The Research Council of Norway

Research in Information and Communication Technology in Norway

Bibliometric analysis

Evaluation
Division for Science

The Research Council of Norway

Research in Information and Communication Technology at Norwegian Universities, University Colleges and Selected Research Institutes

An evaluation, February 2012

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The report can be ordered at:
www.forskningsradet.no/publikasjoner

or green number telefax: +47 800 83 001

Design cover: Design et cetera
Printing: 07 gruppen/The Research Council of Norway
Number of copies: 200

Oslo, March 2012

ISBN 978-82-12-03064-0 (print)
ISBN 978-82-12-03065-7 (pdf)

NIFU

Nordic Institute for Studies in Innovation, Research and Education

Evaluation of ICT – Publication and Citation Analysis

National Indicators and International Comparisons

Institutional Analyses

Dag W. Aksnes

March 2012

Preface

This report presents a bibliometric analysis of research in ICT and is a background report of the evaluation of the discipline. The report is written on the commission of the Research Council of Norway by senior researcher Dr. Dag W. Aksnes (project leader) at the Nordic Institute for Studies in Innovation, Research and Education (NIFU).

Contents

1 Introduction

This report presents the results of a bibliometric study of the institutions included in the evaluation of research in ICT in Norway. Both the institution/department level and the research group level are analysed. In addition the report contains a macro analysis of Norwegian ICT research in an international comparison.

Publication and citation data have increasingly been applied as performance indicators in the context of science policy and research evaluation. The basis for the use of bibliometric indicators is that new knowledge – the principal objective of basic and applied research – is disseminated to the research community through publications. Publications can thereby be used as indirect measures of knowledge production. Data on how much the publications have been referred to or cited in the subsequent scientific literature can in turn be regarded as an indirect measure of the scientific impact of the research.

The report is structured as follows: The first chapter presents the data and the methodology applied in the study. The second chapter gives an overview of Norwegian ICT research in an international context. Next follows separate chapters on each of the departments and institutes included in the evaluation. A final appendix chapter provides a general introduction to bibliometric indicators, particularly focusing on analyses based on Thomson Reuters (ISI) data.

2 Data and methods

2.1 Data sources

The study is based on two main data sources. One source is Thomson Reuters (formerly known as Institute for Scientific Information (ISI)), the producer of the most important database for bibliometric purposes. Another is the publically accessible database Cristin (and the two former databases Frida and Forskdok), which is a joint system for registration of scientific publications applied by Norwegian higher education institutions, including the universities in Oslo, Bergen, Trondheim and Tromsø.

2.2 Included departments and researchers

The analysis covers the following departments and units:

Universities and university colleges:

Norwegian University of Science and Technology (NTNU)

- Faculty of Information Technology, Mathematics and Electrical Engineering
    - Department of Computer and Information Science
    - Department of Electronics and Telecommunications
    - Department of Engineering Cybernetics
    - Department of Telematics

University of Agder (UiA)

- Faculty of Engineering and Science
    - Department of ICT
- Faculty of Economics and Social Sciences
    - Department of Information Systems

University of Bergen (UiB)

- Faculty of Mathematics and Natural Sciences
    - Department of Informatics
- Faculty of Social Sciences
    - Department of Information Science and Media Studies

University of Oslo (UiO)

- Faculty of Mathematics and Natural Sciences
    - Department of Informatics

University of Stavanger (UiS)

- Faculty of Science and Technology
    - Department of Computer Science and Electrical Engineering

University of Tromsø (UiT)

- Faculty of Science and Technology
    - Department of Computer Science

Gjøvik University College (HiG)

- Faculty of Computer Science and Media Technology

Vestfold University College (HiVe)

- Faculty of Technology and Maritime Science
    - Department of Micro- and Nano Systems Technology

Østfold University College (HiØ)

- Faculty of Information Technology

University Graduate Center at Kjeller (UNIK)

Research institutes (institute sector):

- Norwegian Defence Research Establishment (FFI)
- Simula Research Laboratory AS
- SINTEF ICT

The general chapter on Norwegian ICT (chapter 3) is, however, not limited to these units. Here, all Norwegian publishing in journals within Computer science is included.

