KTH RAE BIBLIOMETRIC REPORT

2000 – 2006

NOVEMBER, 2008

ULF SANDSTRÖM
ERIK SANDSTRÖM

MAIN FINDINGS OF THE BIBLIOMETRIC STUDY

This chapter reports on the research potential of staff currently employed by KTH. Papers published by KTH researchers are compared with papers published by their international colleagues during the period 2000–2006. The citation impact of the KTH papers is significantly above international reference levels: they receive 15% more citation in their journals. This translates to a field-normalized impact of 31% above world average, which can be explained by the fact that KTH researchers publish in journals with high impact-levels – 16% above the global reference value.

Several units perform well above global average and these units are found in almost all of the schools at KTH.

The citation impact of KTH researchers is globally competitive in areas such as "Signals and Systems", "Communication Networks", "Optics", "Fiber Polymers", "Mathematics", "Computer Science", "Fluid and Solid Mechanics", "Urban Planning", "Philosophy", and "Biotechnology". Citation impact is generally high in several large areas, e.g. "Computer Science", "Electrical & Electronic", "Chemistry" and "Materials Physics".

The field-normalized impact of about twenty Units of Assessment (UoA:s) is well above average, and for 10 of these there is a significantly high score. Whilst 8 research units are cited as significantly below average (<0.75), it should be noted that these units have few publications, and their total activities are presumably not covered by the Web of Science database.

KTH papers occur about 50% more often than expected among the top 5% most frequently cited papers in their subfields. 27 out of the 46 units have at least the expected number of papers in the 5% category.

KTH researchers contribute substantially to international scientific networks: 41% of papers are the result of international collaborations. A sizeable part of impact comes from publications that are internationally co-authored. Far from being insular, many research units have a widespread geographical network and they receive citations from all over the world.

KTH BIBLIOMETRIC STUDY

As part of its International Research Assessment Exercise (RAE), in March 2008 KTH commissioned Ulf Sandström (employed at the Industrial Economics department) and Erik Sandström (master student at the Center for Intellectual Property at Chalmers/Gothenburg University) to undertake a bibliometric study of the publications produced during 2000–2006 by all members of KTH's research staff currently employed at the University. This bibliometric study comprises one part of the RAE and is complemented by a Peer Review and data from Evaluation Packages submitted by Units of Assessment (UoA).

The objective of the study is a bibliometric analysis based on citations of research papers from KTH. The study is based on a quantitative analysis of scientific articles in international journals and serials processed for the Web of Science versions of the Citation Indices (SCI, SSCI and A&HCI). As such, this study is not a bibliographic exercise trying to cover all publications from KTH researchers. The motivation for using Web of Science is that the database represents the most prestigious journals and serials in all fields of science. The database was set up in the early 1960s by an independent research-oriented company in order to meet the needs of modern science in library and information services. Evidently, the database is also a valuable asset for evaluative bibliometrics, as it indexes the references in articles and connects references to articles (citations).

The key consideration that has guided the approach taken here is a requirement to make use of multiple indicators in order to better describe the complex patterns of publications at a technical research university. The study makes use of several methods, each deepening the understanding of a UoA's publication output from a different angel of incidence. No single indices should be considered in isolation.

Publications and citations form the basis of the indicators used. Citations are a direct measure of impact but they measure the quality of an article only indirectly and imperfectly. Whilst we can undoubtedly measure the impact of a research unit by looking at the number of times its publications have been cited, there are limitations. Citation-based methods enable us to identify excellence in research, however these methods cannot, with certainty, identify the absence of excellence (or quality).

The various insights provided by this study – and the manifold limitations of any bibliometric study – mean that the results presented here should be used as a *starting point* by Faculty and the KTH management for deeper discussion on the positioning of research groups, especially if there is a need for strategic change. If the university and its management are to gain from bibliometrics, focus should not fall only on top performers (Giske, 2008); greater potential for improvement might be found within those groups that underperform.

As well as using traditional bibliometric measures e.g. ratios and numbers, the bibliometric full reports (Sandström & Sandström 2008b) also gives graphs and a new type of

visualizations. These materials in particular, whilst highly informative, call for further informed interpretation and will not be discussed in this chapter.

Recent Bibliometric projects at KTH

Since 2007 KTH has been involved in several bibliometric projects and different analyses have been performed. In the context of the RAE, the following projects should be mentioned as their reports complement the work done within the RAE frame.

- Cluster report by Sandström & Sandström (2007) "Bibliometric Analysis and Visualization of Cluster Universities 1998–2007"[1]
- Evidence report by the Evidence Ltd. (2007) available as a CD
- Input-Output report by Sandström & Sandström (In Swedish; forthcoming)

1. CLUSTER (Consortium Linking Universities of Science and Technology for Education and Research), founded in 1990, is a network of leading European Universities of Technology. Members include EPFL, Eindhoven, Imperial, Helsinki UT, Karlsruhe, Leuven, Catalunya, Turin, Darmstadt, and Grenoble. The CLUSTER Report is based on a past performance approach. All publications with a KTH address during the period 1998–2006 were included in the analysis. The project compared the activities in different ISI sub-fields in order to detect whether there were possible complementary strongholds and collaboration possibilities between CLUSTER universities. The citation analysis indicated that KTH had a field-normalized citation score of 1.21, i.e. 20% above global average. Three CLUSTER universities were significantly better in impact – EPFL, Eindhoven and Imperial – but after these three, Helsinki and KTH were close competitors. The approach taken was to compare strengths in sub-fields and this was also used for visualizations. One conclusion was that KTH was strongly competitive in two macro fields: "Computer Science" and "Physics".

2. The Evidence Report is built up as a comparison between KTH departments and ten British universities and their Units of Assessments as used in the Research Assessment Exercise (RAE 2001). Bibliometric analyses covering the ten year period of 1995–2004 are compared to trend data for research income, research personnel etc. The overall aim of the project was to investigate whether the KTH accounting figures presented in the yearly reports were comparable to and possible to match with British RAE data. The findings indicate clearly that this objective is hard to meet without implementing extensive matching procedures.

3. The Input-Output Study was presented in a preliminary version to the Section for Research Financing in December 2007. The report has been revised and will be published in the near future. The aim of this project is to combine bibliometric information with data on research income and personnel (as gathered from the accounting system used at KTH). Within this project a field factor for research productivity (based on the field factor presented in Sandström & Sandström 2008a) has been tested in an exploratory study.

---

[1] The report is available at <http://www.forskningspolitik.se/DataFile.asp?FileID=164>.

Based on figures for Nordic universities, the results indicate that KTH researchers are more productive than their Nordic colleagues.

EVALUATIVE BIBLIOMETRICS

Bibliometric approaches, whereby the scientific communication process can be analyzed, are based on the notion that the essence of scientific research is the production of "new knowledge". Researchers that have theoretical ideas or empirical results to communicate publish their contributions in journals and books. Scientific and technical literature is the constituent manifestation of that knowledge, and it can be considered as an obligation for the researcher to publish their results, especially if public sector funding is involved.

In almost all areas, journals are the most important medium for communication of results. The process of publication of scientific and technical results involves referee procedures established by academic and scholarly journals. Therefore, internationally refereed journals imply that the research published has been under quality control and that the author has taken criticism from peers within the specialty. These procedures are a tremendous resource for the bettering of research, and are set in motion for free or at a very low cost. A researcher that chooses not to use these resources may seem to be very much outside of the international research community.

The reward system in science is based on recognition, and this emphasizes the importance of publications to the science system. Because authors cite earlier work in order to substantiate particular points in their own work, the citation of a scientific paper is an indication of the importance that the community attaches to the research.[2]

Essentially, this is the starting point of all bibliometric studies: if the above assumption holds, then we should concentrate on finding the best methods for describing and analyzing all publications from those research groups under consideration.[3] When we are searching for such methods our emphasis is on one specific layer of research activities. There are several more layers that can be studied and evaluated, but in the context of RAE our focus is on research, both basic and applied, and especially on excellence in research. Hence, publications are the center of attention. We could have included patents to the family of publications as they indicate a transfer of knowledge to industrial innovation, i.e. into commodities of commercial and social value. However, in the KTH RAE, the sole focus of the bibliometric study is journal and conference publications.

This chapter reports on the performances of research groups consisting of on average 15–20 people. Groups were put together to be presented to panels of reviewers. However, to some extent these constellations were not real functional groups. Therefore, a reshuffling of people according to their functional research might produce a more telling result. There are some minor inconsistencies of this sort, but at the end of the day, *relative scale-independent bibliometric indicators* can indicate the standing and position of a research group[4]: are they clearly above average, are they around average or do the indi-

---

[2] CWTS (2008).
[3] Narin & Hamilton (1996), CWTS (2008).
[4] van Raan (2004)

cators show that the group is clearly below average when they are compared with their international colleagues?

Basics of bibliometrics

International scientific influence (impact) is an often used parameter in assessments of research performance. Impact on the research of others can be considered as an important and measurable aspect of scientific quality, but of course, not the only one. Within most international bibliometric analyses there are a series of basic indicators that are widely accepted.

