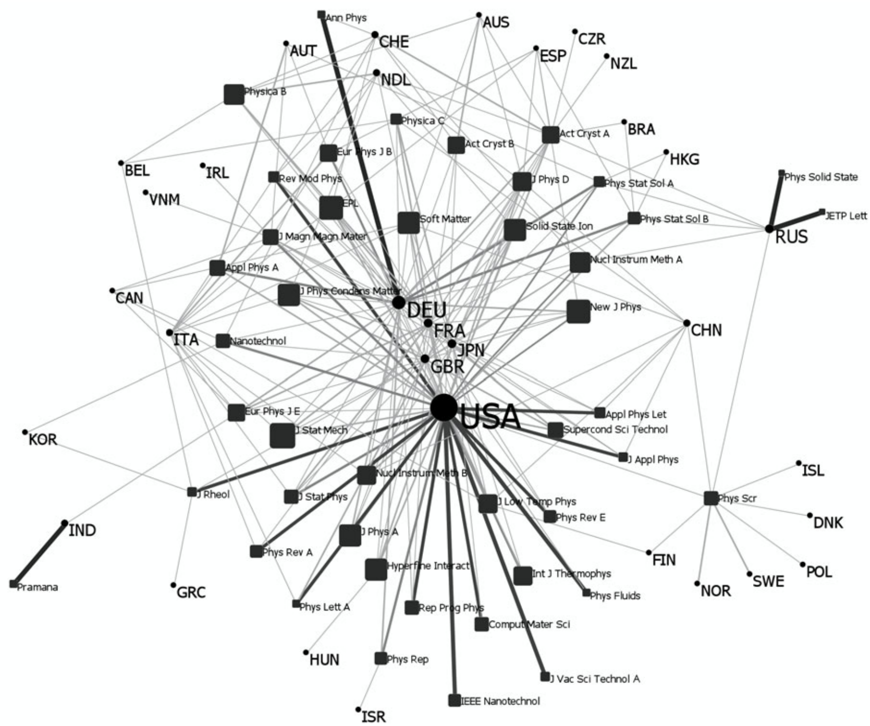

Figure 6.8 2-mode network of 44 journals and nations represented by editorial board members. Node size represents absolute number of contributing countries per journal and sum of normalized number of journals involved per country, respectively. Connections with a normalized strength below 0.05 are excluded.

The boxplots in figure 6.7 shows that the internationality of editorial boards varies between the countries where the journal is published. The mean internationality of editorial boards of US American journals is 36.6% while it equals 94.8% for periodicals published in the Netherlands and 89.2% for those in the UK. The highest internationality values can be observed for Denmark but this result has to be handled with care due to the extremely small number of journals. The same applies to France, India, Russia and Sweden. Differences are, however, striking between Russia and India on the one hand, which publish truely domestic journals, and Denmark, France and Sweden on the other, which show high internationality values. Germany's editorial board internationality amounts to a mean of 55.1% but a large deviation from the standard of 23.7% is caused by Ann Phys, which with an internationality of 9.1% could be identified as a domestic journal in terms of board membership. The median internationality of periodicals published in Germany is thus as high as 61.4%.

Similar to figure 2.17 in section 2.2.3, a 2-mode network of journals and countries represented on the editorial board can show the position of the periodicals' gatekeepers in the international scholarly community. Figure 6.8 displays the affiliation of editorial board members to the particular country of their institution. Link strength equates the number of editors from the particular nation normalized by the total number of board members, i.e. the percentage of membership per country per board. All connections to countries representing less than 5.0% of the board were omitted, which reduced the 2-mode network to 44 journals and 32 countries. Journal node size indicates the number countries represented on the editorial board, while country node size corresponds to the sum of the normalized inlinks, i.e. the overall influence on the 44 editorial boards.

On the one hand, the network reveals the leading positions of American board members, which can be seen in table 6.3 as well: the USA is most frequently represented on the editorial boards of 29 of the 44 journals. The network depicts the central positions of Germany, UK, France and Japan as well. As in figure 2.17 (section 2.2.3), the composition of the editorial board reflects the national scope of Pramana, Solid State Ion and JETP Lett towards India and Russia, respectively, which is also confirmed by the data displayed in figure 6.7 and table 6.3.

6.3 From Submission to Publication

The basic steps from submission to publication of a journal article involve the preparation of a manuscript, where the researcher describes his research results and the ideas behind it, the submission process including peer review and editor's approval and publication in an electronic and/or print form. An overview of the subprocesses included in the review process is given in section 6.3.1.

Mierzejewska (2008) introduced the value-added chain of scholarly journals to illustrate the process from submission to publication in three layers. As seen in layer 2 of figure 6.9, four groups of actors are involved in the publication process, namely the authors, editors and referees, publishers and libraries and/or distribution agents, each of whom play a significant part in the scholarly publication process, that fulfills four main functions listed in layer 3: registration, certification, dissemination and archiving (Rowland, 2002).Each step of the process depicted in layer 1 adds value to the journal publication. Of course the most value to scientific publishing is added by the author, who contributes the actual content (Tenopir & King, 2000). Although authors are crucial to the existence of a periodical, they represent the smallest cost factor or are even charged for publication (see author charges for open access journals in section 6.4.2). Author motivation to publish lies primarily in career advancement (Mierzejewska, 2008). Through publication authors claim priority for their research results (Zuckerman & Merton, 1971). The value added by the editorial board of the journal is quality control applied to submitted manuscripts by selection and expert assessment (Meier, 2002). The publisher manages article and journal layouting, copyright protection and publication. Distribution agents and libraries are responsible for providing immediate and long-term access to published content for readers (Meier, 2002; Keller, 2005; Mierzejewska, 2008).

Many factors influence an author's choice of a suitable venue for publication. Different studies evaluating the journal selection process by readers and authors have found that journal prestige, readership and the impact factor were the most important (Schauder (1994); Tenopir and King (2000); Rowlands and Nicholas (2005), see also section 4.1.1). Journal price is among to the least important factors influencing an author's choice of submission, but is crucial to librarians who need to manage subscriptions within a limited budget (Tenopir & King, 2000; Björk & Holmström, 2006). Journal pricing is described in section 6.4.3.

Most of these journal selection factors and their interactions are displayed in the net value model by Björk and Holmström (2006) in figure 6.10, which identifies 30 concepts involved in journal selection, but does not rank them by relevance, since the influence of single factors "is highly dependent on individual preferences due to career stage, and personality, etc." (Björk & Holmström, 2006, p. 149). Although an author seeks to publish in the most prestigious journal of his field, he might be put off by long publication lags or a high risk of being rejected. These choices depend on the individual's willingness to take risks and how he evaluates the quality of his own particular submission (Björk & Holmström, 2006).

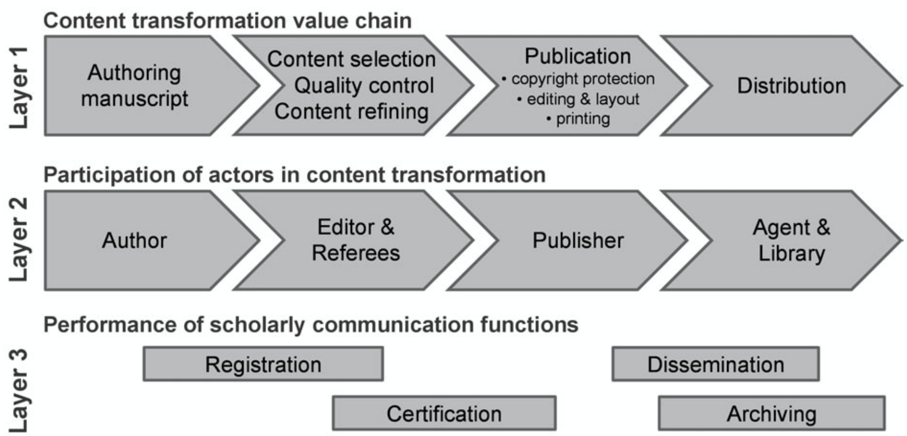

Figure 6.9 Value chain of the academic journal in three layers. Source: Mierzejewska (2008, p. 74).

Of the 30 factors in figure 6.10 which are grouped into four blocks, i.e. journal infrastructure, readership, prestige and performance, eight influence the author's selection directly (direct arrows pointing to 'Net value of submission'), while the other 22 affect him only indirectly. Those concepts which can be attributed to journal management are circled. While the prestige of the editorial board was described in section 6.2 above and author charges are thematized in section 6.4.2, the following subsections describe two of the most important journal selection factors based on and influenced by journal management, i.e. publication delays (section 6.3.2) and rejection rates (section 6.3.3). Together with journal correction rates (section 6.3.4) these metrics can be used to evaluate the peer review process, which is briefly described in the following.

6.3.1 Review Process

The review process which journal submissions have to go through before publication serves the purpose of quality control.

> The purposes of reviewing submitted manuscripts include the elimination of errors and omissions, the encouragement of consideration of other information and interpretations, and the maintenance of standards for significant new results. (Abt, 1992, p. 445)

Through the review process, the journal influences the science system by accepting and rejecting certain contents. The selection process regulates information overflow and manages scarcity of publication space. As a side effect, the journal affects an author's scholarly impact and prestige (Meier, 2002).

Although peer review in its current form has been widely criticized for various reasons including publication delay, subjectivity, biases, discrimination of innovation and other forms of misuse and abuse, no reasonable alternative to the quality control it provides has yet been found (Rowland, 2002; Bornmann & Daniel, 2008; Linde & Stock, 2011).

Proposed alternatives include ex post review, i.e. the application of quality control after publication, which can be disregarded, for it leads to an even greater flood of information (Meier, 2002). Peer commentary allows researchers to comment on publications which have undergone traditional peer review. It can thus be seen as a complement to peer review but not as a replacement (Rowland, 2002). Public peer review on the other hand, wants to replace the traditional way of closed peer review. It is an attempt to improve the transparency of the review process by allowing public comments. Even though first studies (Pöschl, 2004) show that the quality of the public review process remains intact and that decisions are more objective, this method has not been able to establish itself either. Introduced in June 2006, the attempt by Nature had to be cancelled after six month due to lack of participants (in terms of authors and commenting users) and lack of usefulness of comments (Greaves et al., 2006).

Varian (1998) proposes a ranking system of editors and readers, where individual filters can be applied in the form of a recommender system. Meier (2002) proposes to outsource the public review into another form of journal. Although this would make the review process more transparent and solve most of its deficiencies, it is hard to imagine a journal publishing unrefereed submissions and then handing the publicly reviewed paper over to another journal. While the journal hosting the open review process would have to pass on the publication after successful quality control, the other journal would have to publish articles that had been previously published elsewhere. Both journals would have to compete for the same audience and the readership would have to read both or choose between quality control or topicality.

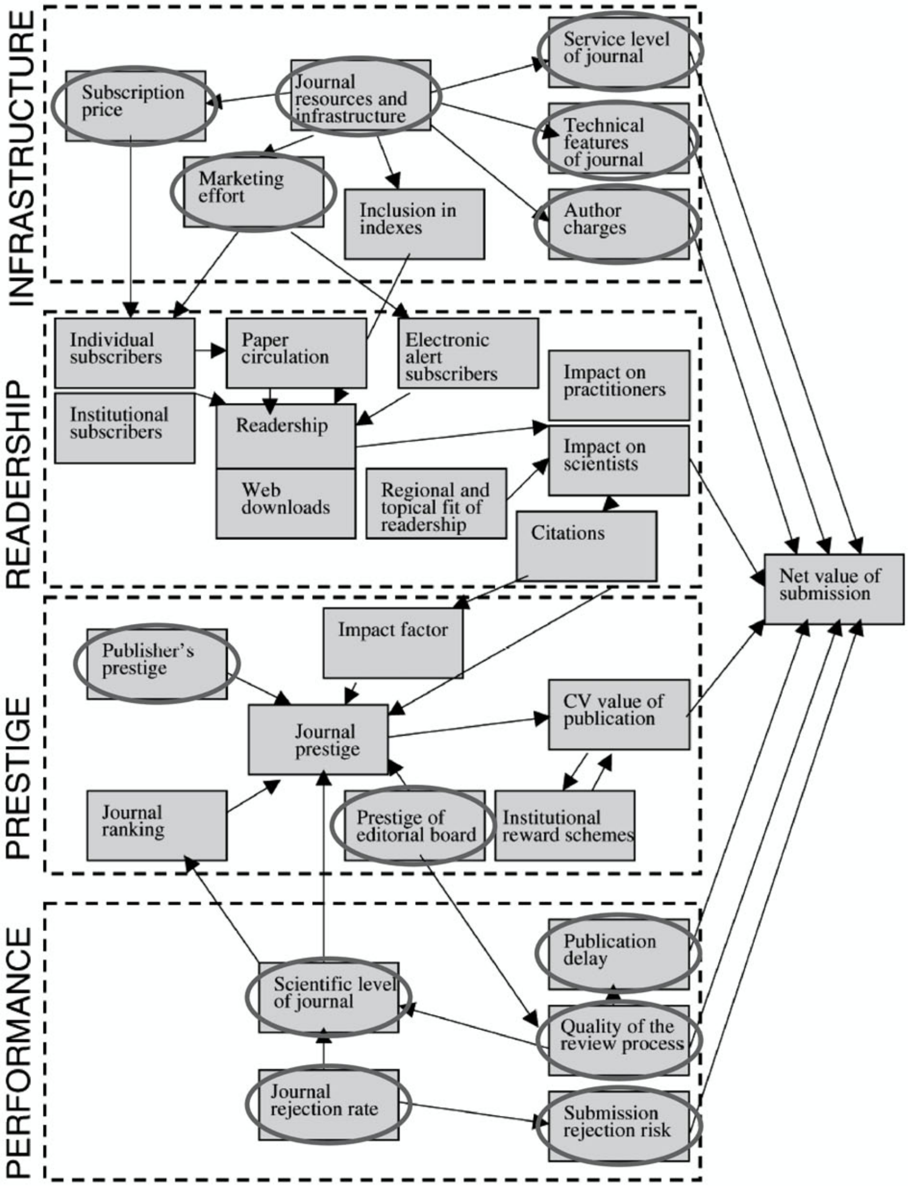

Figure 6.10 Net value model of journal selection (own marking of concepts associated with journal management). Source: Björk and Holmström (2006, p. 149)

A separation of publication and review process can be found in ArXiv[10], an online repository used by researchers to publish electronic documents. ArXiv was founded in 1991 at the Los Alamos National Laboratories by Paul Ginsparg in order to share electronic research results with his colleagues (Meier, 2002). Although ArXiv has experienced great success especially in physics after financial support by the American Physical Society, it has not replaced the journals as such due to the lack of quality control. ArXiv is used to make research results available earlier (by uploading pre-prints) and to a larger audience, if journal articles are uploaded after publication, mostly in a layout different from the actual document (green road to open access, see section 6.4.2). It is currently run by Cornell University Library and financially supported by voluntary contributions from various research institutions and associations through a collaborative business plan announced at the beginning of 2010.[11] As of June 2011, ArXiv contains more than 680,000 documents in the fields of physics, mathematics, computer science, quantitative biology, quantitative finance and statistics.[12] Despite its success, ArXiv has not replaced the traditional journals, since these are still needed for quality control and gatekeeping in scholarly communication and for their prestige in scholarly careers.

As alternative solutions have failed so far, peer review remains the only viable way to ensure the most important aspects of journal editing, i.e. the selection process and quality control (Keller, 2005).

> A major objection to non-refereeing (or post-publication commentary) is that no one has the time to read all the poor material to find the occasional good paper; referees save the rest of us time, by sorting the material out into an order of descending quality. (Rowland, 2002, p. 255)

Since the traditional form of peer review, which is literally the evaluation by fellow scholars, has not yet been replaced and remains the gold standard applied by all examined journals, this section does not question the method as such but is limited to a brief description of the editorial review process in its current form.

Figure 6.11 shows the steps involved in the review process (Weller, 2002). A central point of peer review is that manuscript evaluation takes place outside the editorial office (Weller, 2002). Three different stakeholders can be identified who play a part in peer review, namely the author, editor and referee (Shugan, 2007). After submission by the author, the manuscript reaches the editor, who functions as the initial gatekeeper and makes a "peremptory judgement of relevance" (Cope & Kalantzis, 2009, p. 38). If the editor decides to reject the submission without further review – this is referred to as a desk rejection (Shugan, 2007) – the author is notified of the rejection and can decide whether to submit the manuscript to another journal. Desk rejections occur if the editor regards the document as of too low quality or if the content is out of the journal's scope (Rowland, 2002). Thus, the initial selection procedure fulfills two functions:

> First, manuscripts on topics too far afield of the journal mission can be quickly handled, allowing the author to find a more appropriate journal without additional

10 http://arxiv.org
11 http://news.library.cornell.edu/news/arxiv
12 http://arxiv.org

> delay. Second, if the manuscript is of poor quality, the editor may save the valuable time and effort of peer reviewers. (Schultz, 2010b, p. 237)

The percentage of rejected submissions forms the rejection rate. It is assumed to reflect journal quality (see section 6.3.3), since a high rejection rate indicates that the journal can afford to choose from a large number of high-quality submissions. If the submitted manuscript has passed the first hurdle, it is usually sent to two or three referees and more may be included at a later stages of the review process. Schultz (2010a) and Linde and Stock (2011) found no significant differences regarding acceptance and rejection between review processes including two or three reviewers. A manuscript can be rejected at any stage of the review process (Weller, 2002). In rare cases the editor might also accept it without any adjustments, in which case the manuscript is directly published.

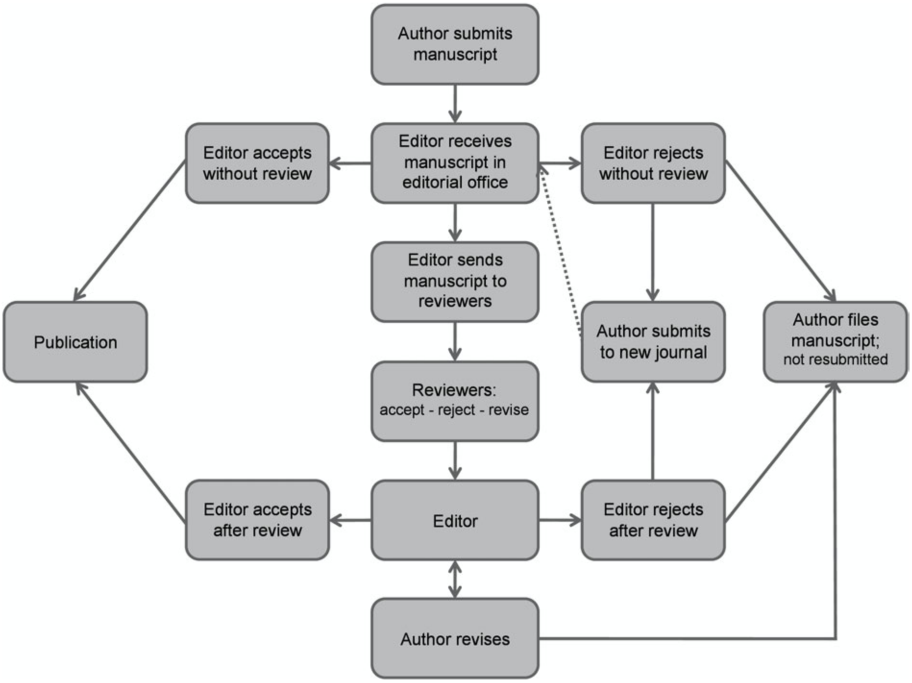

Figure 6.11 The peer review process. Source: Weller (2002, p. 2)

Referees are chosen as subject experts by the editor, who often is not an expert himself, to make corrections and judge the quality of the manuscript (Cope & Kalantzis, 2009). At J Stat Mech, controlled author keywords are used to automatically find a suitable expert (SISSA and IOP Publishing (2004), see section 3.2.2). When referees are invited to review, they can of course turn down the request. Based on title and abstract, and sometimes author name, they should declare any conflict of interest, e.g. if they are prejudiced against the topic or, if applicable, are close to the author. Referees are forbidden to reveal their identity as such and to use any information obtained from the manuscript before its publication (Cope & Kalantzis, 2009). Like authors, referees are not paid for their services to the journal (Keller, 2005; Rowland, 2002).