The analysis of the departments and units is limited to the personnel selected for the evaluation. In other words, we do not present analyses of the total publication output of the departments. Personnel in the following categories are included: Tenured academic employees (professor I, associate professor), post doc fellows and researchers. Also professor IIs (and associate professor IIs) are included in the evaluation (persons with 20 % appointments). However, these are not included in the publication analysis. The same holds for researchers with 20 % appointments. The reason is that their research for the most part is financed and carried out elsewhere.[1] Their research papers co-authored with tenured staff would appear on the publication lists of the latter anyway. It is important to emphasise that the publication output of a department or group sometimes will be substantially higher than what is reflected in our figures. This is not only due to the omission of the publications of adjunct professors. In addition, the analysis does not include publications of retired personnel (e.g. professor emeritus) and personnel not working at the department anymore.

2.3 Methods

The analysis covers the five year period 2006-2010. The general chapter on Norwegian ICT (chapter 3), also includes some publication indicators for the entire 2001-2010 period. From the Research Council of Norway we obtained information on the institutions, departments and persons encompassed by the evaluation, including the distribution of personnel on research groups. The analysis of the departments and research groups is based on the following two basic criteria:

- Only publications where the department/institute is listed as an author address is included in the analysis.
- Only publications where the persons encompassed by the evaluation are employed at the unit and appear as authors are included in the analysis.

Both criteria have to be met. This means that the analysis will not include publications published by a person before he/she became affiliated with their present place of employment. For the newly appointed personnel this means that very few of their publications will be included. The basic justification underlying this methodology is that the evaluation has its focus on the institution and research group level, and is not an evaluation of individual persons.

We have used this list of institutions and persons as a basis for publication searches. The analyses in this report are primarily based on the publications registered in the publically accessible databases Frida and ForskDok (now merged to a database system called Cristin), and not on the comprehensive publication lists compiled for the evaluation. Frida and ForskDok are two different registration systems for scientific publications employed by Norwegian universities and other higher education institutions, and include the scientific publications for all the Higher education institutions to be included in the evaluation. The Frida/ForskDok publication data are summarised in the Norwegian DBH database and are used for the calculation of the performance based budgeting of Norwegian higher education institutions. Publication data for NTNU, UiB, UiO, UiT are registrered in the Frida system, while the other higher education institutions use the ForskDok system. Institutes outside the Higher education sector have previously not registered their publications in these databases. In our study, for FFI, SINTEF ICT and Simula, we therefore had to rely on publication lists that

[1] Since professor IIs usually are appointed on the basis of their scientific merit, they can be very productive, and may account for a major fraction of a group's scientific production if they were included.

were submitted by the researchers, supplied with information from NIFU STEPs publication database of covering the research institutes (Nøkkeltalldatabasen).

We have only included contributions published in publication channels qualifying as scientific in the performance based budgeting system. The following publication types are qualified: full-papers (regular articles, proceedings articles) and review articles published in journals or books (i.e. not short contributions like letters, editorials, corrections, book-reviews, meeting abstracts, etc.) and books/monographs.

Three different databases which NIFU has purchased from Thomson Reuters are applied in the study. One basic database is the *National Citation Report* (NCR) for Norway, containing bibliographic information for all Norwegian articles (articles with at least one Norwegian author address). Data for each paper include all author names, all addresses, article title, journal title, document type (article, review, editorial, etc.), field category, year by year and total citation counts and expected citation rates (based on the journal title, publication year and document type). The 2011 edition of NCR, with data covering 1981-2010 was used.

In addition, the *National Science Indicators* (NSI) database containing aggregated bibliometric data at country and field/subfield level was used. This database has been applied in the general analysis of Norwegian ICT. This database was also applied for the purpose of creating reference standards (see below). Finally, the *Journal Performance Indicator* (JPI) database, containing aggregated bibliometric data at journal level, was used for retrieving citation rates of journals ("impact factors").

The individual researcher represents the basic unit in the study, and the data were subsequently aggregated to the level of departments/units. We have used the group/section structure described in the factual information reports the departments have submitted to the Research Council of Norway. Here the departments have listed the persons who are included in the evaluation and their group/section affiliations. In other words, we have applied a personnel based definition where a department or group is delimited according to the scientific staff included in the evaluation.[2] It should be noted that some of the "groups" represent more informal structures whereas other "groups" correspond to formal subdivisions within the departments. As described above, we have included all publications of the individuals examined, but not work carried out before they became affiliated at the respective departments.