In most bibliometric studies of science and engineering, data is confined to **articles, letters and reviews** in refereed research journals. The impact of a paper is often assumed to be judged by the reputation of the journal in which it was published. This can be misleading because the rate of manuscript rejection is generally low even for the most reputable journals. Of course, it is reasonable to assume that the average paper in a prestigious journal will, in general, be of a higher quality than one in a less reputable journal. [5] However, the quality of a journal is not necessarily easy to determine[6] and, therefore only counting the number of articles in refereed journals will produce a disputable result (Butler, 2002; Butler, 2003).

The question arises whether a person who has published more papers than his or her colleagues has necessarily made a greater contribution to the research front in that field. All areas of research have their own institutional "rules", e.g. the rejection rate of manuscripts differs between disciplines: while some areas accept 30–40 per cent of submitted manuscripts due to perceived quality and space shortages, other areas can accept up to 80–90 per cent. Therefore, a differentiation between *quantity* of production and *quality* (impact) of production has to be established. Several bibliometric indicators are relevant in a study of "academic impact" – the number of citations received by the papers, as well as various influence and impact indicators based on field-normalized citation rates. Accordingly, we will not use the number of papers as an indicator of performance, but we have to keep in mind that fewer papers indicates a low general impact, while a high number of cited papers indicates a higher total impact.

Brain power of research units

The bibliometrics of the KTH RAE focus on the *brain power* (also called the "back-to-the-future or *prospective* approach)[7] of the research personnel employed by KTH in January 2008. Regardless of where individuals were employed before being hired by KTH, all of their publications are counted for the whole evaluation period. Consequently, it is impossible to use the number of papers as an informative indicator when relating to the input indicators for KTH departments or research units. Instead, we use relative bibli-

---

[5] Cole et al. (1988).
[6] Hansson (1995), Moed (2005), ch. 5.
[7] Visser & Nederhof (2007), s. 472.

ometric indicators which set the citation counts in relation to the global journal average and the global field average.

Studies indicate that the size of an institution is seldom of any significance in measuring the quality of its research output.[8] Productivity and quality vary widely, but are not primarily driven by organizational size. When citations are normalized, small highly specialized institutions can produce papers that are of equally high quality per funding increment as the larger well known institutions.

It should be observed that we are dealing with short-term impact (less than ten years) in this evaluation. The focus is on what has happened during the period 2000–2006. A longer impact (>10 yrs) is harder to measure, as research groups have a dynamic of their own and are therefore not easy to follow over time.[9]

Citations and theories of citing

The choice of citations as the central indicator calls for a theory of citing: a theory that makes it possible to explain why author *x* cited article *a* at time *t*. What factors should be considered when we discuss why researchers cite back to former literature? The need for a theoretical underpinning of citation analysis has been acknowledged for a long time and several theories have been put forward.[10] In summary, there are three types of theories: normative, constructive and pragmatic. Normative theories are based on a naïve functionalist sociology, and constructivist theories are opposed to these assumptions. According to the Nordic pragmatist school (e.g. Seglen, 1998, Luukonen, 1997, Amsterdamska & Leydesdorff, 1989; Aksnes 2003), utility in research is one important aspect, and cognitive quality is another, and together they are criterions for reference selection. Based on Cole (1992) the Norwegian Aksnes (2003b) introduces the concepts *quality and visibility dynamics* in order to depict the mechanisms involved.

Factors like journal space limitations prevent researchers from citing all the sources they draw on; it has been estimated that only a third of the literature base of a scientific paper is rewarded with citations. Therefore, citation does not implicate that the cited author was necessarily "correct", but that the research was **useful**. Do not forget that negative findings can be of considerable value in terms of direction and method. If a paper is used by others, it has some importance. In retrospect, the idea or method may be totally rejected; yet use of the citation is clearly closer to "important contribution to knowledge" than just the publication count in itself. The citation signifies recognition and typically bestows prestige, symbolizing influence and continuity.[11] There is no doubt citations can be based on irrational criteria, and some citations may reflect poor judgment, rhetoric or friendship. Nevertheless, the frequency with which an article is cited would appear to establish a better approximation of "quality" than the sheer quantity of production.[12]

---

[8] Van Raan 2006 a and b.
[9] Moed et al (1985), p. 133 ff.
[10] For an excellent review of this topic, see Borgmann & Furner (2002).
[11] Roche & Smith (1980), p. 344.
[12] Martin & Irvine, 1983; Cole and Cole, 1973..

Furthermore, citations may indicate an important sociological process: continuity of the discipline. From this perspective, a positive or a negative citation means that the authors citing and the author cited have formed a cognitive relationship.[13]

From the view of the pragmatist citation school, a discussion of the limits of citation counting is necessary. As stated above, not all works that "ought" to be cited are actually cited, and not all works that are cited "ought" to be. As a consequence, the validity of using citation counts in evaluative citation analysis is problematic. Even if the quality of the earlier document is the most significant factor affecting its citation counts, the combined effect of other variables is sufficiently powerful and much too complex to rule out positive correlations between citation count and cited-document quality.[14]

Moreover, citation practices can be described as results of stochastic processes with accidental effects (Nederhof, 1988:207). Many random factors contribute to the final outcome (e.g. structural factors such as publication time-lags etc.) and the situation can be described in terms of probability distributions: there are many potential citers, each with a small probability of actually giving a reference, but the chance gets higher with each former reference (Dieks & Chang, 1976: 250).

This also creates difficulties when it comes to levels of significance:[15] "…when one paper is cited zero times, another paper, of the same age, has to be cited at least by five different authors or groups of authors, for the difference to be statistically significant. …This implies that when small numbers of papers are involved, chance factors may obscure a real difference in impact. However, as the number of papers involved in comparisons increases, the relative contribution of chance factors is reduced, and that of real differences is increased" (Nederhof, 1988:207). Accordingly, we have to be very careful in citation analysis when comparing small research groups. Chance factors and technical problems with citations have too pronounced an influence.

Principle of anti-diagnostics

The type of insecurities involved in bibliometrics makes it necessary to underscore the **principle of anti-diagnostics**: "… while in medical diagnosis numerical laboratory results can indicate only pathological status but not health, in scientometrics, numerical indicators can reliably suggest only eminence but never worthlessness. The level of citedness, for instance, may be affected by numerous factors other than inherent scientific merits, but without such merits no statistically significant eminence in citedness can be achieved." (Braun & Schubert, 1997: 177).

The meaning of this principle is that it is easier with citation analysis to identify excellence than to diagnose low quality in research. The reasons for absence of citations may

---

[13] Cf. Small (1978) proposed the view that citations act as "concept symbols" for the ideas that are referenced in papers.
[14] Borgmann & Furner (2002). In the words of Cole & Cole (1973) citations measures "socially defined quality". Gronewegen (1989) finds that "irregularities, which show up in the patterns of citations towards the work of groups, can be understood as a *result of changes in the local context*" (p.421).
[15] Cf. Schubert & Glänzel (1983).

be manifold: the research community has not yet observed this line of research; publications might not be addressed to the research community but to society etc. Clearly, results for a unit of assessment that are above the international average (=1,0) – e.g. relative citation levels of 2,0–3,0 or higher – indicate a strong group and lively research, but citation levels below 1,0 do not necessarily indicate a poorly performing group.

Citation indicators

The above review of the literature reveals that there are limitations to all theories and all methods for finding excellence in research. According to Martin & Irvine (1983:70) we have to consider three related concepts: *Quality, Importance* and *Impact*. Quality refers to the inherent properties of the research itself, whilst the other two concepts are more external. Importance and impact are concepts that refer to relations between the research and other researchers/research areas. The latter also describes the strength of links to other research activities.

We can discuss the *quality* of a research paper without considering the number of times it has been cited by others or how many different researchers cited it. It is not an absolute, but a relative characteristic; it is socially as well as cognitively determined, and can, of course, be judged by many other individuals. *Importance* refers to the potential influence[16] on surrounding research and should not be confused with "correct", as an idea "must not be correct to be important" (Garfield et al. 1978: 182).[17] Due to the inherent imperfections in the scientific communication system, the actual impact is not identical with the importance of a paper. Thus it is clear that *impact* describes the actual influence on surrounding research: "*while this will depend partly on its importance, it may also be affected by such factors as the location of the author, and the prestige, language, and availability, of the publishing journal*" (Martin & Irvine 1983: 70; cf. Dieks and Chang 1976). Hence, while impact is an imperfect measure, it is clearly linked to the scientific work process, and, used in a prudent and pragmatic approach, measures based on impact give important information on the performance of research groups.

Validation of bibliographic data

One of the practical problems is that of constructing the basic bibliography for each Unit of Assessment's production. This is not a trivial question as papers from one institution might be headed under several different names (de Bruin & Moed, 1990). The identification of papers included in the KTH RAE has been based on the individual. This was organized by the KTH library unit, and the bibliometric analysis was based on the data yielded by that process. After completing the analysis of each UoA and each individual,

---

[16] Zuckerman (1987) . Of course, some of the influences (and even facts) may be embedded in the author's mind and not easily attributable.