If they agree to review the manuscript referees are provided with the text and can decide to reject, accept directly or accept the submission with revisions (Weller, 2002). Since the editor-in-chief aims for fast, on-time publication, he urges the referees to deliver within a certain period of time (Shugan, 2007). Usually they provide comments on their decisions, some journals also require scoring sheets to be filled out. Shugan (2007) sums up what is expected of the referees:

> Review teams should appraise the importance of the research objective, meticulously check procedures (logic, methods, derivations, data collection, etc.), evaluate the evidence underlying all claims, ensure an adequate and accurate presentation of the results, and consider the contribution of the manuscript to extant knowledge. Review teams should clearly state their concerns and, possibly, recommend courses of actions. However, reviewer teams have no obligations to remedy deficiencies in any of these areas. Improvements are only ancillary. (Shugan, 2007, p. 590)

Depending on the quality of the manuscript and/or the referees' time, thoroughness and knowledge of the subject, recommendations may vary between improvement of graphical material or expanding a reference list to major changes of methods and results (Abt, 1992). The editor receives the referees' recommendations and with this information again decides on acceptance or rejection.

If the manuscript needs revision, the author is provided with the referees' comments in order to satisfy their requirements. He sends the revised manuscript back to the editor, who again decides on how to proceed. This process is repeated until a final decision is reached. Based on particular decision behavior, Schultz (2010a) defined three types of editors: 'editor omnius' who rejects the paper only if all referees recommend rejection, 'editor populus', who sticks to the majority's vote and 'editor quisius', who decides upon rejection, if one of the referees did so. Decision behavior differs between editors but may also vary from one submission to another for one and the same editor. Mostly a final decision can be reached after the first round of review, more than two rounds are extremely rare (Abt, 1992; Schultz, 2010a). If the manuscript is rejected, the author will most likely try to submit it to another journal and the review process starts over (Linde & Stock, 2011).

Peer review can occur as 'open', 'blind' or 'double blind'. While in the open form the names of the author and the referee are both known by all stakeholders, both identities are concealed in the latter. As Linde and Stock (2011) say double-blind peer review is often "hardly possible in practice" (Linde & Stock, 2011, p. 224), since the experienced referee can identify the author by the submitted topic and reference list. Blind peer review is the most common form, where the referee knows the identity of the author but the referee remains anonymous (Rowland, 2002; Linde & Stock, 2011).

One of the main points of criticism of the peer review process is the delay it causes (Clark, Singleton-Jackson, & Newsom, 2000). Publication delay and time consumed by the review process are discussed in detail in section 6.3.2. Clark et al. (2000) demonstrate the delays caused by queue time through mailing and manuscripts lying inactively on an editor's desk and the effect on the economy of time achieved by an electronic manuscript submission and tracking system. E-mail communication and online manuscript submission and tracking systems like Thomson Reuters' ScholarOne Manuscripts[13] or Editorial Manager[14] have sped up communication between the three stakeholders, author, editor and referee quite considerably (Rowland, 2002).

6.3.2 Publication Delay

Since scholarly journals function as the main communication channel in the sciences, the speed with which articles are published is crucial to the communication process and thus the advancement of science. The time between submission and publication is referred to as publication delay, lag or lapse (Amat, 2008).

Peer review constitutes the main factor delaying publication but, as described above, represents a necessary form of quality control which cannot be replaced. The review process is, however, not responsible for the entire time lag between submission and publication. The actual production process of a journal issue delays prompt publication as well. Diospatonyi, Horvai, and Braun (2001) divide the publication lag into two periods from submission to acceptance and from acceptance to publication. While the former delay is caused by the review process, which can indicate thoroughness, the delay from acceptance to publication is referred to as the technical phase influenced by paper backlog and "matter of management, industrial organization, and discipline" (Diospatonyi et al., 2001, p. 1455).

Overall, long delays are considered a negative factor preventing important discussions and scientific discourse and delaying priority claims (Rassam, 2001; Amat, 2008). Sometimes research results are outdated and data has become obsolete by the time the article is published (Clark et al., 2000; Keller, 2005). Publication delay is thus an important indicator in evaluating a journal's timeliness. A short period of time between submission and publication of a document is of interest to all users of journal evaluation methods: authors, readers, librarians, editors and publishers. Authors are interested in publishing quickly in order to immediately distribute their research results and claim priority (Zuckerman & Merton, 1971). Among the physicists surveyed by Tenopir and King (2000), speed of publication was the second most important factor for choosing a periodical for publication (compare table 4.1 in section 4.1.1). Other studies confirm the importance of keeping publication delays to a minimum (Schauder, 1994; Rowlands & Nicholas, 2005). One respondent of the survey conducted by Rowlands and Nicholas (2005) complained:

> While I wholeheartedly support the current publishing system and think that peer review is critical to maintaining a quality publishing industry, the delays that the system currently suffers are a barrier to advances in research. (Rowlands & Nicholas, 2005, p. 51)

Readers (and thus librarians who supply them) seek to find the latest information and do not want to bother with out-dated methods or obsolete data. For editors and publishers it is important to monitor the publication delay of their own periodicals for optimization and that of competitors for market observation purposes (Amat, 2008).

13 http://scholarone.com/products/manuscript
14 http://www.editorialmanager.com

Abt (1992) examined publication times of documents published in 1990 in seven journals from different scientific disciplines and "conclude[s] that the physicists are the fastest to have their papers published, probably due to competition within the field" (Abt, 1992, p. 447). As can be seen in table 6.4, it took on average 196 days for a paper in Physical Review B to appear, whereas a year lay between submission and publication of the average geophysical document. In mathematics, publication delay was greatest with an average of 603 days (Abt, 1992).

Table 6.4 Average number of days between submission and publication of documents published in seven journals in 1990. Source: Abt (1992)

Journal	Field	Mean	Std. Deviation
Physical Review B	Physics	196	70
Journal of the American Chemical Society	Chemistry	235	94
Radiology	Radiology	257	94
Astrophysical Journal	Astrophysics	314	166
Journal of Geophysical Research	Geophysics	370	123
American Journal of Psychiatry	Psychiatry	412	126
American Journal of Mathematics	Mathematics	603	188

Houry, Ernst, Weiss, and Segal (1999) analyzed medical journals in 1996 and computed mean lags between 129 and 328 days. Mathie and Jaffe (1987) found delays of four month to two years for surgical journals in 1986 and 1987 and underlined the importance of timeliness to authors when choosing a periodical for publication. Mean publication lags of 6.3 to 16.9 months were found by Labanaris et al. (2007), who evaluated the publication speed of original research articles published in seven surgical journals in 2005. Amat (2008) found mean publication lags for 14 food research journals in 2004 ranging from 188 to 493 days. In 2009, the publishers of J Phys A announced a reduction of the time between submission and first decision to less than 50 days (Gillan, 2009). Phys Scr claimed a median of 63 days for the same year and 38 days between acceptance and online publication (Physica Scripta, 2011).

Since Abt's study, the publication process has been accelerated. Electronic manuscript tracking systems have optimized the review process in terms of artificial delays and emails have been able to speed it up to a great extent (Wills & Wills, 1996; Meier, 2002; Tobin, 2004). Previously, regular mail had been responsible for great delays in the correspondence between authors, editors and referees (Varian, 1998). With electronic publishing, delays caused by printing and mail distribution have been eliminated (Mierzejewska, 2008; Tenopir & King, 2009). Also the concept of the journal issue has become less important. Documents are available months before they are actually published. Issue and page numbering are relics from print publishing and today serve at most formal citation purposes.

Table 6.5 Statistics for the number of days between the dates of submission, acceptance and online publication of a sample of 180 research articles published in 36 of the analyzed journals between 2004 and 2008. Acceptance dates were only listed in a subset of 106 documents.

	N	Mean	Std. Deviation	Median	Min.	Max.
submission / acception	106	121.0	98.00	90.0	1	535
acception / publication	106	62.3	66.55	46.0	4	502
submission / publication	180	188.4	135.89	152.5	13	1130

In order to gain insight into the average publication delays of the journals under analysis, a small non-representative set of documents were examined per periodical. If available, information on the date of submission is listed in the document, but journal policies differ regarding the level of detail of the data or whether dates are provided at all. Since the data has to be extracted manually from the documents, data collection is time and labor intensive (Diospatonyi et al., 2001). Due to the huge effort of manual data collection, only five documents were randomly selected for each journal and checked for information regarding dates of submission and publication. For reasons of comparability, the selection was limited to research articles, because submission and review processes differ or do not apply to other document types. Phys Rep and Rep Prog Phys were excluded because they did not publish any research articles. For seven journals, the selected documents did not include sufficient information: Phys Today did not list any dates and Hyperfine Interact and Rev Mod Phys did not specify the date of submission but only that of online publication. Int J Thermophys, J Low Temp Phys, J Magn Magn Mater and Pramana did not include date information in any of the selected documents.

For the remaining 36 journals, the length of time between submission and online availability was computed. The actual publication date was selected, if online publication was not specified, because, as mentioned above, online availability is what matters to authors and readers. For the 180 documents analyzed, the average period from submission to online publication was 188 days (table 6.5), which is comparable to the results by Abt (1992) for Physical Review B. The article with the shortest delay was published in Physica C in 2007; it was submitted on February 2nd and available online on the 15th of the same month. The longest delay discovered was 1,130 days and occurred in IEEE Nanotechnol. The paper was submitted in August 2004 and not published until almost three years later in September 2007. For a subset of 106 papers the date of acceptance was provided as well, indicating that on average two thirds of the publication delay is caused by the actual review process, while one third can be attributed to technical production-related causes (table 6.5). Phys Scr was one of the journals that provided the date of acceptance. The period from submission to acceptance as measured by the small sample of five documents was 104 (median = 71) and that from acceptance to online publication 70 (median = 49). The journal claims for 2009 that “the receipt to first decision time was a median average of 63 days, and the time between accept and online publication was 38 days” (Physica Scripta, 2011, p. 2).

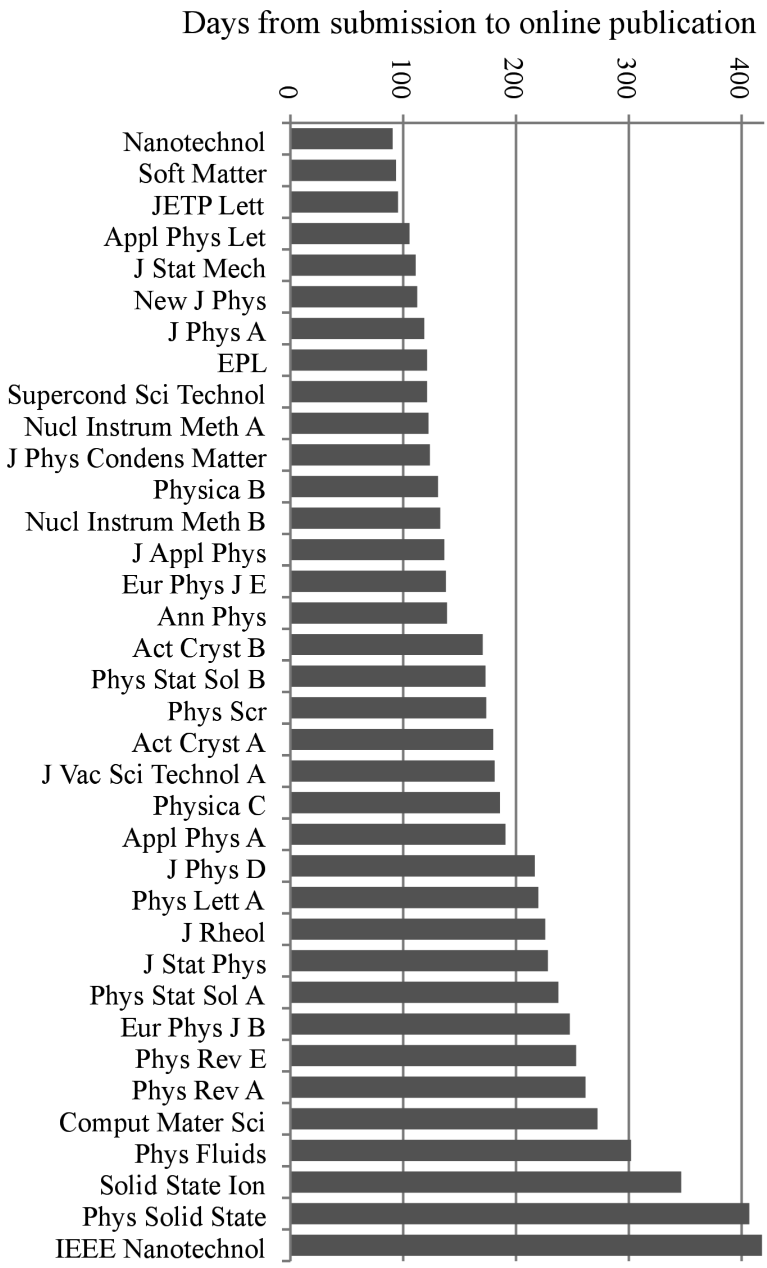

Figure 6.12 Mean number of days between submission and online publication for a small sample of five research articles per journal.

Table 6.6 Statistics for the number of days between the dates of submission, revision, acceptance and online publication of all research articles publication in Solid State Ion in 2008.

	N	Mean	Std. Deviation	Median	Min.	Max.
submission / revision	203	160.4	122.04	136	14	1100
revision / acception	203	22.6	27.29	12	0	160
acception / publication	204	54.0	14.40	52	30	120
submission / publication	204	236.6	129.54	210.5	85	1221

Due to the small size of the sample, these results only reveal a general tendency but are, however, not representative. Thus, publication delay was examined in detail for one journal during one year of publication. Solid State Ion was chosen since it was one of three[15] journals where all the sample documents listed additional dates of the days the papers were revised and accepted, which made it possible to determine the exact length of each sub-process between submission and publication. For all 204 research articles published in Solid State Ion in 2008, these four dates were extracted from the documents. Except for one paper, where the revision date was not specified, all dates were available and time lags could be computed.

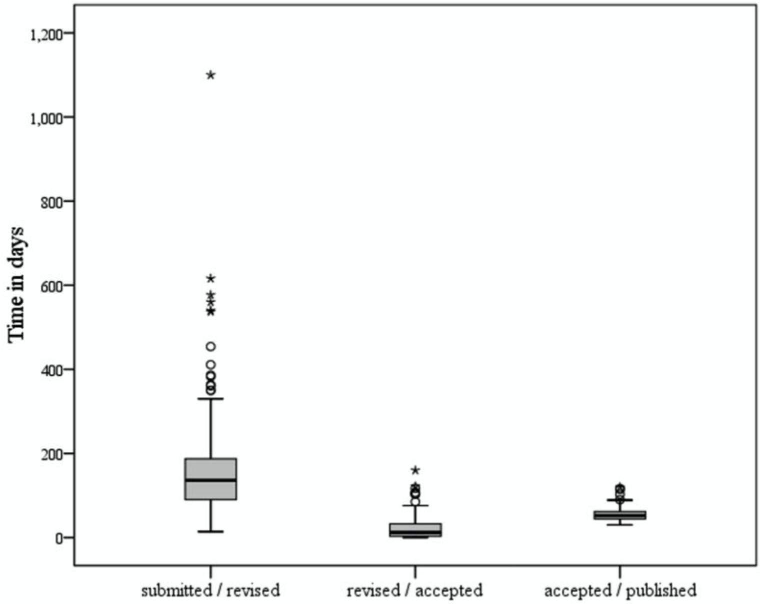

Figure 6.13 Boxplots displaying the the number of days between the dates of submission, revision, acceptance and online publication of all research articles published in Solid State Ion in 2008.

15 The other two journals listing submission, acceptance, revision and publication dates were Phys Stat Sol A and Phys Stat Sol B.

As can be seen in table 6.6 and figure 6.13, the mean time from submission to publication in Solid State Ion in 2008 was 237 days, which is significantly lower than the value based on the sample (figure 6.12), which shows that the selection is not representative, although the random sample for Solid State Ion did not contain documents from 2008. As stated above, the publication delay can be subdivided into peer review and technical delay, while the former consists of two sub-processes, i.e. time from submission to revision and revision to acceptance. The average peer review process for Solid State Ion papers lasted 160 days, while the mean number of days from completion of review to acceptance took 23 and from acceptance to publication 54 days. This confirms previous findings that in physics peer review is responsible for two-thirds of publication time. Abt (1992) found that during most of the review process documents were with the authors not the referees, indicating that most of the delay is caused by the authors themselves. In the area of food research, the technical delay takes longer than the actual review (Amat, 2008).

The fastest review for Solid State Ion was completed in two weeks, while the longest took three years. Fifteen documents were accepted on the same day that the review finished. The period between acceptance and publication ranged from one to four months. The fastest article was available 85 days after submission. It was submitted on October 10th, 2007, after a 40-day review process it was accepted on November 29th and published in January 2008.

6.3.3 Rejection Rate

The rejection rate of a journal is defined as the number of submissions rejected in relation to all submissions during a certain period of time (Ehara & Takahashi, 2007). In general, a high rejection rate indicates journal quality and prestige (Keller, 2005). It is influenced by the journal's ability to attract a large number of submissions, which again can be affected by the journal's reputation and/or breadth of topics covered (Schultz, 2010b).

> Since all scientific journals apply a selection process, it is to be supposed that in those of greater quality this process is stricter and more competitive [...] (Guerrero-Bote, Zapico-Alonso, Espinosa-Calvo, Gomez-Crisostomo, & De Moya-Anegon, 2007, p. 424)

A high rejection rate thus indicates that the journal can afford to choose from a large market of ideas (Mierzejewska (2008), section 6.4) and it can be assumed that it chooses what the referees thought to be the best manuscripts.

> An underlying assumption [...] is that the most important journals in a field or discipline receive the most manuscripts. Therefore, the thinking continues, the journals that receive the most manuscripts can be the most selective, reject the most manuscripts and, as a result, publish the most important material in a field. (Weller, 2002, p. 43)

Bornmann and Daniel (2008) were in the advantageous position of having access to detailed information about accepted and rejected manuscripts at Angewandte Chemie

International Edition and alternative publication of the latter. They were thus able to prove that accepted submissions were indeed more frequently cited than those that were rejected at first but published elsewhere. They concluded that Angewandte Chemie International Edition succeeded in accepting the high-quality papers and rejecting manuscripts of lower impact (Bornmann & Daniel, 2008).