Some publications were multiple reported. The reason is that when a publication is written by several authors it will appear on the publication lists of all the authors, and will accordingly occur more than one time. In order to handle this problem we removed all the multiple reported items in the analysis of departments and groups, i.e. only unique publications were left.

[2] Research assistants are not included. We have included professors with emeritus positions if these have been listed among the staff in the factual reports.

2.3.1 Publication output

Scientific productivity can in principle be measured relatively easy by the quantification of published material. In practice it is more difficult, since a number of issues have to be faced. In particular the choice and weighting of publication types and the attribution of author credit are important questions to consider. Many publications are multi-authored, and are the results of collaborative efforts involving more than one researcher or institution. There are different principles and counting methods that are being applied in bibliometric studies. The most common is "whole" counting, i.e. with no fractional attribution of credit (everyone gets full credit). A second alternative is "adjusted counting" where the credit is divided equally between all the authors (Seglen, 2001). For example, if an article has five authors and two of them represent the department being analysed, the department is credited 2/5 article (0.4). One can argue that these counting methods are complementary: The whole or integer count gives the number of papers in which the unit "participated". A fractional count gives the number of papers "creditable" to the unit, assuming that all authors made equal contributions to a co-authored paper, and that all contributions add up to one (Moed, 2005). As described above, in this study, possible double occurrences of articles have been excluded within each unit. This means that papers co-authored by several researchers belonging to the same department or group are counted only once. We have used the "whole" counting method.

We have also included productivity indicators, measured as number of publications per full-time equivalents (FTE)" (man-years). Although this may appear as a rather abstract measure it, nevertheless, represents the fairest way of comparing and assessing scientific productivity. Some employees have not been affiliated with the departments for the entire five year period. In these cases we have only included publications from the years they have been working at the unit and adjusted the productivity indicator accordingly.

Similarly, fractional man-years were used for persons with part-time positions. We have excluded periods of leave (e.g. maternity leave) in the calculation of man years. Moreover, positions as PhD-students are not counted in the calculation of man years. Data on the employment history of the persons was taken from the submitted CVs. Some of the CVs were deficient when it came to this information.[3] Moreover, there is a delay from the research is carried out to the appearance of the publication, which means that the productivity of the newly appointed persons will be somewhat underestimated. Because of these factors, the numbers on productivity should be interpreted as rough rather than exact measures.

[3] In these cases supplementing information on employment was retrieved from the *Norwegian Research Personnel Register* containing individual data for all researchers in the Higher Education Sector and Institute Sector in Norway.

2.3.2 Citation indicators

Only publications published in journals indexed in the Thomson Reuters database NCR are included in the analysis. The ICT-field is moderately well covered in this database. This is due to the particular publication pattern of ICT-research where proceedings papers play an important role, a significant part of this output will not be covered by the database.

The individual articles and their citation counts represent the basis for the citation indicators. In the citation indicators we have used accumulated citation counts and calculated an overall (total) indicator for the whole period. This means that for the articles published in 2006, citations are counted over a 5-year period, while for the articles published in 2008, citations are counted over a 3-year period (or more precisely a 2-3 year period: the year of publication, 2009 and 2010). Citations the publications have received in 2011 are not included in the citation counts.

The problem of crediting citation counts to multi-authored publications is identical to the one arising in respect to publication counts. In this study the research groups and departments have received full credit of the citations – even when for example only one of several authors represents the respective research groups or department. This is also the most common principle applied in international bibliometric analyses. There are however arguments for both methods. A researcher will for example consider a publication as "his/her own" even when it has many authors. In respect to measuring contribution, on the other hand, (and not participation) it may be more reasonable to fractionalise the citations, particularly when dealing with publications with a very large number of authors.

The average citation rate varies a lot between the different scientific disciplines. As a response, various reference standards and normalisation procedures have been developed. The most common is the average citation rates of the journal or field in which the particular papers have been published. An indicator based on the journal as a reference standard is the Relative citation index – journal (also called the Relative Citation Rate). Here the citation count of each paper is matched to the mean citation rate per publication of the particular journals (Schubert & Braun, 1986). This means that the journals are considered as the fundamental unit of assessment. If two papers published in the same journal receive a different number of citations, it is assumed that this reflects differences in their inherent impact (Schubert & Braun, 1993). Below the indicators are further described.