[17] Again, negative citations are also important: "The high negative citation rate to some of the polywater papers is testimony to the fundamental importance of this substance if it could have been shown to exist" (Garfield et al. 1978.). We assume that the same apply for negative citations to cold fusion papers.

the material was distributed to each UoA and each individual researcher was given the opportunity to validate the material.

The latter phase of the process has shown that:

1. It is important to define the population of researchers beforehand. Some of the UoAs had a more liberal interpretation whilst others were stricter. In the final analysis, 55 researchers were added, bringing the total number of individuals from 867 to 922. Consequently, the number of publications has grown (from 7 798 to 7 992) with 60 researchers correcting their number of publications.
2. Bibliometric identification based on Publication Identification Forms (with information on "author names", "homonyms" and "affiliations") works well. 60 researchers have had doubts about the number of publications and not more than 10 have resulted in substantial corrections.
3. From the responses we can draw the conclusion that the exercise has generated a wide interest for bibliometrics and visualization of scientific data.

Coverage of scientific and technical publications

Explorations made by Carpenter & Narin (1981), and by Moed (2005), have shown that the Thomson Reuters database is representative of scientific publishing activities for most major countries and fields, not counting soft social sciences and humanities: "In the total collection of cited references in 2002 ISI source journals items published during 1980–2002, it was found that about 9 out of 10 cited journal references were to ISI source journals" (Moed 2005:134). It should be emphasized that Thomson mainly covers *international* scientific journals, and that citation analysis is viable only in the context of international research communities. National journals and national monographs/anthologies cannot be accessed by international colleagues. Consequently, publications in these journals are of less interest in a citation exercise of the RAE-type. As long as we are calculating relative citation figures based on fields and sub-fields in the ISI database, the inclusion of national or low cited journals will have the effect of lowering the citation score.

In some studies it has been suggested that there are two distinct populations of highly cited scholars in social science subfields: one consisting of authors cited in the journal literature, the other of authors cited in the monographic literature (Butler, 2008). As the Web of Science has a limited coverage of monographic citing material, the latter population will hardly be recognized in the Web of Science database (Borgmann & Furner, 2002). Related to this question is the language-bias in the citation index. Several studies have evidenced that journal articles written in languages other than English reach a lower relative citation score than articles in English (van Leeuwen et al., 2000). This indicates a bias towards other languages and this should be accounted for in the analytical procedures.

The Web of Science works well and covers most of the relevant information in a large majority of the natural sciences and medical fields, and also works quite well in applied

research fields and behavioral sciences (CWTS, 2007:13). However, there are exceptions to that rule. Considerable parts of the social sciences and large parts of the humanities are either not very well covered in the Web of Science or have citations patterns that do not apply to studies based on advanced bibliometrics (Butler, 2008; Hicks, 1999; Hicks, 2004). The information on why this is the case is lacking, and there may be several explanations.

One explanation could that there are severe lacunas in specific areas of the database, e.g. architecture, computer science, traditional engineering, humanities and soft social sciences. Another interpretation would be that there are areas of research where some of the KTH-groups fail to 'perform' in the internationally recognized journals, and instead choose to publish in other international and more national publication channels, e.g. chapters in books, books in national languages, national and local journals or local report series.

An exception where the Web of Science does not seem represent visibility is the UoA "History of Science and Technology". They have few articles in international journals covered by the WoS. If we go through their total publications, we find two articles in the journal *History of Technology*, a journal not indexed by the ISI. There are several journals in this field and many of them are covered by the ISI.[18] One explanation as to why *History and Technology (HT)* is not indexed is evidenced by the fact that very few papers refer to HT (33 citations to 300 papers during 1990–2008).

The preliminary conclusion would be that there are ISI journals for the UoA "History of Science and Technology", but for some reason they chose not to publish in these journals. They do have a rather wide international publication record, but in books and edited volumes rather than in journals. Some of these are the result of international workshops and conferences. There are several publications at publishing houses of high esteem. Therefore, it is quite clear that the bibliometric KTH RAE does not fully represent the activities of this UoA. The chosen method is too limited in this area (and for several other areas such as Architecture etc.), as the results are based on too small a sample of what is published from the UoA. It should be underlined that the UoA "History of Science and Technology" have stated that they recognize the need for a publication strategy targeting more papers in journals covered by the Web of Science.

A further problem with the citation index is that we tend to drop information in so far as we apply a restricted view of scientific communication. In some specialties of the engineering sciences (applied areas) there might be the same type of problem as discussed

---

[18] E.g. ANNALS OF SCIENCE; ANNALS OF THE HISTORY OF COMPUTING; ARCHIVE FOR HISTORY OF EXACT SCIENCES; BERICHTE ZUR WISSENSCHAFTSGESCHICHTE; BRITISH JOURNAL FOR THE HISTORY OF SCIENCE; BULLETIN OF THE HISTORY OF MEDICINE; CENTAURUS; HISTORICAL STUDIES IN THE PHYSICAL AND BIOLOGICAL SCIENCES; HISTORIA MATHEMATICA; HISTORY AND PHILOSOPHY OF THE LIFE SCIENCES; HISTORY OF SCIENCE; HISTORY OF THE HUMAN SCIENCES; ISIS; JOURNAL FOR THE HISTORY OF ASTRONOMY; JOURNAL OF THE HISTORY OF BIOLOGY; JOURNAL OF THE HISTORY OF MEDICINE AND ALLIED SCIENCES; MEDICAL HISTORY; MINERVA; MINNESOTA STUDIES IN THE PHILOSOPHY OF SCIENCE; OSIRIS; PHYSICS IN PERSPECTIVE; PUBLIC UNDERSTANDING OF SCIENCE; SCIENCE IN CONTEXT; SCIENCE TECHNOLOGY & HUMAN VALUES; SOCIAL HISTORY OF MEDICINE; SOCIAL STUDIES OF SCIENCE; STUDIES IN HISTORY AND PHILOSOPHY OF MODERN PHYSICS; STUDIES IN HISTORY AND PHILOSOPHY OF SCIENCE; TECHNOLOGY AND CULTURE.

above. Traditional engineering sciences might have publication and citation patterns that deviate from scientific fields. This has been a theme in scientometrics studies ever since Derek J de Solla Price, the father of bibliometrics, started to investigate the relationship between science and technology. In summary Price found the following: "*To put it in a nutshell, albeit in exaggerated form, the scientist wants to write but not read, and the technologist wants to read but not write*".[19] Price finds that while technologists are *papyrofobic*, scientists are *papyrocentric*. The way science works at research fronts cannot be found within many of the engineering sciences. Price extended his analysis in these words: "Less dramatically, I would like to split research activity into two sharply defined halves; the one part has papers as an end product, the other part turns away from them. The first part we have already identified with science; the second part should, I think, be called 'technology', though here there is more conflict with intuitive notions." Technology is here used in a wider meaning than just engineering; it includes some of the medical specialties, botany and several disciplines within the humanities. Using the concepts in this unorthodox way, Price is clear about the fact that large parts of the engineering sciences should be considered as science areas: "By this definition, it should be remembered there is a considerable part of such subjects as electronics, computer engineering, and industrial chemistry that must be classified as science in spite of the fact that they have products that are very useful to society."[20]

During the 1980s it was stated that several areas of technology were becoming *science-based technologies*.[21] The dancing partners (Toynbee) were coming closer to each other and the concept of *technoscience* was introduced by the influential French sociologist Latour.[22] The intermixing of both sides was further elaborated by SPRU researchers in the book *Knowledge Frontiers* (1995), a book based on case-studies in areas where the differences regarding ways of gathering, transforming and diffusing information were disappearing between science and technology. According to American information scientists, high-technology and science were analytically "indistinguishable".[23]

A completely opposite perspective has been cultivated by Dutch research managers.[24] From a detailed case study of electron microscopy it was shown that some scientific advances were incorporated in scientific and technical instruments and therefore invisible. Although very important, these advances received few citations and therefore citation analyses were proven not comprehensible. The expression "citation gap" was coined. However, indicators are partial and need to be complemented by other methods. This is the basis for modern advanced bibliometrics and a theme throughout this chapter of the KTH RAE. Certainly there are citation gaps, but there is a problem of knowing what type of conclusions to draw from that. Instruments are developed in almost all fields of science and technology. So, even with severe differences between areas in this respect,

[19] Price (1965), pp. 553-568.
[20] The same idea is apparent in T. Allens *Managing the Flow of Technology*, MIT Press 1977..
[21] Böhme et al (1978), pp. 219-250.
[22] Latour, Bruno (1987).
[23] Narin & Toma (1985).
[24] Le Pair, C. (1988), van Els et.al. (1989).

the method of field normalization should take care of much of the disparity. Relative indicators were not developed at the time when the citation gap was discussed (1980s).[25]
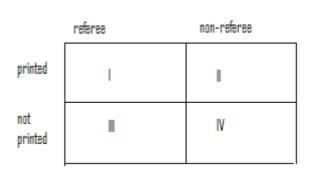
Still, there remain some differences between areas that should be accounted for. Detailed studies of engineering areas show that there are more citations to non-journals (text books and handbooks) and this contributes to a more insecure citation statistic for these fields. We should be observant of this before we draw any conclusions about UoAs in traditional engineering areas.