Ehara and Takahashi (2007) found that the most common reason for rejecting a submission to the American Journal of Roentgenology from 2003 to 2005 was the lack of appropriate, i.e. useful and recent, information on the topic. The major reasons for rejection at Clinical and Experimental Ophtamology, where only 26.4% of submissions were accepted, was that the manuscripts did ‘not add to current literature’ or due to ‘poor methodology/questionable results’ (Wyness, McGhee, & Patel, 2009). In Indian Pediatrics it was ‘absence of a message’ and ‘poor originality’ (Gupta, Kaur, Sharma, Shah, & Choudhury, 2006). Kurmis and Kurmis (2006) collected rejection rates of 17 radiology journals ranging from 8% to 80%, and found that these rates were poorly correlated with the journals’ impact factors.

Of course, editorial decisions such as acceptance or rejection depend on the individual authors, referees and editors, and one can argue like the editor of Atmospheric Chemistry and Physics, Ulrich Pöschl, who defends the low rejection rates of his journal by the high average quality of submissions (Pöschl, 2004). Since it is not possible to objectively and comparably judge the quality of submissions, this factor will be disregarded (Schultz, 2010b). This reveals the importance of a multidimensional approach. Rejection rates assess no more but no less than the general selections of submissions by the journal for publication. Other factors are reflected in different metrics.

Since rejection and acceptance largely depend on the submission process, only unsolicited, i.e. uninvited, manuscripts should be considered when analyzing the rejection rate. As review articles are largely solicited by journal editors, hardly any review is ever rejected. The submission of other document types such as proceedings papers, editorials and letters is subject to special conditions as well, so, if possible, these types should be excluded or treated separately when analyzing acceptance or rejection rates.

Cabell’s Directories of Publishing Opportunities are one of the few sources that collect and list journal acceptance rates. Cabell’s lists the percentage of accepted manuscripts in comparison to all manuscripts submitted during one year as delivered by the journal editors: an example is shown in figure 6.14. Since the data cannot be verified objectively, Cabell’s urges its users to report unsound numbers.[16] The database provides directories for approximately 3,000 journals from different areas of business, computer science, education, health and psychology. For other fields such as physics, acceptance rates are only available if published on the journal’s website or by directly contacting the editor or publisher.

In their important paper, Zuckerman and Merton (1971) identify discipline-specific differences of rejection rates. While most arts and humanities journals had mean rejection rates above 80%, the values for periodicals in the natural science fields were much lower. The mean rejection rate of 12 physics journals was 24%. Zuckerman and Merton (1971) coin the following rule of thumb:

16 http://www.cabells.com/using.aspx#x1

> [T]he more humanistically oriented the journal, the higher the rate of rejecting manuscripts for publication; the more experimentally and observationally oriented, with an emphasis on rigour of observation and analysis, the lower the rate of rejection. (Zuckerman & Merton, 1971, p. 77)

Disciplinary differences were allocated to divergent levels of a field's consensus, which is generally much higher in the the natural sciences than in arts and humanities. These findings were confirmed by Weller (2002), who provides an excellent overview of 34 studies analyzing discipline-specific rejection rates published between 1961 and 1993, which identifies physics as amongst the disciplines with the lowest and history as the field with the highest rejection rates.

Journal Name	Review	No.Ext. Rev.	Acceptance Rate
Asian Journal of Library and Information Science	Blind	3	21%
Bulletin of the American Society for Information Science & Technology	Editorial	0	50%
International Journal of Library and Information Science	Blind	3	21%
Journal of Education for Library and Information Science	Blind	2	30%
Journal of Information Science	Blind	3+	42%
Journal of the American Society for Information Science and Technology	Editorial	2	55%
Library & Information Science Research	Blind	2	21 - 30%
Pakistan Journal of Library and Information Science	Blind	2	30%

Figure 6.14 Information on acceptance rates for Information Science journals in Cabell's Directories of Publishing Opportunities. Source: http://www.cabells.com/dir.aspx

Field differences in page charges, which influence the availability of publication space, were identified as another factor responsible for varying rejection rates. The latter was later disproved by Hargens (1988). Ehara and Takahashi (2007) evaluated the American Journal of Roentgenology's rejection rates between 2003 and 2005 by country and found that manuscripts from Switzerland and Austria were least frequently rejected: in comparison to an overall rate of 33.3%, only 25.5% of Swiss and 26.6% of Austrian submissions were rejected.

Rejection rates examined by Schultz (2010b) for 47 atmospheric science journals varied between 2.4% to 91.5% around a mean of 38.7%. Excluding the outlier with an extremely high rejection rate of 91.5% (Nature), the rejection rates were almost perfectly normally distributed around a mean/median rate of 37.6%/37.9%. Schlögl and Petschnig (2005) examine the rejection rates of 35 German and international library and information science journals by questionnaires sent to the editors. Rejection rates varied between 10% and 80% around a mean of 37%, with the German periodicals having lower rejection rates than the international ones.

Table 6.7 Response by journal editors or publishers to request for annual rejection rates from 2004 to 2008 and period covered by delivered statistics..

Journal	**Data**	**Period covered**
Act Cryst A	(rejected+withdrawn)/submitted	annual rates, 2004 – 2008
Act Cryst B	(rejected+withdrawn)/submitted	annual rates, 2004 – 2008
Ann Phys	rejected/submitted	annual rates, 2005 – 2008
Appl Phys A	*no response*	
Appl Phys Let	rejection rate	annual rates, 2003 – 2010
Comput Mater Sci	*request denied for policy reasons*	
EPL	acceptance rate	annual rates, 2005 – 2008
Eur Phys J B	(rejected+withdrawn)/submitted	annual rates, 2004 – 2008
Eur Phys J E	rejection rate	annual rates, 2004 – 2011
Hyperfine Interact	*no response*	
IEEE Nanotechnol	*request denied for policy reasons*	
Int J Thermophys	*no response*	
J Appl Phys	*no response*	
J Low Temp Phys	*no response*	
J Magn Magn Mater	*request denied for policy reasons*	
J Phys A	rejection rate	5-year rate, 2004 – 2008
J Phys Condens Matter	rejection rate	annual rates, 2004 – 2008
J Phys D	*no response*	
J Rheol	*no response*	
J Stat Mech	*no data collected*	
J Stat Phys	*no response*	
J Vac Sci Technol A	*no data collected*	
JETP Lett	published/submitted	annual rates, 2004 – 2010
Nanotechnol	*no response*	
New J Phys	*no response*	
Nucl Instrum Meth A	*request denied for policy reasons*	
Nucl Instrum Meth B	estimated rejection rate (research articles)	annual rates, 2006 – 2008
Phys Fluids	*no response*	
Phys Lett A	*request denied for policy reasons*	
Phys Rep	*does not apply*	
Phys Rev A	(rejected+withdrawn)/submitted	annual rates since 1993

continued on next page

Journal	**Data**	**Period covered**
Phys Rev E	(rejected+withdrawn)/submitted	annual rates since 1993
Phys Scr	*no response*	
Phys Solid State	*no response*	
Phys Stat Sol A & B	acceptance rate (research articles)	annual rates, 1996 – 2010
Phys Stat Sol A & B	acceptance rate (rapid research letters)	annual rates, 1997 – 2010
Phys Today	*does not apply*	
Physica B	*request denied for policy reasons*	
Physica C	*request denied for policy reasons*	
Pramana	rejection rate	annual rates, 2004 – 2008
Rep Prog Phys	*no response*	
Rev Mod Phys	rejection rate (unsolicited publications)	biennial rate, 2006 – 2007
Soft Matter	*request denied for policy reasons*	
Solid State Ion	*request denied for policy reasons*	
Supercond Sci Technol	rejection rate (research articles)	annual rates, 2004 – 2008

In order to obtain the rejection rates of the 45 journals, several emails were sent in August and September 2011 to the editors-in-chief and responsible publishers, requesting annual rates regarding the analyzed publication years 2004 to 2008. Responses varied from providing detailed annual statistics to insisting upon strict policies which forbade them "to reveal information on circulation, submission figures and rejection rates to third parties"[17]. While the Physical Review journals make detailed annual statistics available online[18], other journals did not keep track of the number of rejected and accepted manuscripts at all, i.e. J Stat Mech and J Vac Sci Technol A, and to certain journals, i.e. Phys Rep and Phys Today, rejection rates do not apply. An overview of responses and data provided can be seen in table 6.7.

While 14 journals did not respond to the e-mail requests, 9 turned down the request due to policy reasons. These journals were Soft Matter (Royal Society of Chemistry) and the eight Elsevier journals Comput Mater Sci, IEEE Nanotechnol, J Magn Magn Mater, Nucl Instrum Meth A, Physica B & C, Phys Lett A and Solid State Ion. Data could be collected for 18 journals, of which 9 supplied a rejection rate, i.e. the ratio of rejected and submitted publications, 5 provided the number of rejected and withdrawn submissions in relation to all submissions and 4 stated the acceptance rate, i.e. the percentage of papers published relative to those submitted. Thirteen editors or publishers provided annual rates covering at least the five years from 2004 and 2008. Ann Phys and EPL could only determine annual rates from 2005 to 2008. J Phys A published a 5-year rejection rate of 60% in an editorial:

17 E-mail correspondence with Elsevier.

18 http://forms.aps.org/general.html

> During the last five years, we have raised the quality threshold for acceptance in the journal and now reject over 60ý% of submissions. As a result, papers published in Journal of Physics A: Mathematical and Theoretical are amongst the best in the field. (Gillan, 2009)

The editor of Nucl Instrum Meth B estimated that between 2006 and 2008 a constant of 50% of all submissions were rejected and the editor-in-chief of Rev Mod Phys calculated a rejection rate of 93.7% for all unsolicited publications submitted in 2006 and 2007. This rejection rate applies to those articles which were not invited. Solicited review papers are hardly ever rejected.[19] Due to the lack of annual rates, J Phys A, Nucl Instrum Meth B and Rev Mod Phys are not further analyzed.

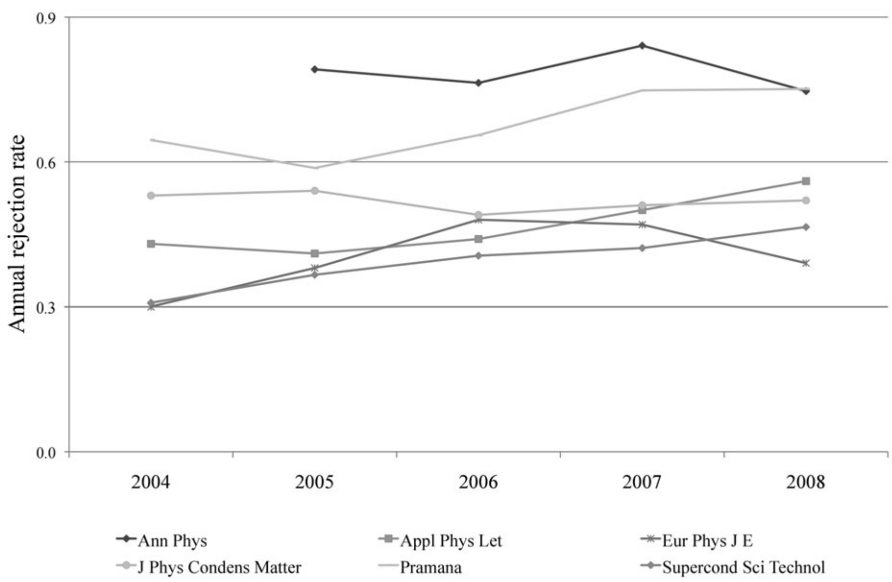

Figure 6.15 Annual rejection rates for Ann Phys, Appl Phys Let, Eur Phys J E, J Phys Condens Matter, Pramana and Supercond Sci Technol.

The annual rejection rates of the remaining 15 journals for which data was sufficient are shown in figure 6.15 and figure 6.16. While figure 6.15 includes all journals which provided annual rejection rates defined as the ratio of rejected divided by the total number of submissions, figure 6.16 shows rejection rates, which include submissions that were withdrawn by the authors during the review process. The latter values are thus somewhat higher than the actual rejection rates. Since some of the editors indicated that they advise some authors to withdraw a submission when it will most likely not pass the review process, withdrawn papers should, however, be included at this point.

It can be seen that no rejection rate was below 30% and that annual rates are constantly increasing. The median rejection rate of the 15 journals was 42.7% in 2004

19 Personal correspondence with editor-in-chief of Rev Mod Phys.

and increased to 46.9%, 49.0%, 50.0% and 52.0% in the four consecutive years. This confirms the general trend of an increasing information overload. Journals receive more submissions, so they can choose those of the highest quality. The mean rates of 44.4%, 48.9%, 50.3%, 53.2% and 52.2% per annum are also much higher than the mean rejection rates for physics journals found by previous studies. For example, the mean rate of Zuckerman and Merton's (1971) 12 physics journals was 24%. The sample sets are, however, much too small to draw general conclusions. It is very possible that the 23 journals which did not respond to or turned down the request did so precisely because their rates were much lower than that of the sample of 15 periodicals.

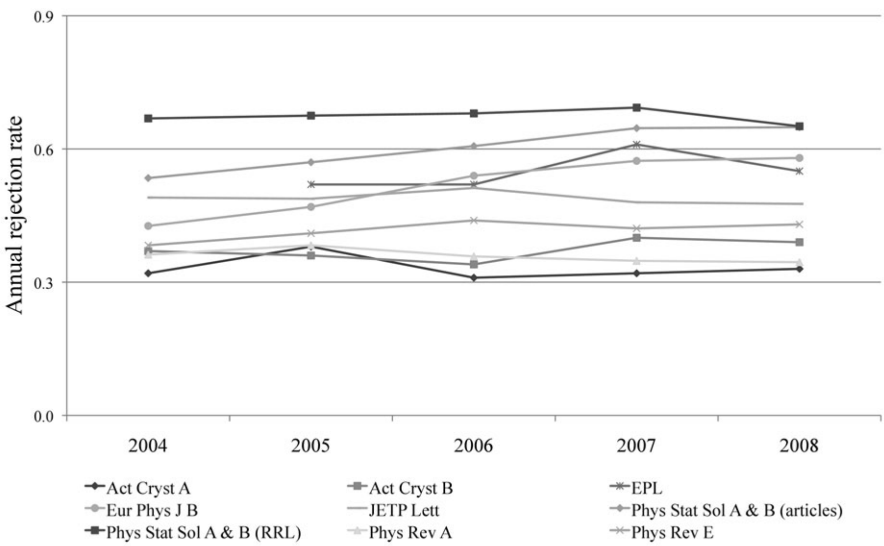

Figure 6.16 Annual rejection rates (including withdrawn submissions) for Act Cryst A & B, EPL, Eur Phys J B, JETP Lett, Phys Stat Sol A & B (separate values for rapid research letters and articles) and Phys Rev A & E.

The highest annual rates can be observed for Ann Phys, which rejected between 74.7% in 2008 and 84.1% of all submissions in 2007. Act Cryst A, which has the highest impact factor of the analyzed journals in 2009 and 2010, has the lowest rejection rates. About two-thirds of all submissions are accepted for publication. Except for minor fluctuations, the majority of the periodicals were able to keep their rejection rates on an equal level between 2004 and 2008. Significant increases can be observed for Supercond Sci Technol, which rejected 30.8% of submissions in 2004 and 46.5% in 2008, Pramana, where the rejection rate increased from 64.5% to 75.1% from 2004 to 2008 and Eur Phys J B, where 42.7% and 58.0% of the submissions were not published in the respective years. While Phys Stat Sol A & B accepted 46.6% of submitted original research articles in 2004, only 35.1% passed the review process in 2008.

6.3.4 Correction Rate

The correction rate of a journal is defined as the number of errata divided by the total number of documents published during a certain period of time (Molckovsky, Vickers, & Tang, 2011). Errata have to be published when a publication contains errors (Sabine, 1985). The share of corrections published per journal can thus, to a certain extent, indicate the quality of the review process. Of course, the publication of corrections depends on many factors, first of all that the errors are noticed and reported. Many mistakes are probably never officially corrected (Molckovsky et al., 2011). Methodological shortcomings may be improved in further publications. Errata thus expose only a fraction of erroneous or deficient publications. They do flag mistakes that were at least so obvious that a reader or the author himself discovered it and can thus be used as a rough estimate of the thoroughness of the review process.

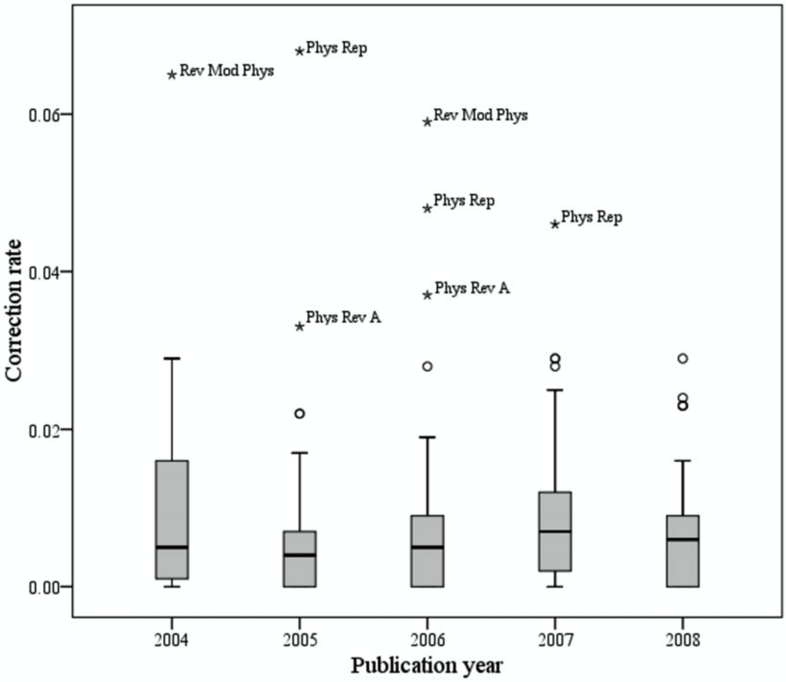

Figure 6.17 Boxplots displaying annual correction rates of 45 journals.

During the five years under analysis, 1,513 corrections were published in the 45 journals. This represents 0.90% of all documents, which is much lower than the 4% discovered by Molckovsky et al. (2011) for high-impact oncology journals. Annual rates vary between 0.70% in 2008 and 0.96% in 2007. The boxplots in figure 6.17 display annual rates and identify extreme outliers. Phys Rep, Rev Mod Phys and Phys Rev A have the highest percentage of errata in comparison to all publications. Phys Rep had the largest overall correction rate of 3.52% and Rev Mod Phys one of 3.47% during the five years under analysis. J Stat Mech and New J Phys did not have to publish any corrections between 2004 and 2008.

Sabine (1985) defines five error types, i.e. marginal (e.g. typos), social (misspelled or forgotten author name), minor (incorrect equation), major errors (changing outcome of results) and retractions (flawed methods, unrepeatable results). Molckovsky et al. (2011) define specific error categories for medical journals, including dosage errors, which can entail serious consequences. Although all types of errata point to shortcomings in the review and editorial processes, two major types should be distinguished, namely content-related errors and layout corrections.

Of the 12 errata published in Phys Rep between 2004 and 2008, 7 were concerned with content and 5 concerned minor aspects, correcting misprints. During the five years under analysis, 2 of the 168,109 publications were retracted. Both of them were published in Appl Phys Let. Kim, Jeong, Moon, Han, and Chung (2007) was withdrawn for having applied unauthorized methods and ignoring previous literature, while Jeong et al. (2004) was retracted due to so-called self-plagiarism, i.e. the results had been previously published elsewhere. The retraction reads:

> Due to an inexcusable fault of the first author, submission of the same results to other journals took place. As the corresponding author, I (Baik) apologize for the unnecessary imposition on the editors' and reviewers' time and resources on the above manuscript published in Applied Physics Letters. This is an unethical practice and a violation of international copyright laws. The first author and I deeply apologize to the coauthors, the editors, the journal publishers, and the scientific community for this blatant breach of the ethical norms. (Jeong et al., 2006)

Fang and Casadevall (2011) analyzed retractions in medical journals and found a significant positive correlation with the impact factors of the journals. They speculate that the pressure to publish in high-impact journals may lead authors to take higher risks or even manipulate data to meet high expectations.