<u>Relative citation index – journal</u>

For the Relative citation index – journal we used the mean citation rate of the department's journal package, calculated as the average citation rate of the journals in which the group/department has published, taken into account both the type of paper and year of publication (using the citation window from year of publication through 2010). For example, for a review article published in a particular journal in 2006 we identified the average citation rates (2006–2010) to all the review articles published by this journal in 2006.

Thomson Reuters refers to this average as the Expected Citation Rate (XCR), and is included as bibliometric reference value for all publications indexed in NCR. For each department we calculated the mean citation rate of its journal package, with the weights being determined by the number of papers published in each journal/year. The indicator was subsequently calculated as the ratio between the average citation rate of the department's articles and the average citation rate of its journal package. For example, an index value of 110 would mean that the department's articles are cited 10 % more frequently than "expected" for articles published in the particular journal package.

<u>Relative citation index – field</u>

A similar method of calculation was adopted for the Relative citation index – field (also termed the Relative Subfield Citedness (cf. Vinkler, 1986, 1997)). Here, as a reference value we used the mean citation rate of the subfields in which the department has published. This reference value was calculated using the bibliometric data from the NSI-database. Using this database it is possible to construct a rather fine-tuned set of subfield citation indicators. The departments are usually active in more than one subfield (i.e. the journals they publish in are assigned to different subfields). For each department we therefore calculated weighted averages with the weights being determined by the total number of papers published in each subfield/year. In Thomson Reuter's classification system some journals are assigned to more than one subfield. In order to handle this problem we used the average citation rates of the respective subfields as basis for the calculations for the multiple assigned journals. The indicator was subsequently calculated as the ratio between the average citation rate of the department's articles and the average subfield citation rate. In this way, the indicator shows whether the department's articles are cited below or above the world average of the subfield(s) in which the department is active.

<u>Relative citation index – Norway</u>

We also calculated a citation index where the average Norwegian citation rate of the subfields was used as basis for comparison. A department with citedness below the world average may, for example, perform better in respect to the corresponding Norwegian average (assuming that the Norwegian research here is cited below the world average). This indicator was calculated as a relative citation index where the index value 100 represents the average Norwegian citation rate in the subfield. The index was calculated using corresponding principles as described for the other two indexes.

Relative citation index – EU-15

We also calculated a citation index where the average citation rate of the EU-15 countries[4] was used as basis for comparison. This indicator was calculated as a relative citation index where the index value 100 represents the average EU-15 citation rate in the subfield.

Example

The following example can illustrate the principle for calculating relative citation indexes: A scientist has published a regular journal article in *Computer Networks* in 2006. This article has been cited 4 times. The articles published in *Computer Networks* were in contrast cited 2.65 times on average this year. The Relative citation index – journal is: (4/2.65)*100 = 151. The world-average citation rate for the subfield which this journal is assigned to is 2.57 for articles published this year. In other words, the article obtains a higher score compared to the field average. The Relative citation index – field is: (4/2.57)*100 = 156. The example is based on a single publication. The principle is, however, identical when considering several publications. In these cases, the sum of the received citations is divided by the sum of the "expected" number of citations.

It is important to notice the differences between the field and journal adjusted relative citation index. A department may have a publication profile where the majority of the articles are published in journals being poorly cited within their fields (i.e. have low impact factors). This implies that the department obtains a much higher score on the journal adjusted index than the field adjusted index. The most adequate measure of the research performance is often considered to be the indicator in which citedness is compared to field average. This citation index is sometimes considered as a bibliometric "crown indicator" (van Raan, 2000). In the interpretation of the results this indicator should accordingly be given the most weight.

The following guide can be used when interpreting the *Relative citation index – field*:

Citation index: > 150: Very high citation level

Citation index: 120-150: High citation level, significant above the world average.

Citation index: 80-120: Average citation level. On a level with the international average of the field (= 100).

Citation index: 50-80: Low citation level.

Citation index: < 50: Very low citation level.