Another problem concerns the computer science areas and their habit of using conference proceedings in the same way as other areas use journals for the communication of results. This has created a lot of questions during the validation phase: typical worries of the researchers are that many of their publications are missing. However, when this was double-checked, only a few papers were missing. Some of the researchers were convinced that at least half of their papers were absent in the presentations of their research. In fields related to computer science this often referred to conference proceedings considered as more prestigious than ordinary journal publications.

In 2008 the Web of Science included a number of serial proceedings: IEEE, LNCS, ACM etc. The coverage in the new *Web of Science with Conference Proceedings* is much better than what is the case in ordinary WoS.[26] Unfortunately, the KTH Library does not have a subscription to the Conference Proceedings and, therefore, the proceedings papers could not be included during the validation phase.

Regardless of that, the level of coverage that could be considered reasonable is very hard to estimate, but we know that researchers from all fields produce conference papers. Normally, half or more of the publications are presented at conferences or published in conference proceedings. Why computer science should be extraordinary in this seems to be an open-ended question.

Swedish publication activities in Computer Science journals are lower (1% of world production) than in other fields, and publications in computer related proceedings are about the same. There are several different types of conferences, and we can distinguish between four general categories: Type I – refereed and printed full paper proceedings; Type II – non-refereed and printed (often meeting abstracts); Type III – refereed and not printed (low prestige conferences); and Type IV – non-refereed and not printed (workshops and meetings).

---

[25] Relative indicators were introduced in 1988 by Schubert, Glänzel and Braun (1988).
[26] For further exploration see Moed & Visser (2007) which reports on an expanded version of WoS with IEEE, LNCS and ACM.

In order to be able to account for computer science as a field we would need a complete list of proceedings and a categorization of conference status. Meanwhile, as we need to perform citation analysis, the present Web of Science database is probably the best resource available. The procedures for normalization take all other publications in computer science fields into consideration. A specific study of on the groups that were concerned about their papers showed that they had a rather high productivity in relation to all other Nordic universities.[27] Accordingly, as long as the number of papers are not too few (>50) there should not be severe coverage problems with the database. Of course, the results would be much better if more of the important proceedings were included, but there are equal opportunities for all researchers in this respect. Moreover, if we were to include a number of low cited proceedings that would probably have the effect of lowering the citation score for the UoA:s.[28]

Matching of references to articles

The Thomson Reuters database consists of articles and their references. Citation indexing is the result of a linking between references and source (journals covered in the database). This linking is done with a citation algorithm, but the one used by Thomson Reuters is conservative and a consequence of this is non-matching between reference and article. Several of the non-matching problems relate to publications written by 'consortia' (large groups of authors), and to things such as variations and errors in author names; errors in initial page numbers; discrepancies arising from journals with dual volume-numbering systems or combined volumes; journals applying different article numbering systems; or multiple versions due to e-publishing.[29] Approximations indicate that about seven per cent of citations are lost due to this conservative strategy. Thomson Reuters seem anxious not to over-credit authors with citations. In the KTH RAE analysis, we have used an alternative algorithm that addresses a larger number of the missing links. Additionally, we have corrected links to KTH using a manual double-check. This should take into account most of the 'missing' citations.

Self-citations

Self-citations can be defined in several ways, usually with a focus on co-occurrence of authors or institutions in the citing and cited publications. In this report we follow the recommendation to eliminate citations where the first-author coincides between citing and cited documents (Aksnes, 2003a). If an author's name can be found at other positions, as last author or middle author, it will not count as a self-citation. This more limited method is applied for one reason: if the whole list of authors is used, the risk for eliminating the wrong citations is increased. On the down-side, this method may result in a senior-bias. This will probably not affect Units of Assessment, but caution is needed in

---

[27] In this case the so called Waring method was applied, see papers by Sandström & Sandström (2007) and (2008a).
[28] Moed & Visser (2007) indicate that a group's citation impact measured in the present WoS universe is statistically speaking a good predictor of citation score in an Expanded database with all LNCS, ACM and IEEE.
[29] Moed (2002) summarizes the major problems found with the citation algorithm, c.f. Moed (2005), ch. 14 "Accuracy of citation counts".

analysis at the individual level (Adams, 2007: 23; Aksnes, 2003b; Glänzel et al., 2004; Thijs & Glänzel, 2005).

Time window for citations

An important factor that has to be accounted for is the time effect of citations. Citations accumulate over time, and citation data has to cover comparable time periods (and be within the same subfield or area of science, see below). However, in addition to that, the time patterns of citation are far from uniform, and any valid evaluative indicator must use a fixed window or a time frame that is equal for all papers. The reason for this is that citations have to be appropriately normalized. Most of our investigations use a decreasing time-window from the year of publication until December 31 2007. However, some of our indicators are used for time-series, and in these cases we apply a fixed two year citation window. Publications from the year 2000 receive citations until 2002; publications from 2001 receive citations until 2003 and so on.

Fractional counts and whole counts

In most fields of research, scientific work is done in a collaborative manner. Collaborations make it necessary to differentiate between whole counts and fractional counts of papers and citations. Fractional counts give a figure of weight for the contribution of the group to the quantitative indicators of all their papers. By dividing the number of authors from the group with the number of all authors on a paper we introduce a fractional counting procedure. Fractional counting is a way of controlling the effect of collaboration when measuring output and impact.

Fields and sub-fields

In bibliometric studies, the definition of fields is generally based on the classification of scientific journals into the 250 or so categories developed by Thomson Reuters. Although this classification is not perfect, it provides a clear and consistent definition of fields suitable for automated procedures. However, this proposition has been challenged by several scholars (e.g. Leydesdorff, 2008; Bornmann et al. 2008). Two limitations have been pointed out: (1) multidisciplinary journals (e.g. *Nature*; *Science*); and (2) highly specialized fields of research.

The Thomson Reuters classification of journals includes one sub-field category named "Multidisciplinary Sciences" for journals like *PNAS, Nature and Science*. More than 50 journals are classified as multidisciplinary since they publish research reports in many different fields. Fortunately, each of the papers published in this category are subject-specific, and therefore it is possible to assign a subject category to these on the article level – what Glänzel et al. (1999) call "item by item reclassification". We have followed that strategy in this report.

Normalized indicators

During recent decades, standardized bibliometric procedures have been developed to assess research performance.[30] Relative indicators or rebased citation counts, as an index of research impact, are widely-used by the scientometrics research community. They have been employed extensively for many years by Thomson Reuters in the Essential Science Indicators. The CHI research team in the United States and the ISSRU team in Budapest popularized the central concepts of normalization during the 1980s.[31] More recently, field normalized citations have been used, for example, the European science and technology indicators used by groups such as the CWTS bibliometrics research group at the University of Leiden (labeling it the "crown indicator"); the Evidence group in the U.K.[32]; leading higher education analysts at the Norwegian institute NIFU/STEP[33]; the analyst division at Vetenskapsrådet[34] and others. Field normalized citations can be considered as an **international standard** used by analysts and scientists with access to the Web of Science database.

In this report we follow the normalization procedures proposed by the Leiden group (van Raan 2004) with only two minor addendums: firstly, while the Leiden method gives higher weight to papers from normalization groups with higher reference values, we treat all papers alike; secondly, while the Leiden method is based on a "block indicators" covering four or five year period,[35] our method rests on a statistic calculation year to year. Publications from 2000 are given an 8 year citation window (up to 2007) and so on. Due to these relatively small differences, we have chosen to name our indicator NCS (Normalized Citation Score), but, it should be emphasized that it is basically the same type of indicator.

The normalization procedure shown I Figure 1 can be further explained thus: The subfield consists of five journals (A–E). For each of these journals, a journal-based reference value can be calculated. This is the journal mean citation level for the year and document type under investigation. A UoA might have a CPP above, below or on par with this mean level. All journals in the sub-field are taken together as the basis for the field reference value. A researcher publishing in journal A will probably find it easier to reach the mean than a researcher publishing in journal E.

[30] Schubert et al (1988), Glänzel (1996), Narin &Hamilton (1996), van Raan (1996), Zitt et al. (2005).
[31] Cf. Zitt (2005: 43).
[32] C.f. Adams et al. (2007).
[33] See, the biannual Norwegian Research Indicator Reports.
[34] Vetenskapsrådet Rapport 2006.
[35] C.f.. Visser and Nederhof (2007), p. 495 ff.

Figure 1. Normalization of reference values.

We consider the field citation score to be the most important indicator. The number of citations per paper is then compared with a sub-field reference value. With this indicator it is possible to classify UoA performances in five different classes:[36]

    A. $NCSf \leq 0.6$ significantly far below international average

    B. $0.60 < NCSf \leq 1.20$ at international average

    C. $1.10 < NCSf \leq 1.80$ significantly above international average

    D. $1.80 < NCSf \leq 2.40$ from an international perspective very strong

    E. $NCSf > 2.40$ global excellence

Standard Citation Score

The heterogeneity between research fields is a well-known fact and has been vigorously described by authors such as Whitley (2000) and Cole (1992). Z-score, which uses the standard deviation as a measure, has been used in bibliometric analyses from the beginning of the 1980s. However, skewing of citation distributions poses problems to this, and therefore McAllister et al. (1983) suggested that the logarithm of citations should be used. We follow their method and use it as another partial indicator.