6.4 The Publishing Market

The academic publishing market began to evolve after World War II, when scholarly communication started to become commercial. Before that, scholarly journals were published non-commercially by academic societies only. Today, the scholarly publishing market is one of the biggest markets profit-wise, although or precisely because it does not follow usual market principles:

> One may consider academic journals as a market product governed by market principles. This assumption is not entirely correct mainly because "the raw material" for production of academic journals is provided to the publishers for free. The point of purchase is not the same as the point of use and there is a lack of substitutability in the market. Therefore, academic journals should not be analysed from a purely economic perspective. (Mierzejewska, 2008, p. 213)

Unlike usual suppliers, authors provide their goods, i.e. articles, without financial compensation. The goods are purchased by libraries, who are not the consumers. Purchase and use are not linked directly. Readers are isolated from the purchase, thus price fluctuations do not influence demand. Libraries are atypical buyers insofar as their purchases are mainly controlled by their budgets instead of their information needs. If subscription prices are high, they have to manage with less, if prices decrease, they subscribe to more. Due to the monopoly position of the publishers, libraries are more or less helpless, for in scholarly publishing, each product represents a unique value and cannot be replaced (McCabe, 2002; Meier, 2002; Keller, 2005; Mierzejewska, 2008).

> It is important to recognize that the academic journal publishing market is very different from conventional models of markets. Conventionally, supply and demand in a market are brought into equilibrium through changes in price. Market clearing mechanisms for STM publishing are inefficient, however, because different parts of the market cannot be brought together through the manipulation of a simple, single variable such as price. The potential for market failure, therefore, is very high. In other words, the market, as it is currently structured, finds it difficult to satisfy the requirements of both those supplying articles and those demanding them. (Wellcome Trust, 2004, p. 1)

Mierzejewska (2008) differentiates between two sides of the publishing market: the content market or market of ideas, where scientists act as the producers of research results, who offer their products (manuscripts) to the publisher, who functions as the middle man between producer and consumer. The latter are represented by the readers, who are stakeholders in the second, the journal market. McCabe and Snyder (2007) analyze the two-sided market from an economic point of view.

> The model has three types of economic agents: journals, authors, and readers. Journals are intermediaries between authors and readers. A journal acquires articles from authors, bundles them into an issue, and distributes the issue to subscribing readers. (McCabe & Snyder, 2007, p. 5)

Other than in regular markets, where the consumer pays the producer for the product through the middleman, in the scholarly publishing market, i.e. the content and the journal market, the middleman is paid by both, while he does not have to pay anyone (Meier, 2002; Keller, 2005). Manuscript and peer review are provided for free by scientists, who do not seek monetary compensation but work for scholarly prestige offered through publications, citations or editorial board membership. This explanatory model is based on the sociological principal of functionalism introduced by Robert K. Merton (Merton, 1996; Stock, 2001).

The business model of commercial academic publishers is based on the exclusiveness of the usage rights of manuscripts, which was initiated by the publisher of the New England Journal of Medicine, Franz Ingelfinger in 1969 (Ingelfinger, 1969; Meier, 2002). The so called Ingelfinger law prohibits authors from submitting their manuscripts to more than one journal, because

> [t]he journal's revenue streams must be protected: subscribers will not subscribe to a journal whose contents have already appeared elsewhere. Without that revenue, the research cannot be refereed or published at all. (Harnad, 2000, p. s16)

Ingelfinger's rule was adopted by many other journals. Copyright transfer agreements, which have to be signed by authors before publication to transfer their rights to the journal, often include a declaration by authors confirming they have not published the particular results nor submitted them to another journal. Harnad (2000), strong advocate of open access (section 6.4.2), argues that Ingelfinger's rule has become invalid with the opportunities of electronic online publishing. In fact, the Ingelfinger principle is currently, however, still a universal rule in academic publishing.

In the following, a brief overview of journal production cost (section 6.4.1), and financial models (section 6.4.2) of scholarly journal, i.e. subscription, open access and hybrid forms, is provided. Section 6.4.3 examines concrete journal pricing for the 45 journals under analysis.

6.4.1 Production Costs

Scholarly publications are typical information goods in terms of high fixed and low variable costs (Shapiro & Varian, 1998; Linde & Stock, 2011). In journal publishing, fixed or first-copy costs comprise all costs arising from the manuscript selection and review process up to the preparation of the published issue (King, 2007). These include copy editing, preparation of illustrations and writing editorials but also marketing, salaries and rent. Due to the peculiarities of the academic publishing market, the two most substantial matters of expense, i.e. manuscript preparation and reviewing, do not add to first-copy costs because they are provided for free by the scholarly community (Mierzejewska, 2008).

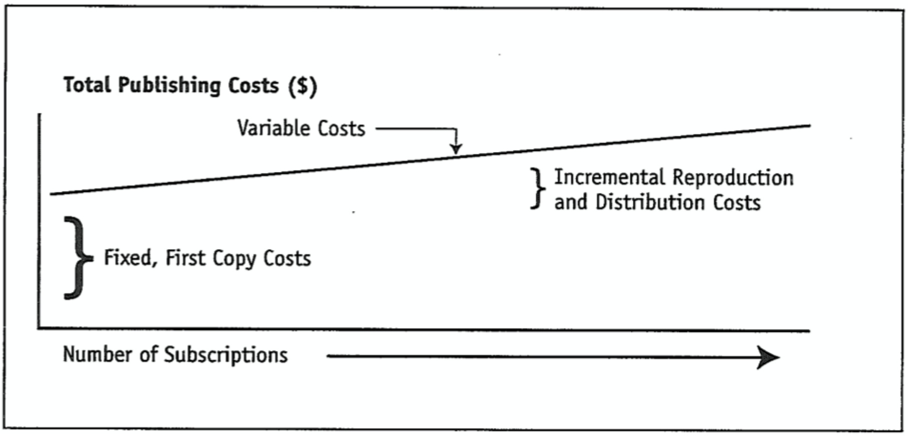

Figure 6.18 Production costs of scholarly journals. Source: Tenopir and King (2008, p. 248)

The variable costs of journal production include printing and distribution of journal issues and subscription management. For e-only journals print and shipping costs are replaced by much lower costs for online servers (Varian, 1998). Low variable costs lead to fixed cost degression. Variable costs are higher for large journals but at the same time costs are covered by a large number of subscribers (Meier, 2002; King, 2007; Wellcome Trust, 2004). The interrelation of fixed and variable costs in academic publishing are illustrated in figure 6.18.

Odlyzko (1995) estimated in the 1990s that an average mathematical manuscript preparation costs about US$20,000 on the author and US$ 4,000 on the peer review side. These costs do, however, not reflect in the budget of academic publishers and the production of scholarly journals because they are indirectly paid by tax payers through research funding.

On the publisher's side, fixed costs per article are estimated to vary between US$ 250 and US$2,000, of which 10% can be attributed to the management of peer review (Rowland, 2002; Mierzejewska, 2008). Tenopir and King (2000) calculate an average first-copy cost of US$20 per page. First-copy costs of a journal issue are increased by high rejection rates, because in general all submissions, not only the published ones, undergo peer review and generate costs (Rowland, 2002). Even though referees are not paid, cost arise through editorial management of the review process. Considering a rejection rate of 50%, Rowland (2002) calculates costs of US$400 per published article or US$40 per page, which is close to the US$500 author charges required to publish in the open access journal New J Phys in 2002. Ten years later these open access fees, which are to cover all costs of publishing New J Phys have, however, doubled.[20]

It becomes clear that, although a large part of journal production is provided for free by the scholarly community, i.e. indirectly financed through taxes by research funding, the compilation of journal issues costs money. In the following section, financial models of academic journals are briefly introduced, before actual subscription prices for the analyzed journals are examined in section 6.4.3.

6.4.2 Financial Models

Three basic financial models exist to cover the production process of scholarly journals: 'reader pays', 'author pays' and full sponsoring through scholarly societies. Since the latter is only rarely applied today and little is known about this perspective, it is not further described. The traditional and prevalent model is financing through the reader-pays model, i.e. subscriptions and pay-per-view. Horrendous increases in journal prices have led to the open-access movement demanding free access to research results and thus implying a shift of journal production costs from the readers to the authors. The financing model is reversed: authors have to pay a fee that covers all publishers' costs and in turn all publications can be distributed for free. Hybrid forms of subscription and publication fees permit the author to choose the financing individually for a particular publication.

Subscription

Subscription is the traditional and most popular way to finance the production and distribution of scholarly journals. Prices depend on the fixed and variable costs generated in journal production and distribution (compare section 6.4.1). These depend on the number of submissions, rejections and issues published per year (Meier, 2002). In academic publishing, the subscription is not paid by the readers but by libraries, who provide the access. Sometimes buyer aggregators like Ebsco, Highwire or AIP

20 http://iopscience.iop.org/1367-2630/page/Article+charge

function as middlemen between publishers and libraries. The user is, however, not directly involved. This separation means that the consumer is in general not interested in the price of the product (Keller, 2005).

Traditionally, subscriptions are fixed annual rates, the library pays to be provided with all issues published during the particular year. Annual rates can be as high as US$23,446, which was the subscription price listed by Elsevier for Brain Research in 2011.[21] With a subscription fee of around US$9,000, Nucl Instrum Meth A was among the most expensive journals in 2000 (Mierzejewska, 2008, p. 34). Its current subscription price is listed as US$12,500.[22] Subscription prices are analyzed in detail in section 6.4.3.

With print journals, the library is responsible for archiving all issues and granting adequate access for its readers. Things are different for electronic journals insofar that a campus license conveniently grants access to journal content from multiple workplaces simultaneously (Robnett, 1997). This has caused publishers to turn from fixed to variable pricing, graduated by the number of users. For example, price differentiation at AIP depends on usage statistics, the number of different AIP subscriptions and affiliated authors publishing in AIP journals (Keller, 2005). Variable pricing allows publishers to maximize profits by selling identical products to different customers at various prices by taking advantage of information asymmetry and monopoly positions (McCabe, 2004; Meier, 2002; Linde & Stock, 2011). Through product bundling, libraries or library consortia are persuaded to agree to so-called 'big deals', which means paying for a large bundle of journals, which they often do not need (Frazier, 2001; Shepherd, 2007). For an overview of library consortia and associated subscription models – additional access, cross access and big deal – refer to Filipek (2010).

As an alternative to subscriptions, journal content can be accessed through pay-per-view. Since a fee is paid to license one article and not the whole journal, it casts doubt upon the medium of the scholarly journal (Meier, 2002), but is especially suitable for serials that are infrequently accessed (Tenopir & King, 2000). Pay-per-view access currently costs between US$20 and US$30 per article (Keller, 2005).

Tokens provide a hybrid solution between subscription and pay-per-view article access for institutions. Tokens are a kind of voucher that can be cashed to access any article of an unsubscribed journal, whenever needed. Since tokens are less expensive than pay-per-view, this form of access provides an alternative for less frequently used journals. However, tokens expire after a certain period of time, so if not cashed, the money is lost, which makes budgeting difficult (Meier, 2002; Keller, 2005).

Open Access

The open access movement arose from a combination of the possibilities of electronic publishing with world wide web distribution and extreme price increases of journal subscriptions associated with the serials crisis (Harnad, 2011). Due to the latter, a vicious circle of price increases and cancellations emerged:

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21 http://www.elsevier.com/framework_products/Wcat/Pricelist2011USD.xls

22 http://www.elsevier.com/framework_products/Wcat/Pricelist2011USD.xls

> [B]ecause price rises have gone up faster than their spending power, many libraries have been forced to cancel a number of journal subscriptions. [. . .] Because many libraries have been forced to cancel their subscriptions, publishers have had no choice but to further increase the subscription prices of their journals to cover their costs for supply to a smaller number of customers. (Oppenheim, 2008, p. 580)

Constant annual rises in subscription rates have lead to what Harnad et al. (2008) call the “journal-affordability problem” of academic institutions. Together with the “article-access/impact problem”, which assumes that subscription fees limit the potential impact of scholarly publications, i.e. create impact barriers, it gave rise to the open access movement, which demands unrestricted access to scholarly literature (Harnad, 2000; Harnad et al., 2004). In the 1990s, the valid question was raised of why institutions have to repurchase publications by their own researchers at enormous subscription rates. The initiative aims to solve the problem of restricted access to research results by restructuring the system of scholarly communication and the publishing industry through a reversal of the financing model (Keller, 2005; Harnad et al., 2008). Instead of financing through access fees, it is proposed that production and distribution costs be covered by publication fees from the authors or their affiliated institutions (McCabe & Snyder, 2007). This eliminates big revenues for publishers and commerciality of academic publishing. Access to scientific results will be free worldwide. Other than the self-archiving approach, open access journals secure quality control and the manuscript selection process through peer review.

Two paths are taken to achieve open access to journal publications: the gold and green roads to open access. These terms were coined by Stevan Harnad, leading figure of the open access movement. The gold road to open access comprises the ultimate goal of reversing the journals’ financing models from ‘reader pays’ to ‘author pays’.

Linde and Stock (2011) classify the open access approaches somewhat differently and differentiate between the green, silver and gold roads. While the green road refers to self-archiving, the silver road describes the author-pays model and the gold road means full sponsorship of publishing costs. Since the latter does not occur in physics, Harnad’s differentiation between green (self-archiving) and gold open access (author pays) is used here.

At the beginning of the new millennium, a few publishers emerged who took up this new business model and charged publication or submission fees, and discarded the traditional role of publishers from “being content sellers to being dissemination service providers, making the authors their clients rather than the readers” (Björk et al., 2010, p. 1). A famous example and an open access success story is the open access journals published by PLoS.

> As a nonprofit organization, PLoS charged authors a fair price that reflects the actual cost of publication. However, the ability of authors to pay publication charges will never be a consideration in the decision whether to publish.[23]

In 2011, author fees at PLoS range from US$1,350 (PLoS ONE) to US$2,900 (PLoS Biology and PLoS Medicine) per accepted article.[24] In general, publication charges depend on publishers, disciplines and journals and vary between US$600 and US$3,000

23 http://www.plos.org/about/principles.php
24 http://www.plos.org/journals/pubfees.php

(Walters, 2007). Walters (2007) shows that the author-paid access model will reduce costs dramatically for most universities, since they are consumers rather than producers of knowledge. On the other hand, large research universities will have to cover the majority of costs, which, as Davis et al. (2004) have shown for Cornell University, exceed current library budgets.

As open access potentially enlarges the readership of scholarly articles, many studies have investigated the citation advantage of open access documents. Lawrence (2001) was the first to compare the citation rates of freely accessible publications in comparison to those with restricted access. Many studies have followed which proved that citation impact was greater for articles which were open access in comparison to those which were not, validating the citation advantage of open access (Harnad & Brody, 2004; Eysenbach, 2006; Davis & Fromerth, 2007). For a critical overview of these kinds of studies refer to Craig, Plume, McVeigh, Pringle, and Amin (2007).

It has, however, been suggested that this advantage is not caused by enlarging readership through open access but that higher citation rates are due to a self-selection bias, implying that authors predominantly choose higher quality papers for open access, or the advantage of the early availability of pre-prints (Kurtz et al., 2005; Craig et al., 2007; Moed, 2007; Davis, Lewenstein, Simon, Booth, & Connolly, 2008). Davis et al. (2008) tried to control for different factors influencing downloads and citations by randomly providing free access to articles from 11 journals published by the American Physiological Society. Usage and citation rates of 1,619 articles were examined, of which 247 were randomly chosen to be available through open access during the four months of analysis. Article-level usage and citation data were collected from the publisher's log files and WoS, respectively. By comparing both sets, i.e. traditional subscription and freely available articles, regarding download and citation characteristics, the study revealed that open access documents were downloaded more often. However, no difference was observed in terms of citations received within one year after publication. On the other hand, Gargouri et al. (2010) examined 27,197 documents published in 1,984 non-open access journals to compare citation rates of self-selected and mandated green open access in contrast to regular articles and found that the citation advantage was as high for mandated as it was for self-selected open access documents and was present even if other influencing factors (e.g., age, number of authors, number of references, publication venue etc.) were controlled for. They conclude:

> OA itself will not make an unusable (hence uncitable) paper more used and cited [. . .] But wherever there are subscription-based constraints on accessibility, providing OA will increase the usage and citation of the more usable and citable papers, probably in proportion to their importance and quality, hence citability. We accordingly infer from our results that the most likely cause of the OA citation advantage is not *author self-selection* toward making more citable articles OA, but *user self-selection* toward using and citing the more citable articles Ð– once OA self-archiving has made them accessible to all users, rather than just to those whose institutions could afford subscription access. (Gargouri et al., 2010, p. 9 f.)

While gold open access represents an alternative business model that publishers can consider, the green open access model can be regarded as a workaround for current access limitations by the authors. Due to a lack of suitable open access journals and dependence on the prestige of traditional publication venues (Swan & Brown, 2004), authors provide free access to high-priced journal articles through self-archiving the documents on institutional[25] or subject-based online repositories (Harnad et al., 2004, 2008). Harnad (2011) argues that green has to come before gold open access in order to lower profit margins and make subscription-financed publishing unsustainable so that there is a need for publishers to switch to the gold model.

Open access publishing invalidates Ingelfinger's rule (see section 6.4), since the authors keep all their rights and are allowed to make their material available elsewhere (Keller, 2005). On the part of conventional publishers, open access has to a large part led to negative reactions due to feared loss of revenue. Author-paid journal financing eliminates the opportunities of high profit margins provided through the current subscription-based financing model. However, no losses in revenue could yet been observed (Oppenheim, 2008).

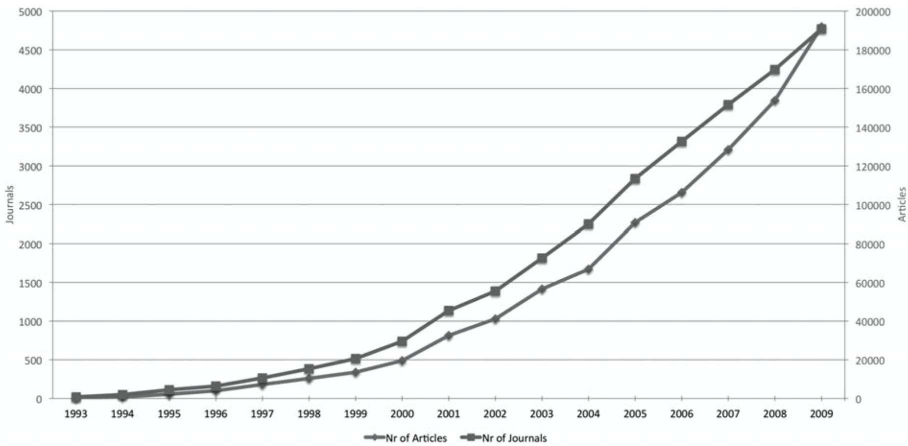

Figure 6.19 Number of gold open access journals and articles between 1993 and 2009. Source: Laakso et al. (2011, p. 6)

Non-profit and society publishers have in general reacted more positively. At the same time, governmental and funding agencies can and do influence the scholarly publishing market by mandating, i.e. make it a condition of grant to publish funded research results, open access, e.g. in the US the NIH[26], in UK the Wellcome Trust[27], and in the EU OpenAIRE[28] (Oppenheim, 2008; Harnad, 2011). Currently, a relatively low percentage of scholarly journals is truly open access with differences from field to field (Björk et al., 2010). For 2009, 5.9% and 6.8% of all articles covered in WoS and Scopus, respectively, are estimated to be published in gold open access journals (Laakso et al., 2011).