It should be emphasised that the indicators cannot replace an assessment carried out by peers. In the cases where a research group or department is poorly cited, one has to consider the possibility that the citation indicators in this case do not give a representative

[4] AUSTRIA, BELGIUM, DENMARK, FINLAND, FRANCE, GERMANY, GREECE, IRELAND, ITALY, LUXEMBOURG, NETHERLANDS, PORTUGAL, SPAIN, SWEDEN, UK.

picture of the research performance. Moreover, the unit may have good and weak years. In computer science the citation rates are generally low compared to for example biomedicine. This weakens the validity of citations rates as performance measure in computer science. Citations have highest validity in respect to high index values. But similar precautions should be taken also here. For example, in some cases one highly cited researcher or one highly cited publication may strongly improve the citation record of a group or even a department. We have only calculated citation indexes for the research groups that have published at least 10 papers during the time period analysed.

As described in Chapter 5, citations mainly reflect intra-scientific use. In a field like ICT with strong technological and applied aspects it is important to be aware of this limitation. Practical applications and use of research results use will not necessarily be reflected through citation counts. Moreover, as described above, the ICT-field is only moderately well covered by the database applied for constructing citation indicators, and the indicators are based on a limited part of the research output (although the most important). During the work with the report, it has become apparent that several departments/groups only have a small proportion of their journal publications indexed in the database. This is important to consider when interpreting the results, and one should be careful with be putting too much emphasis on the citation indicators.

Other databases exist which cover the ICT-field better, for example the Inspec-database. This database is however not as well adapted for bibliometric-analyses as the NCR-database, and has not been available to us. Moreover, citations counts can be retried from Google Scholar which has a much broader coverage of the research literature. Accordingly, the citation counts would have been much higher if this database had been used. Unfortunately, the data quality is not very good, and it is difficult to distinguish between researchers sharing the same name. Therefore, this database has not been applied in the report.

2.2.3 Journal profiles

We also calculated the journal profile of the departments. As basis for one of the analyses we used the so called “impact factor” of the journals. The journal impact factor is probably the most widely used and well-known bibliometric product. It was originally introduced by Eugene Garfield as a measure of the frequency with which the average article in a journal has been cited. In turn, the impact factor is often considered as an indicator of the significance and prestige of a journal.

The Journal profile of the departments was calculated by dividing the average citation rate of the journals in which the department’s articles were published by the average citation rates of the subfields covered by these journals. Thus, if this indicator exceeds 100 one can conclude that the department publishes in journals with a relatively high impact.

3 Norwegian computer science in an international context

This chapter presents various bibliometric indicators on the performance of Norwegian research within Computer science. The chapter is based on *all* publications within Computer science, not only the articles published by the persons encompassed by the evaluation. The analysis is mainly based on the database *National Science* Indicators (cf. Method section), where Computer science is a separate field category and where there also are categories for particular subfields within Computer science. In the analysis we have both analysed Computer science as a collective discipline and subfields. The category for Computer science in the database includes the core subfields within the discipline but one subfield relevant or partly relevant for the evaluation is classified outside the category for Computer science: Information Science & Library Science. The latter subfield, however, has been included in some of the analyses.

3.1 Scientific publishing

The four general/broad universities in Norway (in Oslo, Bergen, Trondheim and Tromsø) together account for more than half (54 %) of the Norwegian scientific journal publishing within Computer Science. This can be seen from Table 3.1, where the article production during the four-year period 2007–10 has been distributed according to institutions/sectors. The basis for this analysis is the information available in the address field of the articles. While the University of Oslo by far is the largest university in Norway, this does not hold for Computer science. Here, the Norwegian University of Science and Technology is the largest contributor with a proportion of 22 % of the national total, followed by the University of Oslo with 17 %, University of Bergen with 12 % and University of Agder with 4 %. In the Institute sector (private and public research institutes), Simula Research Laboratory and SINTEF are the largest single contributors with 7 % and 4 %, respectively, of the national total. It should be noted that the incidence of journal publishing in this sector is generally lower than for the universities due to the particular research profile of these units (e.g. contract research published as reports). The industry accounts for 6 % of the Norwegian scientific journal production in Computer Science. Similar to the Institute sector, only a very limited part of the research carried out by the industry is generally published. This is due to the commercial interests related to the research results which means that the results cannot be published/made public.