---

[36] This classification of performances is inspired from presentations made by van Raan, but the levels are accommodated to the KTH methods used for computation of citation scores. CWTS levels are higher as citations are not fractionalized.

Top 5 percent

The above Standard Citation Score gives a more complete picture, taking the skewed nature of citations into account. Still, we might need simple figures that indicate the excellence of the group in just one number and the *Top5%* is an indicator of that type. As an indicator it expresses the share of publications within the top 5% of the worldwide citation distribution of the fields concerned for the given research group. This approach provides a better statistical measure than those based on mean values. We suggest that this indicator is used together with other indicators and in this case as "*a powerful tool in monitoring trends in the position of research institutions and groups within the top of their field internationally*" (CWTS, 2007: 25*)*. If the research group has a high proportion of articles in the Top5% they will probably have a large impact on their research field.

H-index

The h-index was established in 2005 when Hirsch presented a rather simple method that combined the number of articles and the number of citations. A scientist is said to have Hirsch index h if h of their N papers have at least h citations each, and the remaining ($N-h$) papers have fewer than h citations (Hirsch, 2005: 16569). The h-index measure is easy to compute and is nowadays included in the Web of Science and the Scopus databases as a quick and straightforward yardstick (Lehmann et al., 2006).

There are several problems and biases connected to the h-index. The balance between younger and older researchers is an obvious example. Caution is needed especially when the h-index is to be applied in research assessments where there are several research areas covered (van Leeuwen, 2008; Costas & Bordons, 2007). As we have pointed out many times in this report, there are huge differences in the number of articles produced by a "normal" author depending on his or her discipline (cf. Campiteli et al. 2007). We have decided not to include the h-index in our results as we are aware of the bias in this measure. Nonetheless, we still consider the h-index as an important indicator for comparing *individuals* within the same fields.

Vitality

Boyack and Börner (2003) established the term "vitality", defining vital research with the following features:

1. A stable/increasing number of publications in prominent journals with high impact factors;
2. High *export* factors indicating that research is acknowledged and utilized in other domains;
3. A tightly knit co-authorship network leading to efficient diffusion of knowledge;
4. Funding resulting in larger numbers of high impact publications;
5. New emerging research fields.

Later Boyack (2007) and Klavans & Boyack (2008) operationalized the concept of vitality as field normalized *reference age* of articles. Even if there is a lack of consensus in the field of bibliometrics on how to measure reference age, there are not that many options. Price defines the so-called *Price Index* as ''the proportion of the references that are from the last five years of literature'' (Price, 1979; Egghe, 1997). Klavans and Boyack (2008) suggest the use of the mean age of references with normalization to the field, and we follow their recommendations.

Vitality – recency of cited literature – is an interesting factor in assessments of research performance. It rests on the hypothesis that researchers at the front use the most recent references and that they "are committed to participating at the forefront of science rather than on older science" (ibid.). Typically, they are willing to shift their emphasis from older ideas to newer ideas when warranted. Researchers with an older average reference age are far less committed to focusing on new science. Remember that there are differences between fields of science[37] that have to be accounted for and, therefore, the proposed method uses normalization in relation to WoS sub-fields. Nevertheless, vitality is, as an index, very simple, and hence the sociological interpretation is rather ambiguous.

[37] Originally, the motive for Price's research on this was to demonstrate these differences between areas. Moed (1989) has showed that Price's statement might be an oversimplification.

RESULTS FROM THE BIBLIOMETRIC STUDY

Information gathered and analyzed includes the following indicators:

Table 1: Indicators used in the report

P	NUMBER OF PAPERS	Number of papers (articles, letters and reviews) published by UoA "NN" during 2000–2006.
Frac P	NUMBER OF FRACTIONA-LIZED PAPERS	Sum of author fractionalized papers (articles, letters and reviews) published by UoA "NN" during 2000–2006.
CPP	CITATIONS PER PAPER	Number of citations per paper (31 December 2007).
CPP 2 YR	CPP 2 YEAR	Citations per paper with a 2-year citation window
NCSj	JOURNAL NORMALIZED CITATION SCORE	CPP normalized in relation to the UoA "NN" journal set (average=1.00).
NJCS	NORMALIZED JOURNAL CITATION SCORE	The impact of the journal set normalized in relation to its sub-fields (average=1.00).
NCSf	FIELD NORMALIZED CITA-TION SCORE	CPP normalized in relation to the UoA "NN" sub-field set (average=1.00).
SCSf	STANDARD FIELD CITA-TION SCORE	Z-score standardized citation score in relation to the UoA "NN" sub-field set (N.B! average=0.00).
TOP5%	TOP 5%	Percentage of papers above the 95th citation percentile.
VITALITY	VITALITY	Recency of references
SelfCit	PERCENTAGE SELF-CITATIONS	Percentage self-citations.
Pnc	PERCENTAGE NOT CITED PAPERS	Percentage of not cited papers during the period.

Journal Normalized Citation Score (NCSj): Citations per publication related to the reference value, which in this case is the average number of citations per publication in the journals in which the UoA appears, taking document type and year of publication into account.

[This indicator is almost identical to the CPP/JCS indicator developed by the Leiden group]

Normalized Journal Citation Score (NJCS): This measure is used in order to estimate the average journal impact in relation to other journals in the same sub-field(s).

[This indicator is almost identical to the JCS/FCS indicator developed by the Leiden group]

Field Normalized Citation Score (NCSf): Citation per publication related to a reference value built on the global averages for all articles in the sub-fields to which the UoA papers are assigned.

[This indicator is almost identical to the CPP/FCS indicator developed by the Leiden group]

Major differences between areas of science call for an alternative measure that takes the deviation of citations into account. Since citation data are skewed we use the logarithm of citations before calculating the standard deviation. This measure is called *Standardized Citation Score, field*, SCSf, and measures the number of standard deviations from the average. This indicator is used as complementary to the NCSf.

Top 5% is another measure that takes the citation skews into account. More precisely, this indicator shows how many of the UoA papers that are above the 95th percentile regarding citations in their sub-fields.

Table 2: Indicators used in the report

Symbol	Indicator	Score 2000–2006
PERS	NUMBER OF PERSONNEL	922*
P	NUMBER OF PAPERS	7 992
Frac P	NUMBER OF FRACTIONALIZED PAPERS	3282
CPP	CITATIONS PER PAPER	7.00
CPP(2YR)	CPP WITH A 2-YEAR WINDOW	
NCSj	JOURNAL NORMALIZED CITATION SCORE	1.15
NJCS	NORMALIZED JOURNAL CITATION SCORE	1.16
NCSf	FIELD NORMALIZED CITATION SCORE (Crown Indicator)	1.31
SCSf	STANDARD FIELD CITATION SCORE	0.27
TOP5%	TOP 5%	7.5 %
VITALITY	VITALITY	1.04
SelfCit	PERCENTAGE SELF-CITATION	24.1 %
Pnc	PERCENTAGE NOT CITED PAPERS	12.2 %