25 A list of institutional repositories can be found at http://www.opendoar.org.
26 http://publicaccess.nih.gov/
27 http://www.wellcome.ac.uk/About-us/Policy/Spotlight-issues/Open-access/index.htm
28 http://www.openaire.eu/en/home

Laakso et al. (2011) estimate the number of open access journals over time (figure 6.19), based on stratified random sampling of journals listed in the Directory of Open Access Journals (DOAJ) and found considerable annual growth rates for the number of gold journals (10.7% to 60.0%) and articles (17.1% to 216.0%). Based on their findings, three periods in the development of gold open access were defined, namely the pioneering (1993-1999), innovation (2000-2004) and consolidation phase (2005-2009). As of June 2011, the DOAJ lists 6,569 journals as open access.[29]

In a random sample of 1,837 journal articles examined by Björk et al. (2010), 8.5% were freely available through gold open access and 11.9% via self-archiving with specific differences between disciplines. In physics, publishing in open access journals was rather low (3.0% gold open access) but green open access was above-average (20.5%), which can be explained by a long tradition of self-archiving pre-prints on ArXiv. In the life sciences, gold open access was, on the contrary, more popular than the green approach (figure 6.20).

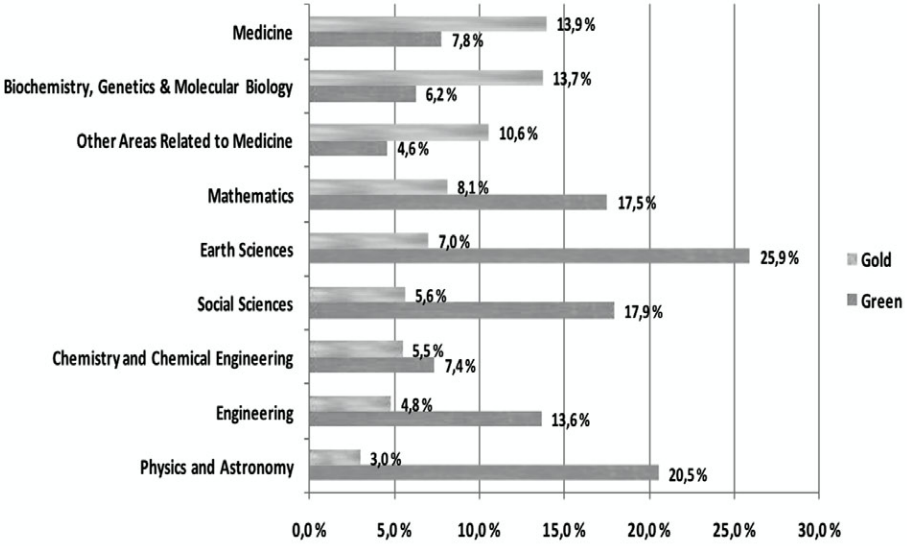

Figure 6.20 Open access availability by discipline. Source: Björk et al. (2010, p. 8)

While publishers can choose whether or not to change their financial model and become an open access journal, they are forced to react to the self-archiving approach by authors. The majority of publishers actually allow self-archiving by authors but make restrictions concerning time or manuscript versions. In general, authors are allowed to post the accepted version of the manuscript, but not the copy-edited and layouted publisher version (Björk et al., 2010). Other publishers allow authors to make a free copy accessible a certain time after publication. Harnad et al. (2004) claim that even though 90% of all journals allow some form of self-archiving, only 10% to 20% of scholarly articles are 'green'. A problem of the green open access approach is the detection of self-archived documents. Search engines have to be able to find

29 http://www.doaj.org

self-archived journal articles. The Open Access Initiative tries to solve this problem by OAI-PMH[30], a protocol supporting the harvesting of open access documents from e-print repositories, so that these are centrally accessible, for example through a search engine like OAIster[31] (Harnad et al., 2004).

Elsevier, who have always been very restrictive towards full open access models, granted authors some rights in 2004 permitting them to publish their manuscripts on homepages or institutional repositories:

> An author may post his version of the final paper on his personal web site and on his institution's web site (including its institutional repository). Each posting should include the article's citation and a link to the journal's home page (or the article's DOI). The author does not need our permission to do this, but any other posting (e.g. to a repository elsewhere) would require our permission. By "his version" we are referring to his Word or Tex file, not a PDF or HTML downloaded from ScienceDirect - but the author can update his version to reflect changes made during the refereeing and editing process. Elsevier will continue to be the single, definitive archive for the formal published version.[32]

These concessions took the open access initiative by surprise. Stevan Harnad admitted that with these rights, giving the green light to open access, "one could not have asked for more"[33].

Instead of librarians, the open access movement is is headed by leading scientists, which Okerson (2003) refers to as the "great person phenomenon". Basic principles and aims have been outlined in several declarations published around the world in 2002 and 2003, e.g. the Budapest Open Access Initiative[34], the Bethesda Statement on Open Access Publishing[35] and the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities[36].

Of the 45 journals under analysis, New J Phys is the only fully open access journal financed by author charges. Fees were listed as US$500 in 2002 (Meier, 2002), and US$1,040 in 2010 and 2011 per article independent of its length. Special discounts are granted to members of various scholarly societies.[37] Although DOAJ lists Pramana as open access, it is not: authors have to sign a publication authorization and copyright transfer form, where they transfer the copyright to the Indian Academy of Sciences for both print and online versions of the particular publication. However, more and more publishers offer hybrid solutions, where authors can choose to make a particular article open access by paying an author fee for a document published in a regular subscription journal. While of the 45 journals only New J Phys can be regarded as an open access journal, 11 other journals provide open access solutions for individual articles (compare table 6.1).

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30 http://www.openarchives.org/
31 http://oaister.worldcat.org/
32 E-mail of May 27th, 2004 by Elsevier's vice president Karen Hunter to open access advocate Stevan Harnad, available at https://mx2.arl.org/Lists/SPARC-OAForum/Message/759.html
33 https://mx2.arl.org/Lists/SPARC-OAForum/Message/759.html
34 http://www.soros.org/openaccess
35 http://www.earlham.edu/~peters/fos/bethesda.htm
36 http://oa.mpg.de/files/2010/04/berlin_declaration.pdf
37 http://iopscience.iop.org/1367-2630/page/Article+charge

Free Choice and Other Forms of Access

Besides the author-pays model, free access to journal content can be provided in other ways as well. As Cope and Kalantzis (2009) states "open access also now comes in many hues": access to journal content can be financed through subsidies by universities, scholarly societies or associations. Some journals also apply delayed open access, which means making articles available free of charge after a certain period of time. Subscribers thus pay a priority fee for the time advantage (Meier, 2002; Keller, 2005; Cope & Kalantzis, 2009). This kind of delayed open access is for example applied by PNAS (Proceedings of the National Academy of Sciences), where all articles are free of charge six months after publication[38].

A new and common approach applied by conventional publishers can be subsumed under the term 'free choice'. Publishers let the authors choose whether his or her submission is financed by the subscriber-pays or author-pays model, while the journal itself remains a subscription title. Those documents financed by their authors can be accessed freely by anyone, whereas access to regular publications remains limited to subscribers (Oppenheim, 2008; Filipek, 2010). Journals offering 'free choice' solutions thus apply hybrid financing (Cope & Kalantzis, 2009). Subscribing institutions, which allow their authors to make use of the open access option, hence actually pay the publisher twice for the same content, because when paying the publication fee, the annual submission rates have already been paid. Publishers, however, promise to lower subscription prices, if a large number of authors pay the publication fee (Oppenheim, 2008).

Springer was among the first to successfully introduce a hybrid option, called 'Open Choice', where for a fee of US$3,000 the particular document is made freely available (Mierzejewska, 2008) and all copyrights remain with the author:

> Open Choice allows authors to decide how their articles are published in the leading and highly respected journals that Springer publishes. Choosing open access means making your journal article freely available to everyone, everywhere in exchange for your payment of an open access publication fee. If authors choose open access in the Springer Open Choice program, they will not be required to transfer their copyright. The final published version of all articles can be archived in institutional or funder repositories and can be made publicly accessible immediately.[39]

Elsevier followed with a similar free choice solution in June 2006 and so did other publishers (Oppenheim, 2008). Of the 44 subscription journals studied, 11 provided open access solutions and can be thus defined as hybrid journals (table 6.1).

6.4.3 Journal Prices

As subscription prices increase annually above normal inflation and library budgets tend to decrease, it is crucial for librarians and university faculty to analyze journals in terms of their prices. More than ever it is important to optimize collection management

38 http://www.pnas.org/site/subscriptions/open-access.shtml
39 http://www.springer.com/open+access/open+choice?SGWID=0-40359-0-0-0

in terms of costs (Van Hooydonk, Gevaert, Milisproost, Van de Sompel, & Debackere, 1994; McCabe, 2002).

When analyzing journal prices, it is clear that appropriate normalization is necessary. The most common and obvious approach is to calculate average cost-per-publication rates, relativizing annual subscription prices by the annual number of documents received in return. Price/output ratios can equally be computed according to the number of pages, words or characters to obtain a more appropriate normalization unit, as discussed in section 2.1.2. In his renown cost-effectiveness studies, Barschall (1986, 1988) chose the number of characters as a measure to normalize journal subscription prices. In addition to this cost-per-output measurement, Barschall (1988) introduced a cost-effectiveness indicator based on citation impact, which divided the annual subscription price by the impact factor. Citation-based cost-benefit calculation had already been proposed by Garfield (1972) as a tool for collection management in libraries:

> Another application, which harried librarians may welcome, is the correlation of data on citation frequency and impact with subscription costs. Such a correlation can provide a solid basis for cost-benefit analysis in the management of subscription budgets. (Garfield, 1972, p. 477)

Table 6.8 lists both cost-effectiveness ratios for 17 of the 45 journals covered by Barschall (1988). Low values indicate good cost benefit, high values show low cost-effectiveness. Barschall (1988) found very high values of cost-effectiveness for non-profit and low cost-effectiveness for profit journals, revealing the high profit margins of commercial publishers:

> All the publishers whose journals have low average costs per character or low ratios of cost to impact are scientific societies or associations, while the publishers whose journals have high costs per character or high ratios of cost to impact are commercial firms. (Barschall, 1988, p. 57)

Gordon and Breach, the commercial publisher that was identified as the least cost-effective by the study, decided to act upon the poor scores of their journals and sued Barschall, AIP and APS on the grounds of illegal comparative advertising (ARL, 1999). Unfortunately, this has had "a chilling effect on systematic data gathering and cost analysis of journals" (ARL, 1999), until more than fifteen years after Barschall's studies, two economics professors, Theodore C. Bergstrom and R. Preston McAfee launched http://journalprices.com, a website which systematically calculates cost-effectiveness data for journals listed in the JCR. The current, which after its launch in 2004 is the fifth, version provides data for 8,422 scholarly journals. One of the few global datasets collected prior to the work by Bergstrom and McAfee is a study conducted by Van Hooydonk et al. (1994), which evaluates serials from a 'bibliotheconomic' perspective. For 4,319 journals listed in the 1990 science edition of the JCR, subscription prices were collected in order to compute cost-performance ratios on a discipline level for six faculties at the University of Ghent. Van Hooydonk (1995) covers a total of 5,399 journals and and twelve major scientific disciplines.

Table 6.8 Cost (in US$) per character and cost per citation impact for 17 of the 45 journals covered by Barschall (1988). Source: Barschall (1988, p. 58)

Journal	**Publisher**	**Price 1987**	**Price 1988**	**Cost per character**	**Cost per impact**
Rev Mod Phys	APS	160	170	1.7	0.1
Phys Rev A	APS	510	715	0.7	0.3
Appl Phys Let	AIP	330	425	1.1	0.3
J Appl Phys	AIP	580	725	0.8	0.4
Rep Prog Phys	IOP	375	430	5.1	0.8
J Vac Sci Technol A	AIP-AVS	450	375	1.8	0.9
Phys Rep	North Holland	1607	2383	6.9	1.0
J Phys D	IOP	355	420	3.2	3.4
Phys Lett A	North Holland	742	953	4.9	4.4
Phys Stat Sol B	Akademie	789	875	3.8	5.2
Phys Stat Sol A	Akademie	790	873	3.5	5.8
J Magn Magn Mater	North Holland	1493	1716	9.0	6.3
Nucl Instrum Meth A	North Holland	2112	2240	6.8	6.4
Solid State Ion	North Holland	473	767	6.8	6.6
Hyperfine Interact	Baltzer	1010	1213	11.0	10.1
Nucl Instrum Meth A	North Holland	2640	2800	6.8	13.0
EPL	EPS	416	500	3.4	n/a

Prices were normalized by number of annual documents (price per article), impact factors and field citation rates. Van Hooydonk et al. (1994) found high prices per article for review journals, which, however, are more cost-effective when normalization is based on the impact factor. Since subscription prices are much higher in the applied sciences, engineering and agriculture than in the medical sciences, it is proposed to use weighted cost ratios to determine fair allocations of budgets to faculty libraries (Van Hooydonk et al., 1994). Van Hooydonk (1995) found a negative correlation between the discipline impact factors and subscription prices. Physics is identified as the discipline with the highest average subscription costs per journal and mathematics as that with the highest price per document.

Table 6.9 Mean journal subscription price per article per year in US$. Source: http://journalprices.com

Journals	**2004**	**2006**	**2008**	**2009**	**2010**
Appl Phys Let	0.97	0.72	0.60	0.09	0.81
Phys Rev A	1.56	1.21	1.20	1.31	1.51
Phys Rev E	1.18	1.21	1.36	1.72	1.84
J Appl Phys	1.41	1.41	1.28	1.47	1.63
Pramana	1.11	0.78	2.02	2.13	1.95
J Vac Sci Technol A	2.22	4.09	4.44	3.20	5.06
Supercond Sci Technol	4.89	3.68	4.38	4.94	4.86
EPL	4.48	4.25	5.42	3.91	3.95
J Phys D	6.51	5.99	5.46	4.66	4.94
Phys Fluids	6.64	4.95	4.95	5.93	6.53

continued on next page

Journals	2004	2006	2008	2009	2010
IEEE Nanotechnol	n/a	6.74	4.72	5.00	7.37
Physica B	4.23	7.34	5.01	5.70	7.41
Phys Lett A	n/a	6.05	5.76	5.89	6.32
Act Cryst B	5.01	6.99	6.68	6.25	7.59
J Phys A	9.66	8.31	1.46	n/a	7.38
Comput Mater Sci	n/a	8.17	6.36	6.03	7.00
Phys Scr	n/a	10.17	6.74	5.97	4.18
Nanotechnol	17.99	3.44	5.01	3.88	4.68
J Magn Magn Mater	n/a	5.82	9.74	6.97	7.80
Nucl Instrum Meth A	8.59	8.49	9.06	6.88	8.16
Phys Today	5.62	8.73	9.51	8.87	9.65
J Rheol	n/a	7.15	8.75	9.90	8.20
J Phys Condens Matter	9.37	7.73	9.09	8.20	8.11
Nucl Instrum Meth B	n/a	8.15	8.47	9.11	10.26
Act Cryst A	6.22	7.69	12.09	13.77	11.03
Appl Phys A	13.02	7.32	10.25	11.89	10.74
J Low Temp Phys	8.14	8.40	11.99	13.79	12.15
Solid State Ion	9.58	9.11	10.36	14.08	12.48
JETP Lett	n/a	8.07	11.76	13.22	13.22
Physica C	7.63	10.43	15.84	11.59	13.05
Phys Stat Sol A	10.24	12.00	10.40	13.28	15.71
Phys Stat Sol B	9.46	12.34	13.83	12.63	15.98
Eur Phys J B	10.66	12.42	13.42	15.12	15.22
Int J Thermophys	11.54	10.86	15.89	15.49	15.79
Phys Solid State	11.36	12.13	15.49	18.49	19.18
J Stat Phys	13.12	14.03	19.10	18.58	20.13
Soft Matter		n/a	21.84	13.56	15.31
Ann Phys	13.55	13.78	20.57	23.48	21.43
Eur Phys J E	29.48	16.79	19.01	21.21	0.00
Rev Mod Phys	12.50	20.75	19.35	21.23	23.12
Hyperfine Interact	n/a	32.54	41.02	45.73	n/a
Rep Prog Phys	77.48	57.80	62.47	70.44	72.90
Phys Rep	n/a	81.07	114.52	125.75	118.09
Mean	10.48	11.41	13.64	14.56	13.40
Median	8.37	8.11	9.09	8.99	8.14

As described in section 6.4.2, today prices of electronic journals are subject to negotiation. They depend on the number of potential users and are greatly influenced by bundle deals and consortia membership. Hence they vary from one institution to another. To determine the subscription price of a journal has thus become a complex process (Craig & Ferguson, 2009). To be independent of these factors and price negotiations by individual institutions, the evaluation of journal prices for the 44 periodicals[40] is based on the general subscription prices collected by http://journalprices.com. These are based on institutional online subscriptions as stated in publishers's price lists, journal websites or directly from editors and publishers. If prices varied by institutional size, subscription costs for large universities with more than 25,000 members were chosen. Missing data

40 As an author-paid open access journal, New J Phys is not evaluated in this section.

is complemented by price information listed in Ulrich's Periodicals Directory.[41] Annual subscription prices are normalized by the number of publications and citations. For the 2010 edition, publication and citation data is based on data listed in the JCR from 2004 to 2008. Previous editions cover prices for 2009, 2008, 2006 and 2004 normalized by respective 5-year publication and citation windows. The price per article provided by http://journalprices.com is the annual subscription price divided by the arithmetic mean of the total number of articles published by the particular journal during five years as listed in the particular editions of the JCR. Table 6.9 lists the prices per article calculated for the years 2004, 2006 and 2008 to 2010.

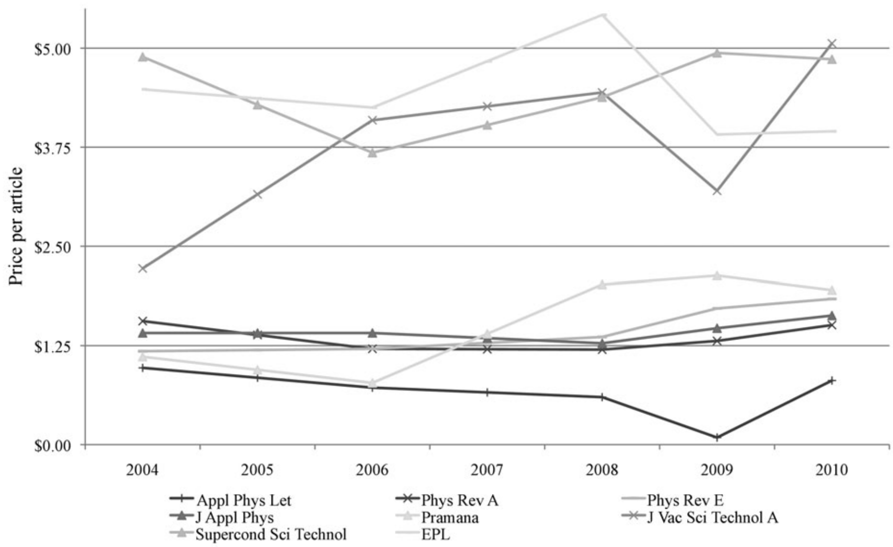

Figure 6.21 Mean journal prices per article per year for eight journals with the lowest article price. Since data was only available for the years 2004, 2006 and 2008 to 2010, prices for 2005 and 2007 are means of the previous and subsequent years. Source: http://www.journalprices.com

While the median price per article for all journals does not change more than US$0.98 between US$8.11 in 2006 and US$9.09 in 2008, the mean increases from US$10.48 in 2004, to US$14.56 in 2009 and settles at US$13.40 in 2010. This indicates that prices increase for a few high-priced journals. The most expensive journals are the review journals because they publish a small number of articles. With annual article prices between US$81.07 and US$125.75, Phys Rep is least cost-effective. Best cost-effectiveness is reached by the journal with the highest number of publications, Appl Phys Let. On average, an article published in Appl Phys Let in 2009 costs only US$0.09.