*Note: *Ten persons have a double affiliation and are in more than one UoA*

Table 3: Bibliometric Results 2000–2006 per Unit of Assessment

UoA (School) [No of personnel]	P	Frac P	CPP	CPP (2YR)	NCSj	NJCS	NCSf Crown	SCSf	TOP5%	Pnc	Scit	Vitality	AUm	Int Collm
Panel 1														
Computer Science (CSC) [51]	351	173.9	5.80	2.15	1.16	1.34	1.58	0.34	9.3%	34.9%	9.0%	1.07	2.3	1.4
Mathematical Statistics (SCI) [8]	28	10.6	2.90	0.99	0.90	1.03	0.65	-0.12	1.0%	35.3%	32.6%	1.06	2.6	1.9
Mathematics (SCI) [35]	227	148.6	4.91	1.82	1.20	1.44	1.72	0.44	8.5%	28.8%	14.5%	1.03	1.6	1.4
Optimization Systems Theory (SCI) [6]	58	28.5	5.76	1.33	1.03	1.34	1.63	0.55	11.4%	21.7%	13.7%	0.93	2.1	1.4
Panel 2														
Human Communication (CSC) [46]	110	58.4	2.43	0.80	0.81	0.92	1.95	-0.02	3.4%	54.4%	6.0%	1.12	2.2	1.2
Network Info Control Syst (EES) [19]	96	48.6	8.03	3.15	1.61	1.14	2.00	0.44	11.8%	38.3%	4.6%	1.19	2.3	1.3
Telecommunications (EES) [15]	314	128.1	5.09	2.66	1.22	1.09	1.37	0.27	9.9%	25.7%	13.9%	0.99	2.6	1.6
Communication Systems (ICT) [16]	73	23.5	1.65	0.61	1.38	0.88	0.64	-0.07	1.5%	53.5%	6.9%	1.12	3.4	1.5
Information Software Syst (ICT) [8]	52	27.5	0.82	0.33	1.06	0.55	0.49	-0.25	2.4%	61.6%	3.2%	1.07	2.1	1.3
Panel 3														
Physics (SCI) [13]	295	48.3	7.66	3.98	1.45	1.04	1.19	0.34	2.5%	16.0%	9.4%	1.18	7.8	2.7
Theoretical Physics (SCI) [13]	174	86.9	10.23	4.52	1.01	1.36	1.21	0.20	8.8%	24.3%	15.3%	1.08	2.2	1.4
Panel 4														
Materials Physics (ICT) [12]	304	71.8	6.85	3.33	1.16	1.23	1.33	0.23	8.7%	21.1%	10.4%	1.15	4.7	1.7
Applied Physics Med Imaging (SCI) [23]	296	101.7	8.34	3.54	1.08	1.34	1.25	0.40	5.9%	12.2%	13.4%	1.10	3.9	1.3
Medical Technology (STH) [22]	138	37.2	6.88	2.93	1.48	0.96	1.20	0.26	2.8%	16.9%	5.3%	0.98	4.2	1.3
Panel 5														
Electrical Power Engineering (EES) [25]	46	21.9	5.78	1.48	1.40	0.88	1.34	0.26	15.2%	35.1%	7.6%	0.98	2.7	1.3
Fusion Space Plasma Physics (EES) [23]	295	82.7	4.72	2.37	0.94	1.00	0.88	0.02	3.5%	25.2%	14.1%	1.02	5.0	1.9
Energy Transformation (ITM) [20]	62	31.5	3.23	0.97	0.88	0.97	1.00	0.04	5.7%	45.5%	20.1%	1.08	2.4	1.1
Nuclear Power Reactor Phys (SCI) [13]	95	34.4	4.39	2.05	1.34	0.91	1.28	0.19	6.4%	40.2%	20.1%	0.98	3.1	1.5

UoA (School) [No of personnel]	P	Frac P	CPP	CPP (2YR)	NCSj	NJCS	NCSf Crown	SCSf	TOP5%	Pnc	Scit	Vitality	AUm	Int Collm
Panel 6														
Mems (EES) [6]	65	26.9	9.79	3.64	1.09	2.03	2.22	0.84	17.1%	7.4%	9.2%	1.30	3.6	1.1
Embedded Electr Comp Syst (ICT) [12]	115	52.2	1.56	0.61	0.50	0.69	0.41	-0.30	0.1%	52.6%	10.8%	1.14	2.9	1.3
Optics & Optonics (ICT) [19]	277	101.9	8.99	4.38	1.65	1.16	1.90	0.43	13.8%	19.2%	10.1%	1.15	3.3	1.6
Semiconductor Components (ICT) [17]	473	156.4	4.69	2.15	0.87	0.90	0.80	-0.04	4.0%	27.9%	14.2%	1.16	4.4	1.4
Panel 7														
Fluid Mechanics (SCI) [19]	145	69.2	5.86	2.40	1.06	1.39	1.52	0.41	8.1%	17.5%	16.7%	1.07	2.5	1.3
Mechanics Biomechanics (SCI) [8]	51	29.2	3.66	1.39	0.87	0.85	0.82	-0.11	3.8%	35.1%	32.2%	0.94	1.9	1.2
Solid Mechanics (SCI) [11]	122	64.8	7.83	2.57	1.65	1.19	2.02	0.41	13.1%	31.0%	18.0%	0.99	2.2	1.1
Vehicle Engineering (SCI) [35]	127	79.0	2.17	0.98	1.00	0.98	1.03	0.12	4.8%	30.9%	15.6%	1.08	1.8	1.1
Panel 8														
Industrial Prod Development (ITM) [23]	55	27.4	2.84	0.96	0.99	1.24	0.84	0.14	0.9%	31.8%	5.0%	0.97	2.4	1.1
Materials Sci Engineering (ITM) [31]	701	251.3	6.14	2.35	1.15	1.24	1.20	0.27	5.2%	25.3%	12.8%	0.87	3.4	1.5
Production Engineering (ITM) [13]	25	11.1	2.10	0.83	1.16	0.71	0.52	-0.18	0.0%	39.4%	11.8%	0.96	2.5	1.1
Panel 9														
Chemical Engineering (CHE) [28]	303	124.2	6.22	2.27	0.91	1.19	1.16	0.24	6.5%	21.5%	11.4%	1.02	2.8	1.2
Chemistry (CHE) [42]	977	366.7	10.99	4.85	1.10	1.25	1.37	0.34	8.1%	16.8%	12.3%	1.02	3.3	1.3
Fibre Polymer Technology (CHE) [27]	520	222.0	9.93	3.88	1.38	1.30	1.86	0.56	13.2%	13.5%	11.5%	0.99	3.2	1.2
Theoretical Chemistry (CHE) [9]	350	126.3	11.38	5.35	1.21	1.21	1.40	0.41	10.6%	5.7%	9.6%	1.06	4.1	1.6
Panel 10														
Industrial Biotechnology (BIO) [21]	253	72.6	10.49	4.82	1.21	0.97	1.20	0.29	3.9%	10.5%	6.3%	1.00	4.6	1.4
Medical Biotechnology (BIO) [11]	223	58.8	15.66	7.78	1.22	1.15	1.47	0.43	9.8%	2.8%	6.4%	1.12	5.4	1.3
Protein Atlas (BIO) [9]	127	33.7	16.85	8.45	1.29	1.11	1.49	0.50	11.6%	3.1%	7.4%	1.22	4.9	1.2

UoA (School) [No of personnel]	P	Frac P	CPP	CPP (2YR)	NCSj	NJCS	NCSf Crown	SCSf	TOP5%	Pnc	Scit	Vitality	AUm	Int Collm
Panel 11														
Civil Architectural Eng(ABE) [20]	65	28.9	2.06	0.49	1.44	0.49	0.74	-0.16	1.7%	45.6%	14.1%	0.95	2.3	1.2
Land Water Resources(ABE) [24]	143	62.6	6.12	2.21	1.00	1.04	1.00	0.12	5.2%	27.7%	16.0%	1.00	2.5	1.4
Industrial Ecology (ITM) [7]	21	8.1	5.29	2.80	1.27	0.90	1.03	0.14	0.0%	24.8%	7.8%	1.05	3.2	1.3
Health (STH) [1]	5	1.3	12.19	6.08	1.19	1.24	1.84	0.70	19.6%	15.7%	4.2%	0.99	3.9	1.8
Panel 12														
Architecture (ABE) [17]	2	0.6	1.00	0.57	0.34	0.80	0.27	-0.30	0.0%	0.0%	0.0%	0.91	3.4	1.0
History (ABE) [11]	7	4.3	2.23	0.55	1.18	1.07	1.07	0.29	23.3%	34.9%	0.0%	0.90	1.6	1.1
Philosophy (ABE) [5]	63	53.2	2.39	1.32	1.35	1.10	1.40	0.20	8.8%	29.3%	21.8%	0.98	1.4	1.0
Real Estate Construction (ABE) [20[	17	9.7	2.00	1.09	0.73	0.92	0.57	-0.02	0.0%	21.6%	5.0[	0.82	2.1	1.4
Transport Economics (ABE) [27]	91	54.5	3.05	0.98	1.05	0.88	0.76	-0.06	1.2%	26.9%	14.6%	0.93	1.9	1.2
Urban Planning Environ (ABE) [44]	68	34.5	4.57	2.62	1.68	0.88	1.41	0.32	8.2%	20.9%	6.3%	1.12	2.3	1.2
Industrial Management (ITM) [35]	11	8.5	1.06	0.24	0.34	0.85	0.40	-0.18	0.0%	47.1%	0.0%	0.85	1.5	1.2

Explanations to the indicators are given in Table 1. The crown indicator (NCSf) is highlighted in the table.

CONCLUSION AND DISCUSSION

In general bibliometric indicators provide useful information that can be used by peers or by prudent university management. Several studies have shown that usually there is a good correspondence between peer ratings and bibliometrics.

Results indicate that in 2008 KTH has a research personnel base with a high capacity for internationally competitive research. The citation impact is well above the global average (1.31) and seven out of 47 UoAs have a record of achievement close to global excellence; with very strong performances from an international perspective.

Bibliometric indicators should be treated with caution and cannot be interpreted without detailed knowledge of the research units under assessment and the context of their research. Is it a group that was recently started? Has there been a lot of mobility or fluctuations in the support of research students or research income? These are questions that cannot be answered without additional information.

If the bibliometric analysis indicates a low correlation with the peer ratings there are several possible explanations. Firstly, the peers might not see the scientific potentials of the group. Secondly, and probably more common, there might be flaws in the bibliometric data. Imperfections and limitations of bibliometric analysis can be addressed under two headings:

1) ISI classification of journals into sub-fields is a powerful instrument for normalizations procedures, but the categorization has to be stable over time. For areas under fast transformation this might lead to inconsistencies, and new areas in between sub-fields, or old areas where two disciplines are collaborating, may not receive optimal attention in all actual cases. In such cases, if the NCSj figures (Normalized Citations Score, journal) deviates from the NCSf, the former might give a more appropriate description of performances.

2) Coverage issues in the Web of Science selection of journals and serials is an important problem, and this could be a more pertinent problem especially in the applied engineering areas than for other fields. The investigations reported here cannot discount this, as ICT units do seem to be disadvantaged by the bibliometric analysis. ICT consists of several areas with a typically high number of specialized conference proceedings which were not retrievable from the Thomson Reuters database during spring of 2008.

There are no obvious tendencies in the results pointing to severe problems with the underlying data. However, units with a small international exposure, many of them within typical engineering areas (e.g. the ITM School), do show results with an undersized number of papers. To draw any general conclusions from this would be unwarranted; instead, we should use the information for a further investigation of publication strategies from those units and examine the different possibilities and options for the researchers with the objective of international competitiveness in mind.

A low number of publications in the Web of Science database can also indicate a different type of focus for the research of a UoA. There are many different stakeholders at a technical university and certainly not all of them are content with international publications as the main result of their academic research. Nevertheless, such UoAs might need advice from the point of view of advanced research, thus increasing international publications in refereed journals as a visible sign of competence which could eventually act as a vehicle for getting even more of the consulting and commissioned projects that are their specialty.

Researchers in the UoAs of the present study need not have been at KTH for the whole period. In essence, this is the method of prescriptive "brain power" analysis. With this method we are looking towards the future, since the personnel currently employed are likely to remain at KTH for the immediate future. The downside of this method is that we cannot relate personnel structure, research income or any other structural indicator to the bibliometric indicators. Unfortunately, this is the main limitation of the applied method, but on the plus side we have relevant information to use for future knowledge assessment strategies.

To conclude, a bibliometric analysis is not a representative report on the activities of a full university. Many other methods have to be applied in order to account for the variety of functions performed by academic researchers in society. In this context we emphasize that the bibliometric methods used here are geared towards an international comparison, and it is important that any conclusions drawn take this into account.

TECHNICAL APPENDIX

Citation normalization

In this report normalization of citations is performed with reference to two different normalization groups: WoS sub-fields and journals. When normalizing, we also take into account the publication year and publication type. A normalization group might then look as follows: papers of the type "review" within the sub-field "Metallurgy & Metallurgical Engineering" published in 2002.

The most commonly used normalization type was developed by Schubert, Glänzel and Braun during the 1980s (1988). Simultaneously the Leiden group (Moed et al. 1988) developed a variant methodology with the well known "crown indicator". These normalized indicators are typically named CPP/JCS or CPP/FCS depending on whether the normalization is carried out in relation to journals or sub-fields. The Leiden indicator is defined as follows:

$$\frac{\sum_{i=1}^{P} c_i}{\sum_{i=1}^{P} [\mu_f]_i}$$

where c is the number of citationss to a paper i and $[\mu_f]_i$ is the average number of citations received by papers in the normalization group of paper i. In our calculations of "Field normalized citation score" and "Journal normalized citation score" we have chosen to adjust this as follows:

$$\frac{1}{P} \sum_{i=1}^{P} \frac{c_i}{[\mu_f]_i}$$

The difference is that our calculation treats all papers as equal, while the Leiden version gives higher weight to papers in normalization groups with higher reference values, cf. Lundberg (2006), pp. III:3; cf. Visser et al, (2007).

When calculating the "Normalized journal citation score" (similar to the Leiden-measure JCS/FCS), we use the following formula:

$$\frac{1}{P} \sum_{i=1}^{P} \frac{[\mu_j]_i}{[\mu_f]_i}$$

where $[\mu_j]_i$ is the average number of citations received by papers in the journal of paper i and $[\mu_f]_i$ is the average number of citations received by papers in the sub-field of paper i.

Another citation indicator used in the report is the "Standard citation score". This indicator is defined as follows:

$$\sum_{i=1}^{P} \frac{ln(c + 0,5) - \left[\mu_{f[ln]}\right]_i}{\left[\sigma_{f[ln]}\right]_i}$$

where $[\mu_{f[ln]}]_i$ is the average value of the logarithmic number of citations (plus 0.5) in the normalization group and $[\sigma_{f[ln]}]_i$ is the standard deviation of the $[\mu_{f[ln]}]_i$ distribution (based on McAllister, PR, Narin, F, Corrigan, JG. 1983).

REFERENCES

Adams J, Jackson L, Marshall S (2007). Bibliometric analysis of interdisciplinary research. Report to Higher Education Funding Council for England. November 2007. Evidence/HEFCE.

Adams, J et al. (2007). The use of bibliometrics to measure research quality in UK higher education institutions. Universities UK, Research Report. Evidence.
    <http://www. book-shop.universitiesuk.ac.uk/downloads/bibliometrics.pdf>

Aksnes, DW (2003a). A macro study of self-citations. Scientometrics 56(2):235–246.

Aksnes, DW (2003b). Characteristics of highly cited papers. Research Evaluation 12 (3): 159–170.

Aksnes, DW & Taxt, RE (2004). Peer reviews and bibliometric indicators: a comparative study at a Norwegian university. Research Evaluation, 13 (1): 33–41.

Amsterdamska, O & Leydesdorff, L (1989). Citations: indicators of significance? Scientometrics 15 (5-6):449–471.

Böhme, van den Daele, Krohn (1978) The 'Scientification' of Technology. In: (Eds) Krohn, Layton & Weingart, The dynamics of Science and Technology. Sociology of the Sciences Yearbook 1978, pp. 219–250.

Borgmann, CL & Furner, J (2002). Scholarly Communication and Bibliometrics. Annual Review of Information Science and Technology: Vol. 36, pp-

Bornmann, L & Daniel HD (2008). What do citation counts measure? A review of studies on citing behavior. Journal of Documentation, 64(1), 45–80.

Boyack, KW (2007). Using detailed maps of science to identify potential collaborations. Proceedings of ISSI 2007, edited by Torres-Salinas & Moed. Madrid, Spain June 25-27, 2007. Vol 1, s. 124–135.

Butler L (2003). Explaining Australia's increased share of ISI publications – the effects of funding formula based on publication counts. Research Policy 32:143–155.

Butler L (2008). Using a balanced approach to bibliometrics: quantitative performance measures in the Australian Research Quality Framework. Ethics in Science and Environmental politics, vol 8, preprint doi: 10.3354/esep00077.

Butler, L (2002). A list of published papers is no measure of value. Nature vol 419 (31 OCTOBER).

Campiteli, M. Batista, P.D. & Martinez, A.S. (2007). A research productivity index to account for different scientific disciplines. In: Proceedings of the ISSI 2007, pp. 185–188.

Carpenter, M. & Narin, F. (1981). The adequacy of the Science Citation Index (SCI) as an indicator of international scientific activity. Journal of the American Society for Information Science, 32 (6): 430–439.

Cole, JR & Cole, S (1973) Social stratification in science. Chicago, Ill.: University of Chicago Press.

Cole, S (1992). Making science: between nature and society. Cambridge, Mass.: Harvard University Press.

Cole, S, Simon, G & Cole JR (1988) Do Journal Rejection Rates Index Consensus? American Sociological Review, Vol. 53, No. 1 (Feb., 1988), pp. 152–156

CWTS (2007). Scoping study on the use of bibliometric analysis to measure the quality of research in UK higher education institutions. Report to HEFCE by the Leiden group. November 2007. [http://www.hefce.ac.uk/pubs/rdreports/2007/rd18_07/rd18_07.pdf]

De Bruin, RE & Moed HF (1990). The unification of addresses in scientific publications. Informetrics 89/90: 65–78 <https://doclib.uhasselt.be/dspace/>

Dieks D. & Chang H. (1976). Differences in Impact of Scientific Publications: some indices derived from a citation analysis. Social Studies of Science, 6: 247–267.

Egghe L (1997). Price index and its relation to the mean and median reference age. JASIS, 48 (6): 564–573.

Frame, JD & Narin, F (1976). NIH funding and biomedical publication output. Federation Proceedings, 35 (14): 2529–2532.

Garfield, E (1979). Citation indexing – its theory and application in science, technology, and humanities. New York: Wiley.

Garfield, E, Malin, MV, Small, H (1978). Citation Data as Science Indicators. In: (Eds.(Elkana et al. *Toward a Metric of Science: the advent of science indicators*. New York: John Wiley & Sons, pp. 179–208.

Giske J (2008). Benefitting from bibliometrics. Ethics in Science and Environmental Politics, 8: 93–102.

Glänzel W, Schubert A, Schoepflin U, et al. (1999). An item-by-item subject classification of papers published in journals covered by the SSCI database using reference analysis. Scientometrics, 46 (3): 431–441.

Glänzel W, Thijs, B., Schlemmer, B. (2004), A bibliometric approach to the role of author self-citations in scientific communication, Scientometrics, 59 (1): 63–77.