41 http://www.mcafee.cc/Journal/explanation2010.html

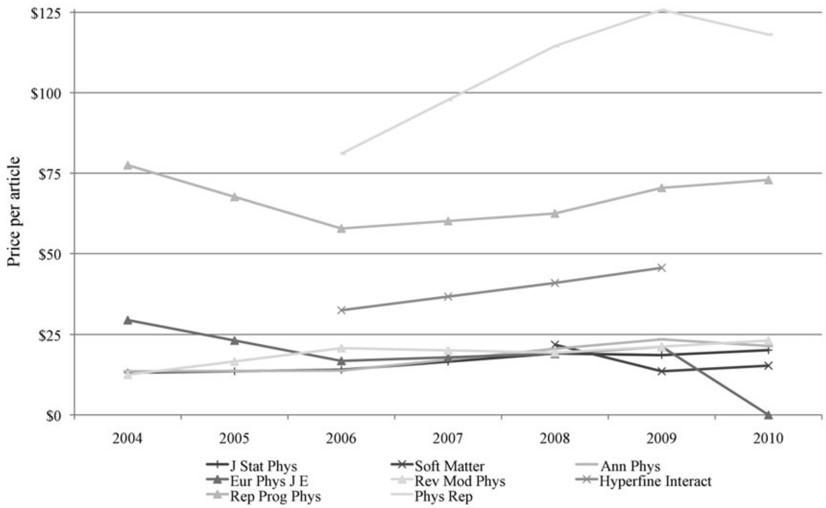

Figure 6.22 Mean journal prices per article per year for eight journals with the highest article price. Since data was only available for the years 2004, 2006 and 2008 to 2010, prices for 2005 and 2007 are means of the previous and subsequent years. Source: http://www.journalprices.com

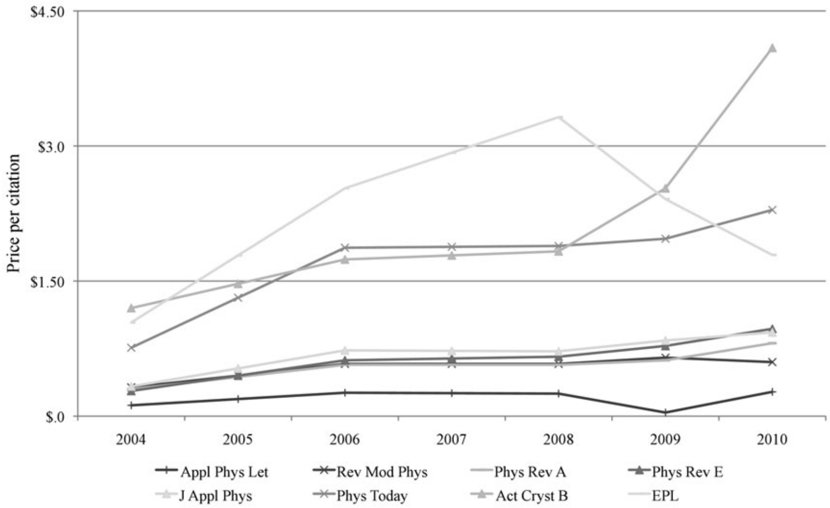

Figure 6.23 Mean journal prices per citation per year for eight journals with the lowest price. Since data was only available for the years 2004, 2006 and 2008 to 2010, prices for 2005 and 2007 are means of the previous and subsequent years. Source: http://www.journalprices.com

Figure 6.21 and figure 6.22 display the development of prices from 2004 to 2010 for the eight most inexpensive and most expensive journals, respectively. Since no data was collected for 2005 and 2007, these values are means of the particular previous and consecutive years. The journals with the highest cost-effectiveness with respect to average price per article are Appl Phys Let, Phys Rev A, Phys Rev E, J Appl Phys, Pramana, J Vac Sci Technol A, Supercond Sci Technol and EPL. On the other hand, Phys Rep, Rep Prog Phys, Hyperfine Interact, Rev Mod Phys, Eur Phys J E, Ann Phys, Soft Matter and J Stat Phys were the most expensive, if one normalizes the subscription price by the number of publications.

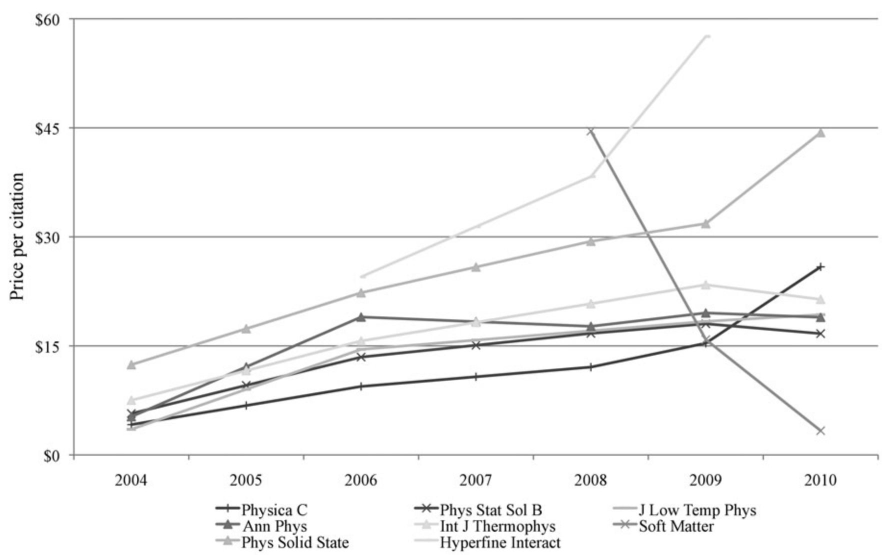

Figure 6.24 Mean journal prices per citation per year for eight journals with the highest price. Since data was only available for the years 2004, 2006 and 2008 to 2010, prices for 2005 and 2007 are means of the previous and subsequent years. Source: http://www.journalprices.com

A different picture presents itself if cost-effectiveness values are calculated on the basis of number of received citations. Due to the high number of citations, Rev Mod Phys becomes the second most cost-effective journal. For the calculation of an average price per citation, the annual subscription price is divided by a mean citation rate: for the 2010 edition the publication window remains the same 5-year period between 2004 and 2008 as is used for the price per article calculation but only citations from 2009 are counted. Thus, the windows for the citation rate are equivalent to that of a 5-year impact factor (see section 5.1.1). Instead of dividing by the number of publications, the total number of citations are, however, divided by 5 to obtain an average number of annual citations, which can be used for the calculation of an average price per citation.[42] Median costs per citation ranges from US$2.96 in 2004 to US$6.65 in 2009, mean values vary between US$3.57 in 2004 and US$9.43 in 2009.

Figure 6.23 and figure 6.24 depict the annual trend of price per citation from 2004 to 2010. 2005 and 2007 values are again derived from the means of 2004 and 2006 and 2006 and 2008, respectively. In terms of citations, Appl Phys Let is again the most cost-effective journal. Phys Rev A, Phys Rev E, J Appl Phys and EPL are also among the eight most inexpensive periodicals, normalized by both number of citations and publications, respectively. Phys Today and Act Cryst B perform better in price per citation.

Hyperfine Interact is the least cost-effective journal based on price per citation. An average citation costs between US$24.50 in 2006 and US$57.57 in 2009. Together with Soft Matter and Ann Phys, it belongs to the eight least cost-effective journals based on both publication and citation counts. Phys Solid State, Int J Thermophys, J Low Temp Phys, Phys Stat Sol B and Physica C are among the eight most expensive journals per citation as well, but performed better in publication-based cost-effectiveness.

In addition to price per publication and citation values, http://journalprices.com also lists the profit status of a journal, the composite price index, the relative price index and a classification into high, medium and low cost-effectiveness categories. These indicators are displayed in table 6.10 for the 41 of the 45 journals that were evaluated in the 2010 edition. 58.5% of these journals were non-profit in 2010. The profit status refers to the profit status of the journal owner, which is not necessarily the publisher. The journal prices team states:

> In many cases, a journal owned by a non-profit organization will contract with a for-profit publisher to handle publication and fulfillment while the society generally retains control of pricing.[43]

Since the big commercial publishers were not willing to provide profit status information, http://journalprices.com collected this information by asking editors and examining journal websites. The composite and relative price index are measures which combine the publication- and citation-based indicator of cost-effectiveness. The composite price index is the geometric mean (i.e. the square root of the product) of the price per publication and price per citation. The relative price index relates the composite price index to the average value of that indicator for all non-profit journals in the same scholarly fields, of which there are 17. A relative price index below 1 thus indicates that the journal has a better cost-performance ratio than average, a value above 1 indicates that the journal is less cost-effective than the average. These results are further illustrated by the classification into value categories. If the relative price index is lower than 1.25 the journal is marked as 'good value for money', if it is higher than 2.0 it is classified as 'bad' and everything in between as 'medium' cost-effective. More than half of the set of journals are classified as 'good value for money' (table 6.10). Appl Phys Let, Phys Rev A, J Appl Phys and Phys Rev E can be identified as the most cost-effective journals. As to be expected, all of these are non-profit journals: journal

42 http://www.mcafee.cc/Journal/explanation2010.html
43 http://www.mcafee.cc/Journal/explanation2010.html

prices are low in comparison to the number of publications and citations, because they do not include the large profit margins of the publishers. Hence, only 3 of these 21 are marked as for-profit journals, namely Comput Mater Sci, Phys Lett A and J Magn Magn Mater. On the other hand, only 3 of the 12 with a relative price index above 2.0 are non-profit, i.e. Phys Solid State, Rep Prog Phys and JETP Lett.

Table 6.10 Profit status, composite price index (CPI), relative price index (RPI) and value category of 41 journals for 2010. Source: http://journalprices.com

Journal	**Profit status**	**CPI**	**RPI**	**Value category**
Appl Phys Let	non-profit	0.46	0.09	good
Phys Rev A	non-profit	1.11	0.22	good
J Appl Phys	non-profit	1.23	0.25	good
Phys Rev E	non-profit	1.33	0.27	good
Nanotechnol	non-profit	2.68	0.42	good
Act Cryst A	non-profit	2.44	0.50	good
EPL	non-profit	2.66	0.54	good
Pramana	non-profit	3.51	0.72	good
J Phys D	non-profit	3.63	0.74	good
Rev Mod Phys	non-profit	3.73	0.76	good
J Vac Sci Technol A	non-profit	4.83	0.77	good
Comput Mater Sci	for-profit	6.10	0.79	good
Supercond Sci Technol	non-profit	4.20	0.86	good
IEEE Nanotechnol	non-profit	5.77	0.92	good
Phys Today	non-profit	4.71	0.96	good
Phys Lett A	for-profit	4.94	1.01	good
Phys Scr	non-profit	5.04	1.03	good
J Rheol	non-profit	5.23	1.07	good
Phys Fluids	non-profit	5.27	1.08	good
Act Cryst B	non-profit	5.57	1.14	good
J Magn Magn Mater	for-profit	7.40	1.18	good
J Phys Condens Matter	non-profit	6.13	1.26	medium
Soft Matter	non-profit	7.14	1.31	medium
Appl Phys A	for-profit	8.54	1.36	medium
J Phys A	non-profit	6.78	1.39	medium
Nucl Instrum Meth A	for-profit	10.07	1.61	medium
Physica B	for-profit	8.42	1.73	medium
Nucl Instrum Meth B	for-profit	11.72	1.87	medium
Solid State Ion	for-profit	8.34	1.94	medium
Phys Stat Sol A	for-profit	15.23	2.43	bad
JETP Lett	non-profit	12.58	2.58	bad
Eur Phys J B	for-profit	13.70	2.81	bad
J Low Temp Phys	for-profit	15.31	3.15	bad
Phys Stat Sol B	for-profit	16.33	3.36	bad
J Stat Phys	for-profit	18.33	3.77	bad
Physica C	for-profit	18.37	3.78	bad
Ann Phys	for-profit	20.14	4.14	bad

continued on next page

Journal	Profit status	CPI	RPI	Value category
Int J Thermophys	for-profit	18.38	4.27	bad
Rep Prog Phys	non-profit	21.16	4.35	bad
Phys Solid State	non-profit	29.16	6.00	bad
Phys Rep	for-profit	29.79	6.12	bad
Mean		9.21	1.82	
Median		6.13	1.18	

Apart from journal output and journal citations, there are other methods for normalizing subscription prices and calculate journal cost-effectiveness. A common approach is the cost-per-use ratios based on journal use measured, for example, through reshelving (ARL, 1999; Nixon, 2000; Ward, Christensen, & Spackman, 2006). With electronic publishing, cost-per-download ratios have become a popular indicator used in libraries to indicate candidates for cancellations (Hahn & Faulkner, 2002; Bucknell, 2008; Carroll & Cummings, 2010; Emrani, Moradi-Salari, & Jamali, 2010). Due to the current problems associated with local download data, which are described at length in section 4.2.1, this method is not applied here.

Summary

This chapter described and applied various methods for evaluating those aspects associated with the management of scholarly journals by editors and publishers. Among these aspects are general journal characteristics (section 6.1), such as a serial's age and publication history, reflecting its standing in the scholarly community, and the journal's scope, which can be regarded as a kind of self-portrait aiming to attract potential readers and contributing authors. An analysis of the publisher affiliation reveals that the journal market is controlled by a few large publishing houses.

The editorial board (section 6.2) is crucial to journal quality since it undertakes the powerful function of gatekeeping journal content. Editors decide upon the acceptance or rejection of submitted manuscripts and thus shape journal content and thus scholarly communication. The editor-publication ratio indicates the intensity devoted to editorial decisions. A high ratio reflects the availability of a large number of editors per submission and thus a high level of expertise. The international composition of the editorial board in terms of affiliated countries of board members reflects the level of international influence of the journal.

The quality and length of the peer-review process (section 6.3) can be evaluated through a journal's rejection and correction rates, on the one hand, and the average time between submission and publication on the other. While a high rejection rate indicates that the periodical is in the favorable position of being able to choose from a large number of high-quality submissions, the correction rate can be used as an estimate of its thoroughness. Long publication delays are negatively perceived because they slow down the scholarly communication process and delay authors' priority claims.

Journal pricing (section 6.4) can be evaluated in terms of the underlying business model, i.e. reader pays or author pays, and through cost-effectiveness ratios which examine subscription prices.

While librarians place special emphasis on journal prices, authors who want to submit their manuscripts attach more weight to rejection rates and short publication delays. Readers are, above all, interested in thorough quality control, so they seek journals with low correction rates and a large editorial board composed of acknowledged experts.

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Chapter 7
Conclusions and Outlook

It has been shown that there are multiple aspects contributing to the impact, prestige and standing of scholarly periodicals in the scientific community and that the impact factor is clearly not able to reflect all of them. Many studies reveal the influence of the impact factor in terms of journal selection by authors, readers and librarians and for marketing purposes by publishers. The indicator has gained such influence because it is well known and recognized, easily understood and accessible. The popularity of the impact factor has lead to a kind of vicious circle that does not make it a better indicator but rather one that is widely used as a testimony to journal prestige. As long as publishing in high impact factor journals is rewarded in research evaluation, authors will try to publish in those, "even if they might not be the most appropriate outlet for a particular article" (Nicholas as cited in Shepherd (2007, p. 6)).

Since one indicator is clearly not able to represent journal impact entirely, journal evaluation should be multifaceted. Five dimensions have been identified which subsume the major factors contributing to a scholarly periodical. These dimensions are journal output (chapter 2), considering aspects of the documents published, journal content (chapter 3), journal perception and usage (chapter 4), evaluating the readership, journal citations (chapter 5), analyzing the impact of the periodical in the scholarly communication process, and journal management (chapter 6), which comprises the publication history, journal pricing and all aspects of the peer review process. Each chapter has described one of these five dimensions in detail and introduced and applied various indicators associated with it.

Four stakeholders of journal evaluation were identified, namely authors, readers, librarians, and editors and publishers. Not all of the described indicators are helpful to every user of journal evaluation, nor are all necessary. Several studies have shown that each user group has its own requirements regarding the analysis of scholarly periodicals. While one aspect is especially important to one user, it is marginal to another (compare section 4.1). Schauder (1994), Tenopir and King (2000) and Rowlands and Nicholas (2005) found that readership, speed of publication, journal reputation and prestige of the editorial board and the impact factor were the most important factors influencing an author in selecting a publication venue.

As Björk and Holmström (2006) state, the weighting of different indicators influencing the decision to select a journal is highly individual. While some indicators are important to all user groups, others matter only to some of them. In their role as authors, researchers choose journals differently than in their function as readers. Mabe and Amin (2002) talk about the asymmetry between the author's and reader's perspective as 'Dr Jekyll and Dr Hyde'. Publishers monitor the performance of their periodicals and that of competitors from a different angle than librarians. The selection criteria are even subject to change for the same author when submitting manuscripts of different quality.

The four user groups place a different emphasis on various indicators. While, on the one hand, long publication delays are considered negatively by all users of journal evaluation alike, journal prices, on the other hand, are crucial to librarians but not important to authors. Authors are interested in publishing their results as fast as possible to claim priority and distribute results rapidly. A survey among physicists identified publication speed as the second most important factor influencing authors with respect to submission (Tenopir & King, 2000). Librarians aim to supply their users, who do not want to spend time on reading obsolete research results, with current and up-to-date literature. As rapidity of publication is crucial to authors and readers, editors and publishers seek to minimize delays by optimizing the submission and review process. Journal prices are not important to authors, because they affect them only indirectly, while they are crucial to librarians, who need to compile a collection within a budget. Librarian's decisions to select and deselect serials is largely influenced by subscription rates and local readership patterns, often reflected in cost-benefit ratios (Van Hooydonk, Gevaert, Milisproost, Van de Sompel, & Debackere, 1994; Hahn & Faulkner, 2002; McCabe, 2002). Besides price and usage, Shepherd (2007) also identified user feedback, publisher reputation and the impact factor as key factors influencing librarians in the selection of new subscriptions.

Some indicators may be even interpreted in different ways by two user groups. While editors and publishers seek to increase their rejection rates indicating that their journals publish only the highest quality manuscripts, this could discourage authors from submitting their manuscripts due to the fear of being rejected. On the other hand, the author might put up with high rejection rates, if the peer review process is fast and the journal is able to reach out to a large readership. In certain circumstances, the author's main goal is to publish his results as fast as possible. In this case, a serial with short publication lags may be the most favorable regardless of its citation impact or readership.