Hansson S (1995). Impact factor as a misleading tool in evaluation of medical journals. Lancet, Sep 30, 346(8979):906.

Hicks D (1999). The difficulty of achieving full coverage of international social science literature and the bibliometric consequences. Scientometrics, 44(2):193–215.

Hicks D (2004). The four literatures of social science. (Eds.) Moed et. al. Handbook of Quantitative Science and Technology Research: The use of publication and patent statistics in studies of S&T systems. Dordrecht/Boston/London: Kluwer Academic Publishers 2004, pp. 473–496.

Hirsch, JE (2005). An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America, 102 (46): 16569–16572.

Jansz, MCN (2000). Some thoughts on the interaction between scientometrics and science and technology policy. Scientometrics 47 (2): 253–264.

Kaplan, N (1965). The norms of citation behavior: Prolegomena to the footnote. American Documentation 16: 179–187.

Klavans, R & Boyack, KW (2008) Thought leadership: A new indicator for national and institutional comparison. Scientometrics , 75 (2): 239–252.

Knothe G (2006). Comparative citation analysis of duplicate or highly related publications. JASIST, 57 (13): 1830–1839.

Latour, B (1987). Science in Action: how to follow scientists and engineers through society. Milton Keynes (UK): Open University Press.

Le Pair, C. (1988). The citation gap of applicable science, In: A. F. J. Van Raan (Ed.), Handbook of Quantitative Studies of Science and Technology, Elsevier Science/North-Holland, Amsterdam, pp. 537–553.

Lehmann, S, Jackson, A & Lautrup, BE (2006). Measures for measures. Nature, 444 (21/28 dDecember), pp. 1003–1004.

Leydesdorff, L & Amsterdamska, O (1990). Dimensions of citation analysis. Science, Technology & Human Values 15 (3): 305–315.

Leydesdorff L & Cozzens SE (1993). The delineation of specialties in terms of journals using the dynamic journal se to the ISI. Scientometrics 26 (1): 135–156.

Leydesdorff, L. (2008) Caveats for the Use of Citation Indicators in Research and Journal Evaluations. Journal of the American Society for Information Science and Technology, 59(2): 278–287.

Lundberg, J (2006) Bibliometrics as a research assessment tool – impact beyond the impact factor. PhD-thesis, Karolinska Institute. Stockholm.

Luukonen, T (1997). Why has Latour's theory of citations been ignored by the bibliometric community? Scientometrics 38 (1):27–37.

Martin, B.R. & Irvine J. (1983). Assessing basic research: some partial ndicators of scientific progress in radio astronomy. Research Policy, 12: 61–90.

McAllister, PR, Narin, F, Corrigan, JG. (1983), Programmatic evaluation and comparison based on standardized citation scores. IEEE Transactions on Engineering Management, 30: 205–211.

Merton, RK (1973). The Sociology of Science: theoretical and empirical investigations. Chicago: Chicago University Press.

Moed HF (2002). The impact-factors debate: the ISI's uses and limits. Nature vol 415, 14 feb p. 731–732.

Moed HF (2005). Citation Analysis in Research Evaluation. Dordrecht: Springer Verlag.

Moed HF, van Leeuwen TN (1995). Improving the Accuracy of Institute for Scientific Information's Journal Impact Factors. JASIS 46(6):461–467

Moed HF, Vriens M (1989). Possible inaccuracies occurring in citation analysis. Journal of Information Science 15;95–107.

Moed, H & Visser, MS (2007). Developing Bibliometric Indicators of Research Performance in Computer Science: An Exploratory Study. CWTS, Leiden. Avaialbe at <http://www.cwts.nl/pdf/NWO_Inf_Final_Report_V_210207.pdf>

Moed, HF. & van Raan, A.F.J. (1988). Indicators of research performance: applications in university research policy. In: van Raan, (Ed.) Handbook of Quantitative Studies of Science and Technology. Amsterdam: North-Holland, pp. 177–206.

Narin & Toma (1985) Is technology becoming science? Scientometrics 7 (3-6):369–381.

Narin, F. & Hamilton, KS (1996). Bibliometric performance measures. Scientometrics, 36 (3): 293–310.

Narin, F. (1976) Evaluative bibliometrics: the use of publication and citation analysis in the evaluation of scientific activity. New Jersey: Computer Horizons, Inc.

Nederhof, A.J. (1988) Evaluation of Scholarly Performance. In: van Raan, (Ed.) Handbook of Quantitative Studies of Science and Technology. Amsterdam: North-Holland, pp. 207–228.

Price, D.J.S: "Is technology historically independent of science?" Technology and Culture, Vol. 6, No. 4, (Autumn, 1965), pp. 553–568.

Price, D. (1965). Networks of scientific papers. Science, 149(3683), 510–515.

Price, D. (1976). A general theory of bibliometric and other cumulative advantage processes. Journal of the American Society for Information Science, 27(5-6), 292–306.

Price, D. (1986). Little science, big science – and beyond. New York: Columbia University Press.

Roche, T., Smith, D. L. (1978) Frequency of citations as criterion for the ranking of departments, journals and individuals. Sociological Inquiry, 48(1): 49–57.

Sandström U & Sandström E (2007). A Metrics for Academic Science applied to Australian Universities. [http://eprints.rclis.org/archive/00011776/]

Sandström U & Sandström E (2008a). Resurser för citeringar. Högskoleverket Rapport 2008:18R.

Sandström U & Sandström E (2008b). UoA – Interpretation material. [Unpublished material KTH].

Schubert A & Glänzel W (1983). Statistical reliability of comparisons based on the citation impact of scientific publications. Scientometrics 5: 59–74.

Schubert A, Glänzel W, Braun T. (1987). Subject field characteristic citation scores and scales for assessing research performance. Scientometrics 12 (5-6 / November): 267–292.

Schubert, A. Glänzel, W. Braun, T. (1988). Against absolute methods: relative scientometric indicators and relational charts as evaluation tools. In: van Raan, (Ed.) Handbook of Quantitative Studies of Science and Technology. Amsterdam: North-Holland, pp. 137–176.

Schubert, A, Glänzel, W, Thijs, B (2006). The weight of author self-citations: a fractional approach to self-citation counting. Scientometrics, 67 (3): 503–514.

Seglen, P. O. (1992). The skewness of science. Journal of the American Society for Information Science, 43(9), 628–638.

Seglen, P.O. (1994). Causal relationship between article citedness and journal impact. Journal of the American Society for Information Science 45, 1–11.

Seglen, PO (1998) Citation rates and journal impact factors are not suitable for evaluation of research . *Acta Orthop Scand* 69 (3): 224–229.

Small, H. (1978). Cited documents as concept symbols. Social Studies of Science, 8, 327–340.

Thijs B, & Glanzel W (2005). The influence of author self-citations on bibliometric meso-indicators. The case of European universities. Scientometrics, 66 (1): 71–80.

van Els, W.P., C.N.M. Jansz & C. Le Pair (1989). The citation gap between printed and instrumental output of technological research: the case of the electron microscope, Scientometrics, 17, 4 t 5–425.

van Leeuwen, TN (2008). Testing the validity of the Hirsch-index for research assessments purposes. Research Evaluation, 17(2):157–160.

van Leeuwen, TN, Moed, HF, Tijssen, RJW, Visser, MS, van Raan, AFJ (2000). First evidence of serious language-bias in the use of citation analysis for the evaluation of national science systems. Research Evaluation, 9 (2):155–156.

van Raan, AFJ (1996). Advanced bibliometric methods as quantitative core of peer review based evaluation and foresight exercises. Scientometrics, 36(3):397–420.

van Raan, AFJ (2004). Measuring Science: Capita Selecta of Current Main Issues. (Eds.) Moed et. al. Handbook of Quantitative Science and Technology Research: The use of publication and patent statistics in studies of S&T systems. Dordrecht/Boston/London: Kluwer Academic Publishers 2004, pp.19–50

van Raan, AFJ (2006a). Statistical properties of Bibliometric indicators: Research group indicator distributions and correlations. Journal of the American Society for Information Science and Technology 57 (3), 408–430.

van Raan, AFJ (2006b). Performance-related differences of bibliometric statistical properties of research groups: cumulative advantages and hierarchically layered networks. Journal of the American Society for Information Science and Technology 57 (14), 1919–1935.

Vetenskapsrådet. (2006). Hur mycket citeras svenska publikationer? Vetenskapsrådets rapportserie 13:2006.

Visser, M.S. Nederhof, A.J. (2007) Bibliometric study of the Uppsala University, Sweden, 2002–2006. In: Quality and renewal 2007: An overall evaluation of research at Uppsala University 2006/2007. Uppsala: Uppsala University.

Whitley, R. (2000). The intellectual and social organization of the sciences. Second Edition (First ed. 1984). Oxford: Oxford University Press.

Zitt, M, Ramanana-Rahary S, Bassecoulard E (2005). Relativity of citation performance and excellence measures: from cross-field to cross-scale effects of field-normalisation. Scientometrics, 63 (2): 373–401.

Zitt, M. (2005). Facing diversity of science: a challenge for bibliometric indicators. Measurement, 3(1): 38–49.