> The scholarly communication system is highly complex, citations constitute one of its representations – though a most valid and useful one – and journal performance is a multi-dimensional concept that cannot be expressed by a single measure. The adequacy of a journal impact measure is related to the type of use made of it, and the type of research question addressed. A particular indicator may be appropriate in one context, and less appropriate in another. (Moed, 2005, p. 39)

This shows that journal evaluation should be multidimensional. Multidimensional journal evaluation can be achieved by including various facets of scholarly journals, depending on the individual information needs and requirements of the four groups of users. Instead of conflating these facets into one ranking, users should be able to weigh the metrics individually depending on their particular priorities. In the following, four scenarios representing the author's, reader's, librarian's and editor's and publisher's perspective, are provided which, as an example, combine indicators from the different dimensions that are especially interesting to one of the four stakeholders.

7.1 The Author's Perspective

In the role of an author, a researcher can apply journal evaluation to find a suitable venue for publication. The dimension of journal content helps to narrow down the number of periodicals by subject area. The other four dimensions are represented by indicators helping the author to identify a suitable journal for manuscript submission. Journal output identifies the number of research articles published per year, which helps to determine the chances of being published. The size of the potential readership (journal perception and usage) can be estimated by usage diffusion, i.e. the number of unique users of the journal on social bookmarking platforms. In the dimension of journal citations, it is helpful to analyze the percentage of uncited papers in the journal and the SCImago journal rank to indicate in how far the journal is cited by other prestigious sources. In journal management, the rejection rate and publication delay are the most important aspects influencing an author's choice of whether to submit his manuscript. Although a high rejection rate indicates high quality of published content, it may discourage an author from submitting. His chances of being published are higher if the rejection rate is low. Since the author aims to publish as fast as possible, journals with short publication delay are appealing.

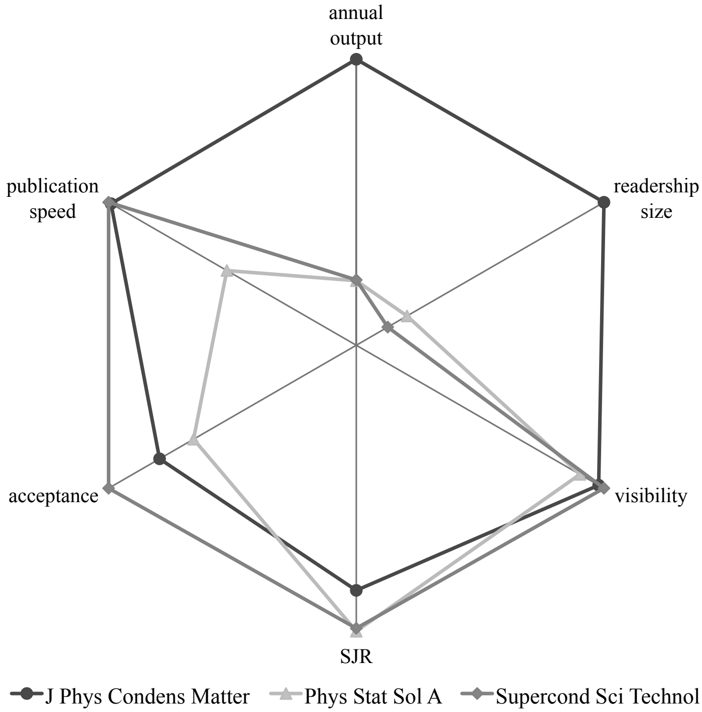

Figure 7.1 Comparison of J Phys Condens Matter, Phys Stat Sol A and Supercond Sci Technol in terms of journal output (annual output), journal perception and usage (readership size), journal citations (visibility, SJR) and journal management (acceptance rate, publication speed).

Since the selection process depends on various factors and is highly individual it would be counterproductive to conflate different aspects to one ranking. One author might emphasize speedy publication more than another, who would prefer a low rejection rate to short publication delay so that he can be sure that his manuscript passes the review process. A third might attach great importance to the ranking of the journal in terms of its citation and disregard the size of potential readership. Also, one author might behave differently based on the particular manuscript he wants to submit. If he regards the submission as of extremely high quality, he might prefer a high rejection rate because he is convinced that his manuscript will pass the review process. When the same author wants to publish a medium-quality manuscript, he might attach great importance to a journal with a large annual output of research articles, so that he has a higher chance of being published, and a higher potential readership so that his results are read by as many people as possible. Multidimensionality has to be preserved to allow for an individual weighting of indicators.

Table 7.1 Mean number of research articles published per year (P_{Art}), usage diffusion (UD), uncitedness, SCImago journal rank (*SJR*), mean rejection rate and mean publication delay for J Phys Condens Matter, Phys Stat Sol A and Supercond Sci Technol.

Journal	P_{Art}	UD	Uncitedness	*SJR*	Rejection rate	Publication delay
J Phys Condens Matter	1056.4	244	17.1%	0.084	51.8%	123.6
Phys Stat Sol A	238.4	50	23.5%	0.098	60.1%	237.6
Supercond Sci Technol	241.1	31	15.3%	0.097	39.3%	121.2

The radar chart in figure 7.1 shows the performance of three journals in six indicators of the four dimensions of journal output, perception and usage, journal citations and management. The dimension of journal content is not reflected in an indicator but is used to determine a set of related periodicals in terms of subjects covered.

For the scenario shown in figure 7.1, three serials were chosen classified as condensed matter journals by the ERA and WoS classification schemes. These are J Phys Condens Matter, Phys Stat Sol A and Supercond Sci Technol. In order to obtain an intuitive and easily interpretable representation of the performance, the metrics were adjusted so that on the radar chart the favored indicator value is displayed on the outer rim. As only three journals are compared, the relative performance of these three is sufficient. In each category, the highest value thus represents 100%. The performance values are thus not absolute but in relation to the best journal per category. The absolute values are, however, listed in table 7.1 for a more detailed comparison.

The dimension of journal output is represented by the annual publication output, i.e. the mean number of research articles the journal published annually between 2004 and 2008 (section 2.1.1). The higher the mean annual output, the higher the general chances that the author's manuscript will be published, although this depends on the number of submissions as well. The ratio of publications and submissions is, however, expressed in the rejection rate. Journal usage is included in terms of global readership size, i.e. usage diffusion (section 4.3.2), which is the absolute number of unique users who saved at least one document published between 2004 and 2008 on a social bookmarking platform. The usage diffusion thus indicates the size of the potential readership. The dimension of journal citations is represented by two metrics, namely the SCImago journal rank (section 5.2.3) and uncitedness (section 5.1.2). The SCImago journal rank value is the indicator value from 2009, which covers the weighted citations the journal received in 2009 for documents published from 2004 to 2009. A high SCImago journal rank value thus indicates that the journal has been cited frequently by prestigious periodicals. The uncitedness indicates the share of documents which are not cited and hence invisible to the scholarly community. Two indicators from the dimension of journal management are particularly important to authors, i.e. the rejection rate (section 6.3.3) and publication delay (section 6.3.2). The former indicates the manuscript's overall chances of passing the review process and the latter informs the author about the length of the delay period between submission and publication.

Other than annual output, readership size and SCImago journal rank, uncitedness, rejection rate and publication delay are measurements whose value should be as low as possible. Hence, complementary values are chosen so that the radar chart in figure 7.1 can be read intuitively. The journal placed on the outer rim of the chart thus performed best. Uncitedness is replaced by the percentage of cited publications, i.e. $P_{cited} = 100\% - P_{uncited}$ and the acceptance rate replaces the rejection rate, i.e. $P_{accept} = 100\% - P_{reject}$. As there is no complementary indicator for publication delay, one year was chosen as a benchmark from which to subtract the actual lag. The metric hence indicates publication speed.

Figure 7.1 shows the relative performance of the three journals with respect to the six metrics. Supercond Sci Technol performs best in terms of citation visibility, publication acceptance and speed. An author who attaches great importance to getting published rapidly in a journal which performs well in terms of citations with a low chance of being rejected would probably choose Supercond Sci Technol. The potential readership of Supercond Sci Technol is, however, rather small, so if the author's emphasis was to be perceived by as many readers as possible, he would submit his manuscript to J Phys Condens Matter. Publication delay and citation visibility are almost as good as for Supercond Sci Technol and although more than half of all submissions are rejected, J Phys Condens Matter publishes more than four times as many research articles per year. With regard to the SCImago journal rank, J Phys Condens Matter ranks lowest, indicating that, in comparison, the journal is not cited as frequently by prestigious serials as the other two. Phys Stat Sol A has the highest SCImago journal rank value but with the lowest number of research articles published annually and the lowest acceptance rate, the chances of being rejected are high. If the author valued the quality of his submission high enough to pass the review process and was not discouraged by a comparably long publication delay, he would submit to Phys Stat Sol A.

7.2 The Reader's Perspective

When the same researcher selects journals as a reader instead of as an author, different criteria are important to him. The reader's perspective differs from that of the author's in so far as readers want to read as little as possible to satisfy their information needs.

Two major types of information demands can be distinguished, namely to obtain an overview of the research field, on the one hand, and to be updated in detail about current results from the research front, on the other. Since these requirements contradict each other in so far as most journals veer towards specialization in one of the two directions, these two information needs are treated separately. The reader's perspective is thus subdivided into a review and research journal scenario.

Review journals specialize in the publication of overview articles that summarize developments in a research field. In contrast to research journals which publish new research results of detailed topics, review journals typically have a general scope. As shown in table 2.5 in section 2.1.4, three of the 45 journals can be identified as review journals, i.e. Rev Mod Phys, Rep Prog Phys and Phys Rep. All of these are classified as general or multidisciplinary physics journals (section 3.2.1).

Table 7.2 Mean number of review articles published per year (P_{Rev}), mean document length, citations/citee-ratio, 5-year impact factor, journal age and number of countries represented on the editorial board for Phys Rep, Rep Prog Phys and Rev Mod Phys.

Journal	P_{Rev}	Document length	Citations/ citee-ratio	5-year IF	Journal age	Countries on EB
Phys Rep	63.2	73.3	5.2	17.334	40	7
Rep Prog Phys	42.6	53.6	6.1	13.355	70	9
Rev Mod Phys	27.0	44.5	7.5	41.344	82	6

Figure 7.2 shows five indicators and the relative results for Phys Rep, Rep Prog Phys and Rev Mod Phys, which can be used to select a review journal. A reader who is looking for an overview wants to read as few reviews as possible, which, however, cover the reviewed topic extensively. In terms of journal output, the mean number of reviews published annually and the average page length are suitable indicators. In contrast to the author's perspective, the reader prefers a small output. Annual output represents the mean number of reviews published between 2004 and 2008 (section 2.1.1). Document length describes the average number of pages per document (section 2.1.2). The longer the review, the more detailed and comprehensive it is. The citations/citee-ratio is helpful to determine the diversity of the knowledge import, since it is a ratio of the number of cited references per cited journal (section 2.1.5). For a comprehensive and well-balanced review it is important to consider various informational sources, which is reflected in a low citations/citee-ratio. The 5-year impact factor can be used to determine the average citation rate of the review journals (section 5.1.1). The 2009 values are used since they cover the average number of citations of the documents published between 2004 and 2008. The number of nationalities represented on the editorial board indicate the international influence of the journal (section 6.2.2) and its publication tradition can be determined through journal age (section 6.1.1). For review journals, rejection rate and publication delay can be neglected, since most articles are solicited and topicality is not so important. The radar chart in figure 7.2 was constructed in the same manner as described above. The highest value per category was chosen as the benchmark and complementary values were used for those indicators, where low values

are regarded as better performance, i.e. mean number of reviews published annually and the citations/citee-ratio, where a low value indicates a broad and diverse import of knowledge. The absolute values per indicator per journal are listed in table 7.2.

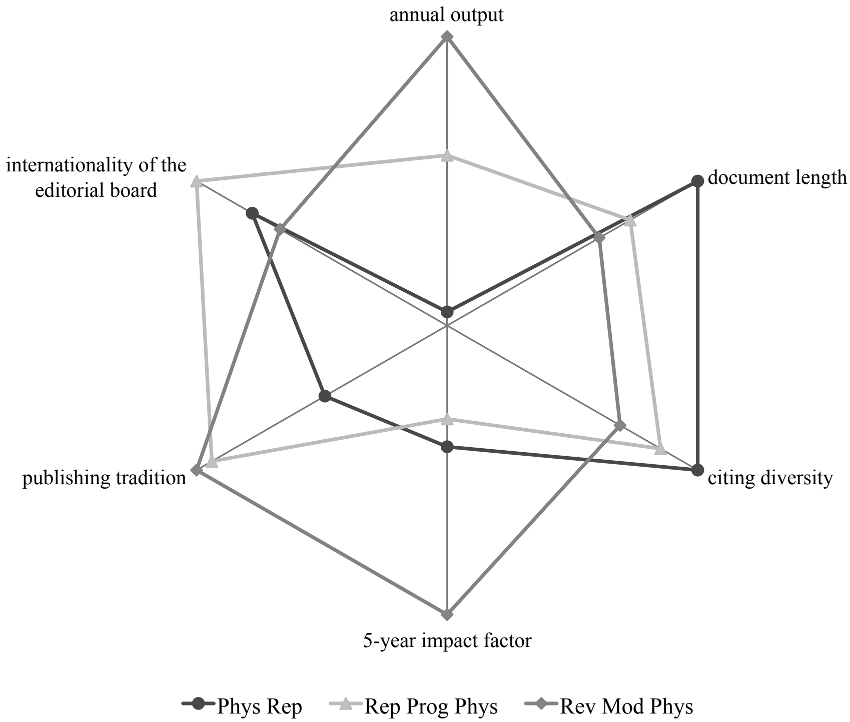

Figure 7.2 Comparison of Phys Rep, Rep Prog Phys and Rev Mod Phys in terms of journal output (annual output, document length, citation diversity), journal citations (5-year impact factor) and journal management (publication history, internationality of the editorial board).

As shown in figure 7.2, the performance of the three review journals is well-balanced. While Rev Mod Phys has the highest 5-year impact factor, the lowest publication output and the longest publishing tradition, it is outdone by the other two journals in terms of comprehensiveness of the reviews, citing diversity and the internationality of the editorial board. Rep Prog Phys performs second best in all categories except board internationality, where it shows the highest number of nationalities, and the 5-year impact factor, where it has the lowest score. Phys Rep publishes the most comprehensive reviews and the most diverse citation behavior. However, it publishes the most documents per year, so that the reader has to read more. With an age of 40 years, it has the shortest publication history. A reader who wants to read as little as possible will probably select Rev Mod Phys. On average, it publishes only 27 reviews per year of 44.5 pages each. It is the journal with by far the highest 5-year impact factor and the longest publication history. Choosing Rev Mod Phys, one has to compromise with regard to the citing diversity and the international influence of the editorial board.

Table 7.3 Median number of references per page (scholarliness), usage ratio (UR), highly citedness (C_{max}), cited half-life ($T_{\frac{1}{2}}^{cited}$), editor-publication ratio and correction rate for Eur Phys J B, Phys Fluids and Soft Matter.

Journal	Scholarliness	UR	C_{max}	$T_{\frac{1}{2}}^{cited}$	Editor-publ. ratio	Correction rate
Eur Phys J E	3.6	11.2%	5.6%	5.6	0.237	0.6%
Phys Fluids	2.6	8.1%	2.6%	> 10	0.018	1.3%
Soft Matter	5.6	14.2%	13.5%	2.1	0.134	0.3%

A reader interested in the current results of the research front is interested in a specific subject area. The network graph in figure 3.33 in section 3.4.1, which displays journal similarity based on bibliographic coupling and co-citations, is used to identify Eur Phys J E, Phys Fluids and Soft Matter as similar journals in terms of their co-citation and bibliographic coupling values. They belong to the large group of mathematical and statistical physics and more specifically focus on the sub-specialty of soft matter physics.

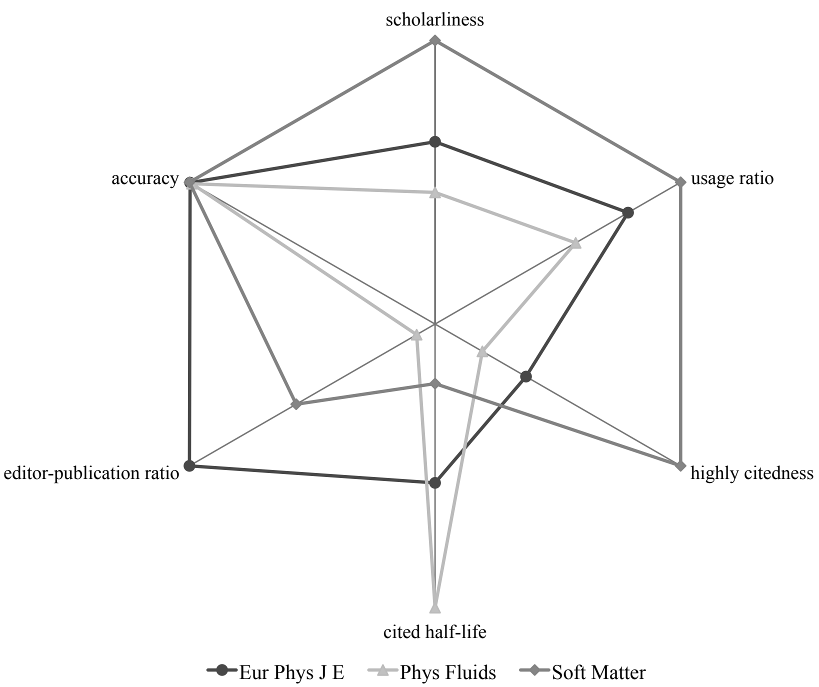

Figure 7.3 Comparison of Eur Phys J E, Phys Fluids and Soft Matter in terms of journal output (scholarliness), perception and usage (usage ratio), journal citations (highly citedness, cited half-life) and journal management (editor-publication ratio, accurateness).

A reader who wishes to be informed about current research results prioritizes the quality aspect of published contents reflected in a low correction and high rejection rate, a large editorial board in relation to journal output and a high level of scholarliness. He wants to read a journal that publishes the most important papers in the field and whose content remains relevant for a long period of time. The median number of references per page is chosen as an indicator of the journal's level of scholarliness (section 2.1.5). It represents the dimension of journal output. Journal perception and usage is reflected in the usage ratio, indicating the percentage of documents which have been bookmarked at least once (section 4.3.2). Scholarly communication, i.e. journal citations, is represented by the percentage of highly cited papers as an indicator of excellence (section 5.1.2) and cited half-life analyzing obsolescence (section 5.1.4). The editor-publication ratio (section 6.2.1) and the correction rate (section 6.3.4) represent journal management in terms of the quality of the review process. A high editor-publication ratio indicates that a relatively high number of subject experts is available to decide upon acceptance and rejection of submissions. A reader does not want to read flawed data, so the percentage of documents that need to be corrected after publication should be as low as possible. Since the correction rate represents the share of errata in relation to the total journal output, it can be used as an estimate of the thoroughness of the review process. These indicators are used to compare Eur Phys J E, Phys Fluids and Soft Matter to find the most suitable journal for reading the latest research results in soft matter physics. The absolute values of the six indicators representing the dimensions of journal output, perception and usage, citation and management are given in table 7.3.

Figure 7.4 Tag cloud depicting 50 most frequently assigned user tags to articles published in Soft Matter between 2004 and 2008.

Figure 7.3 shows the radar chart comparing the three soft matter physics journals in terms of scholarliness, usage ratio, highly citedness, cited half-life, editor-publication ratio and accuracy. The latter is the complementary indicator of the correction rate, which had to be adjusted in terms of $P_{corrected} = 100\% - P_{accurate}$, to allow an intuitive comparison of performance through the radar chart. Soft Matter can be identified as the journal which performs best in all categories except for the editor-publication ratio and cited half-life. As described in section 5.1.4, the latter is, however, due to only being founded in 2005. Phys Fluids has a cited half-life value above 10, indicating that content published in the journal stays relevant for a long period of time. Half of all articles are cited, and thus used, for ten years and longer. Cited half-life is, however, the only indicator where Phys Fluids performs better than any other journal. Both of the other two journals perform better in every other category. Consequently, Eur Phys J E is ranked second best in all categories except for the editor-publication ratio, where it performs best. Out of the three journals, Soft Matter can be identified as the most suitable soft matter journal from the reader's perspective.

Figure 7.4 represents an aspect of journal content interesting to potential readers. It shows the tags assigned to documents published in Soft Matter, highlighting topics other readers regarded as important content. The tag cloud depicted in figure 7.4 might thus be a helpful orientation for new readers.

7.3 The Librarian's Perspective

The librarian's perspective corresponds to a certain extent to that of the reader's, as it is the information needs of the latter that librarians intend to satisfy. As a study by the UKSG discovered, library users' feedback is most important to librarians and directly influences the selection and deselection of scholarly journals (Shepherd, 2007). This is also why usage-based reading statistics have become one of the most important resources for librarians in optimizing journal collection management. Together with subscription prices, local usage statistics represent the two major pillars of quantitative journal evaluation by librarians. Annual subscription prices and usage data are often combined in a calculation of cost-benefit ratios such as price per downloaded article, price per document published or citations received, which are used for cancellation purposes (McCabe, 2002). Librarians also use the impact factor to identify new titles. In some cases the reputation of the publisher plays a role (Shepherd, 2007).

Since local usage statistics and cost-performance ratios are crucial to librarians, they play a major role in this scenario. Figure 7.5 includes the mean download rate (section 4.2.3) and the absolute number of downloads (section 4.2.1) as representatives of the dimension of journal perception and usage and the price per article and price per citation (section 6.4.3), which are part of journal management. Journal output is represented by the mean number of documents published per journal per year between 2004 and 2008 without limitations in terms of the document type (annual output, section 2.1.1). The regular 2-year impact factor of 2009 covers the dimension of journal citations (section 5.1.1). The three journals analyzed are specialized in applied physics, as can be seen in the bibliographic coupling and co-citation similarity network in figure 3.33 in section 3.4.1 and the 2-mode network (section 3.2.1, figure 3.6) depicting the WoS classification. The absolute values for the five indicators and three journals are shown in table 7.4.

Table 7.4 Mean number of documents published per year (P), mean download rate, absolute downloads 2006 to 2010, impact factor (IF), price per article and price per citation for Appl Phys A, J Appl Phys and J Phys D.

Journal	P	Download rate	Downloads	IF	price per article	price per citation
Appl Phys A	537.0	0.098	3698	1.595	$10.64	$5.77
J Appl Phys	3565.4	0.000	23713	2.072	$1.44	$0.71
J Phys D	910.8	0.060	5168	2.100	$5.51	$3.54

In contrast to the author and reader scenarios, the annual output in the librarian scenario is not restricted to any particular type of document. It is the mean annual number of documents published from 2004 to 2008. Since librarians subscribe to the journal, which represents the package of all documents published in it, they are interested in how much content they get for each subscription. Figure 7.5 shows that J Appl Phys has by far the largest annual output of the three journals. Of course, a librarian has to acquire a balanced collection containing both research and review journals to fulfill the various information needs of the readers, as described above. In an analysis comparing a large number of journals, it would thus be helpful to identify the distribution of pages per document type as described in section 2.1.4.

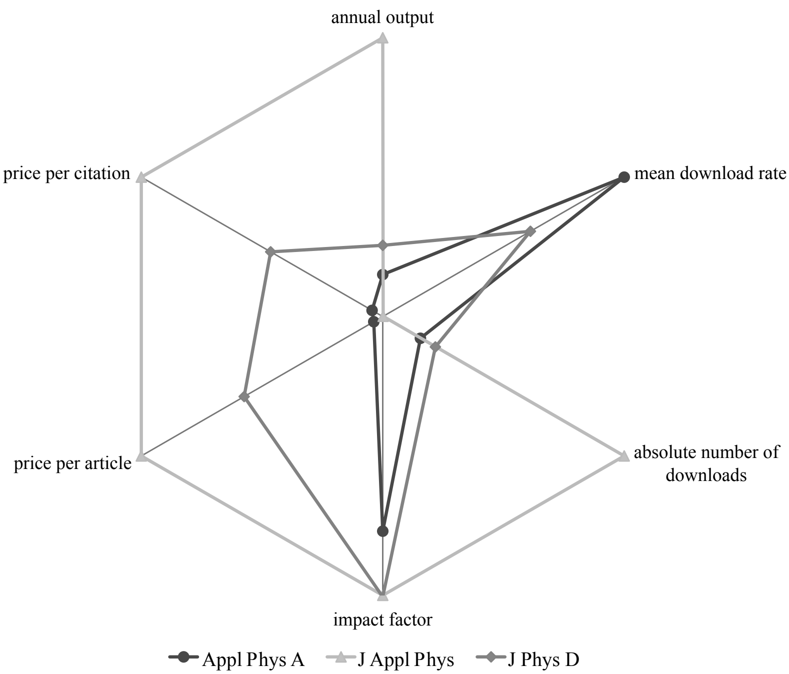

Figure 7.5 Comparison of Appl Phys A, J Appl Phys and J Phys D in terms of journal output (annual output), perception and usage (mean download rate, absolute number of downloads), journal citations (impact factor) and journal management (price per article, price per citation).

The mean download rate is based on the COUNTER Journal Report 5 including the full-text requests at Forschungszentrum Jülich in 2010 for documents published in 2004 to 2008. The indicator is defined as in section 4.2.3, however, the value used in figure 7.5 and listed in table 7.4 is the mean of the particular annual values. The absolute number of downloads is based on Journal Reports 1, indicating the number of full texts accesses per journal at Forschungszentrum Jülich from 2006 to 2010. As described in section 4.2.1, the absolute value should be handled carefully and always compared with journal output. As can be seen in figure 7.5, J Appl Phys was accessed most frequently, which is due to the large annual output. In contrast, it has a mean download rate close to zero. Since it is a size-independent measure, the mean download rate is more suitable for depicting relative usage. On average, Appl Phys A publications are read most frequently.

Since librarians need to budget, they want to get as much for their money as possible. In figure 7.5, the price per article and price per citation are thus adjusted so that a high value indicates a good cost-benefit ratio, i.e. the journal performs well from the librarian's perspective, if the price per article or citation are low. The data is based on the data compiled by http://www.journalprices.com. Since subscription prices are negotiable and depend on various factors such as consortia membership, institutional size and bundle deals, it would be more appropriate for librarians to use their own data. Appl Phys A is most expensive but compared to the average usage per document, it has good cost performance. Appl Phys A has also the highest impact factor, although differences between the impact factors of three journals are so small, that in view of the problems constructing the impact factor (compare section 5.1.1), it should in this case not be used to decide in favor or against any of the journals.

Since J Appl Phys performs best in all categories except mean download rate, a librarian would probably select it for subscription. Since the average document published in Appl Phys A is, however, most frequently used, he would probably include it in the collection as well despite its high cost, if the budget allows.

7.4 The Editor's and Publisher's Perspectives

Editors and publishers are interested in monitoring the journal market and improving the performance of their journals so that they are chosen by authors, readers and librarians in favor of competing periodicals. In so far, they should be interested in analyzing their journals for aspects which are important to these three stakeholders. Sometimes the editor's and publisher's interests, however, conflict with that of some of the user groups. For example, a publisher seeks to maximize profits, while the librarian has to keep to a budget. The editors seek to increase the rejection rate to indicate high quality of published content to the readers, while this may discourage authors from submitting.

Table 7.5 Number of contributing countries, growth rate from 2004 to 2008, mean response time 2004, SCImago journal rank (SJR), mean price per article and mean rejection rate for JETP Lett, Phys Rev A and Pramana.

Journal	Contributing countries	Growth rate	Mean response time	SJR	Price per article	Rejection rate
JETP Lett	48	+6.2%	1.1	0.070	\$11.57	48.9%
Phys Rev A	91	+48.7%	0.6	0.101	\$1.36	35.9%
Pramana	64	−1.6%	1.6	0.032	\$1.60	67.7%

Figure 7.6 includes six indicators representing the three dimensions of journal output, journal citations and journal management. Many publishers collect detailed usage

data on their titles to monitor demand, which is particular helpful in individual price negotiations, and download rates are used for marketing purposes as well. Since these statistics are not published, usage statistics of competing journals are not available for comparison. The dimension of journal perception and usage is thus not included in this scenario although it is important to analyze journal performance from the editor's and especially publisher's point of view. Shepherd (2007) discovered that interest in usage statistics by publishers is growing. He also found that publishers, in contrast to authors and librarians, were more reserved about compiling global usage statistics.

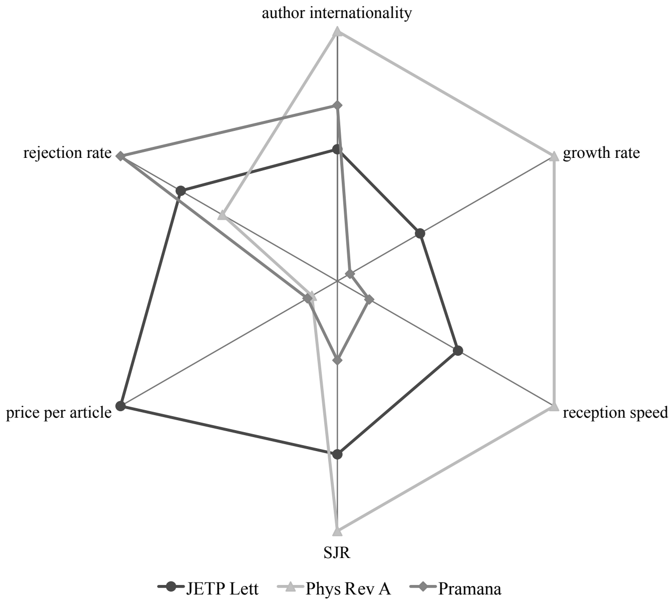

Figure 7.6 Comparison of JETP Lett, Phys Rev A and Pramana in terms of journal output (author internationality, growth rate), journal citations (reception speed, SJR) and journal management (price per article, rejection rate).

JETP Lett, Phys Rev A and Pramana are three general physics journals which are analyzed from the editor's and publisher's perspective as an example. Indicator values are listed in table 7.5. Author internationality is measured by the number of countries contributing to journal output during the five years under analysis (section 2.2.3). The more authors from different countries publish in the journal, the more international it is. Editors and publishers often emphasize internationality in the journal's scope (section 6.1.3), and the number of contributing countries is a suitable indicator for monitoring actual internationality. The growth rate compares the size of annual publication output from 2008 to 2004 and thus reflects whether journal output has increased or decreased (section 2.1.1). Journal citations are measured by the mean response time (section 5.1.4) and the SCImago journal rank (section 5.2.3). While the SCImago journal rank mirrors the mean number of citations weighted by the citation prestige of citing journals, the mean response time reflects the average time it takes for a document to receive its first citation. A low mean response time thus reflects the reception speed of journal content by citing authors. As a low indicator value is favorable, the metric was adjusted so that the journal with the fastest citation response is displayed on the outer rim of figure 7.6.

Phys Rev A performs best in most of the categories. It is the most international journal in terms of contributing authors, produced 48.7% more output in 2008 than five years before and its documents are cited quickly after publication by prestigious sources. Out of the three journals, Phys Rev A has the lowest price per article. This may be positive from the editor's perspective but is perceived negatively by publishers due to lower profit margins. Publication growth influences the rejection rate. Almost two-thirds of all submissions are published. From the editor's perspective Phys Rev A performs very well but rejection rates could be raised to further improve the quality of published content, which would attract more readers.

From the editor's and publisher's point of view, JETP Lett is a general physics journal of medium performance with low author internationality but high profit margins in terms of average price per article. As mentioned before, JETP Lett has a national focus on Russia. Pramana, which is an Indian journal, has by far the highest rejection rate but does not perform so well in the other categories. It has an average ability to attract international authors, annual output decreased slightly and reception speed and SCImago journal rank are low.

7.5 Outlook

The present work has shown that journal evaluation needs to be multidimensional in order to reflect various aspects of scholarly periodicals. Based on the concept of the five dimensions of output, content, perception and usage, citations and management, numerous journal indicators have been categorized, described, compared and applied to a test set of 45 physics journals. Although the small size of the journal set does not allow for a generalization of indicator results, it made it possible to provide detailed analyses of differences and effects regarding individual periodicals, which for users of journal evaluation methods is most important.

This book aimed to explore the possibilities of journal evaluation beyond the impact factor. It has been shown that the process of formal scholarly communication reflected in journal citations is so complex that no single indicator incorporating all aspects has yet been constructed. While the computational methods of basic, weighted and normalized indicators become more and more complex in order to counterbalance biases caused by skewed distributions, discipline-specific citation and publication behavior, different document types and publication age, users are left behind and select journals based on the well-known, comprehensible and easily accessible impact factor. Although countless studies have proved its flawed nature such as the asymmetry between numerator and denominator, the too short publication and citation window and the inability of a mean to accurately reflect skewed citation distributions, the impact factor is still used and misused as a cure-all in research evaluation.

This study revealed that there are many other more suitable methods of analyzing scholarly journals from various perspectives. Indicators are described in terms of construction, applicability and deficiencies, strengths and weaknesses are highlighted, so that each user can decide for himself which methods are the most suitable for his purpose. In this chapter, four scenarios have been provided which represent the author's, reader's, librarian's and editor's and publisher's point of view as an example and combine methods from five dimensions of journal evaluation. The extent to which a multidimensional approach will be able to establish itself and compete with the pre-eminence of Thomson Reuters's impact factor depends, on the one hand, on the willingness and ability of the bibliometric community and creators of indicators to make methods more transparent, compute metrics on a regular basis and make results accessible. On the other hand, users of journal and research evaluation have to be willing to engage with new methods and accept that one single indicator is not able to reflect the multifaceted picture of journal impact, quality and prestige.

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List of Abbreviations

ABS	Australian Bureau of Statistics
ACCELERATE	ACCess to ELEctronic liteRATurE
Act Cryst A	Acta Crystallographica Section A: Foundations of Crystallography
Act Cryst B	Acta Crystallographica Section B: Structural Science
Act Cryst C	Acta Crystallographica Section C: Crystal Structure Communications
Act Cryst E	Acta Crystallographica Section E: Structure Reports Online
A&HCI	Arts & Humanities Citation Index
AIP	American Institute of Physics
Ann Phys	Annalen der Physik
API	Application Programming Interface
APS	American Physical Society
Appl Phys A	Applied Physics A: Materials Science & Processing
Appl Phys Let	Applied Physics Letters
AVS	American Vacuum Society
Comput Mater Sci	Computational Materials Science
COUNTER	Counting Online Usage of NeTworked Electronic Resources
CPCI-S	Conference Proceedings Citation Index – Science
CWTS	Centrum voor Wetenschap- en Technologie Studies, Leiden University
DDC	Dewey Decimal Classification
DOAJ	Directory of Open Access Journals
ECOOM	Expertisecentrum O&O Monitoring, Katholieke Universiteit Leuven
EPL	EPL. A Letters Journal Exploring the Frontiers of Physics
EPS	European Physical Society
ERA	Excellence in Research for Australia
Eur Phys J B	The European Physical Journal B: Condensed Matter and Complex Systems
Eur Phys J E	The European Physical Journal E: Soft Matter and Biological Physics
EZB	Elektronische Zeitschriftenbibliothek (Electronic Journals Library)

Hyperfine Interact	Hyperfine Interactions
IAS	Indian Academy of Sciences
IEEE	Institute of Electrical and Electronics Engineers
IEEE Nanotechnol	IEEE Transactions on Nanotechnology
IEEE T Appl Supercon	IEEE Transactions on Applied Superconductivity
Inorg Chem	Inorganic Chemistry
Int J Thermophys	International Journal of Thermophysics
IOP	Institute of Physics
ISI	Institute for Scientific Information
IUCr	International Union of Crystallography
J Appl Phys	Journal of Applied Physics
JCR	Journal Citation Reports
JETP Lett	JETP Letters
J Low Temp Phys	Journal of Low Temperature Physics
J Magn Magn Mater	Journal of Magnetism and Magnetic Materials
J Phys A	Journal of Physics A: Mathematical and Theoretical
J Phys Condens Matter	Journal of Physics: Condensed Matter
J Phys D	Journal of Physics D: Applied Physics
J Rheol	Journal of Rheology
J Stat Mech	Journal of Statistical Mechanics: Theory and Experiment
J Stat Phys	Journal of Statistical Physics
J Vac Sci Technol A	Journal of Vacuum Science & Technology A: Vacuum, Surfaces and Films
KVA	Royal Swedish Academy of Sciences
MESUR	MEtrics from Scholarly Usage of Resources
Nanotechnol	Nanotechnology
NIH	National Institutes of Health
New J Phys	New Journal of Physics
Nucl Instrum Meth A	Nuclear Instruments & Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Nucl Instrum Meth B	Nuclear Instruments & Methods in Physics Research Section B: Beam Interactions with Materials and Atoms
OAI-PMH	Open Archives Initiative – Protocol for Metadata Harvesting
Phys Fluids	Physics of Fluids
Physica B	Physica B: Condensed Matter
Physica C	Physica C: Superconductivity and its Applications
Phys Lett A	Physics Letters A
Phys Rep	Physics Reports. A Review Section of Physics Letters
Phys Rev	Physical Review
Phys Rev A	Physical Review A: Atomic, Molecular and Optical Physics

Phys Rev B	Physical Review B: Condensed Matter and Materials Physics
Phys Rev E	Physical Review E: Statistical, Nonlinear and Soft Matter Physics
Phys Rev Lett	Physical Review Letters
Phys Scr	Physica Scripta
Phys Solid State	Physics of the Solid State
Phys Stat Sol A	Physica Status Solidi A – Applications and Materials Science
Phys Stat Sol B	Physica Status Solidi B – Basic Solid State Physics
Phys Today	Physics Today
Pramana	Pramana – Journal of Physics
PLoS	Public Library of Science
R&D	Research and development
RAS	Russian Academy of Sciences
Rep Prog Phys	Reports on Progress in Physics
Rev Mod Phys	Reviews of Modern Physics
RSC	Royal Society of Chemistry
SCI	Science Citation Index
SERUM	Standardized Electronic Resource Usage Metrics
SIF	Societa Italiana de Fisica
SNIP	Source normalized impact per paper
STM	Science, technology and medicine
Soft Matter	Soft Matter
Solid State Ion	Solid State Ionics – Diffusion and Reactions
SoR	Society of Rheology
SSCI	Social Sciences Citation Index
Supercond Sci Technol	Superconductor Science & Technology
SUSHI	Standardized Usage Statistics Harvesting Initiative
UKSG	United Kingdom Serials Group
WoS	Web of Science
ZDB	Zeitschriftendatenbank

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