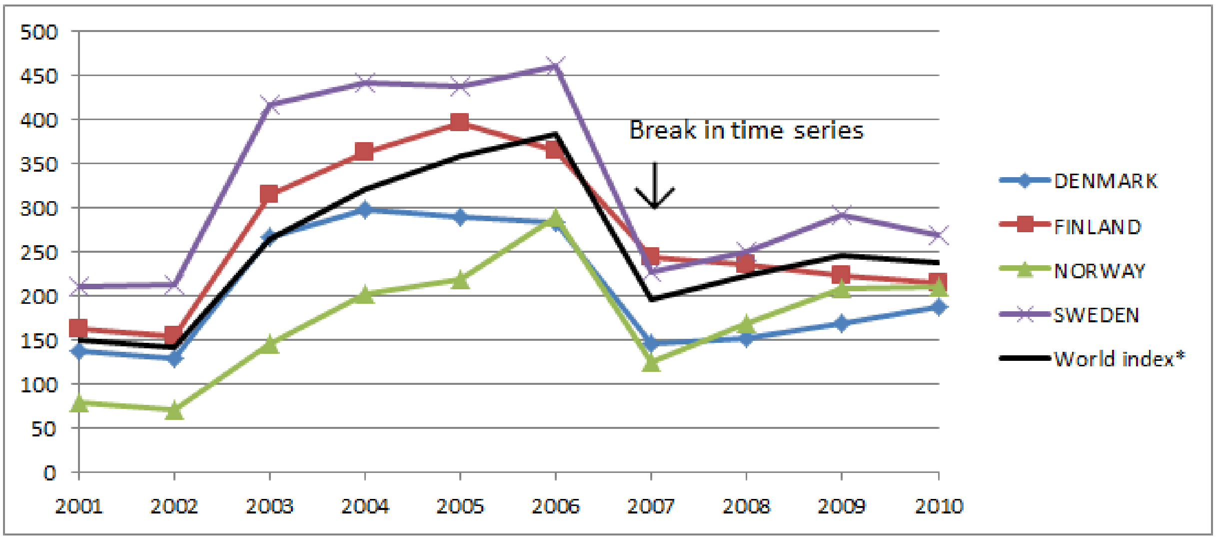
Table 3.1 The Norwegian profile of scientific publishing in Computer science. Proportion of the article production 2007-2010 by institutions*/sectors.

	Number of articles	Proportion
Norwegian University of Science and Technology	346	22 %
University of Oslo**	278	17 %
University of Bergen	186	12 %
University of Agder	66	4 %
Norwegian University of Life Sciences	57	4 %
University of Tromsø	55	3 %
Oslo University College	26	2 %
University of Stavanger	24	1 %
Other Higher Education institutions	120	7 %
Simula	106	7 %
SINTEF	65	4 %
Norwegian Defence Research Establishment	29	2 %
Institute sector - other institutes	109	7 %
Hospitals	45	3 %
Industry	91	6 %

*) Only institutions/institutes with more than 20 publications within the Computer science category (as defined by Thomson Reuters) during the time period are shown separately in the table.
**) Including the University Graduate Center at Kjeller (UNIK).

In Figure 3.1 we have shown the development in the annual production of articles in Computer science for Norway and three other Nordic countries for the period 2001–2010. Among these countries, Norway is the third largest nation in terms of publication output with 210 articles in 2010. Sweden is the largest country and has 30 per cent larger production than Norway (270 articles). In the figure there is a time series break in 2007 due to changes in Thomson Reuters` classification of publications. From this year Thomson Reuters classified journal articles that had been published at conferences as “proceedings papers”, these papers were previously classified as articles. As the NSI-database applied in the macro-analyses of this report, only includes the publication types (regular) articles and review articles, and not proceedings papers, there is a significant drop in the numbers. Thus, it is difficult to assess the development over the 10 year period. However, there is anotable positive trend during the period, this holds for all the displayed countries. The increase is particularly strong for Norway. In 2001, the Norwegian production of publications in Computer science was far below the one of the other Nordic countries. In 2010 Norway produced more publications than Denmark and almost on par with Finland.

Figure 3.1 Scientific publishing in Computer science 2001-2010 in four Nordic countries.**



*) The “world index” is a reference line, calculated as the world production of articles in Computer Science divided by 100.

**) In the figure there is a time series break in 2007 due to changes in Thomson Reuters` classification of publications. From this year Thomson Reuters classified journal articles that had been published at conferences as “proceedings papers”, these papers were previously classified as articles. As the NSI-database applied in the figure, only includes the publication types (regular) articles and review articles, and not proceedings papers, there is a significant drop in the numbers.

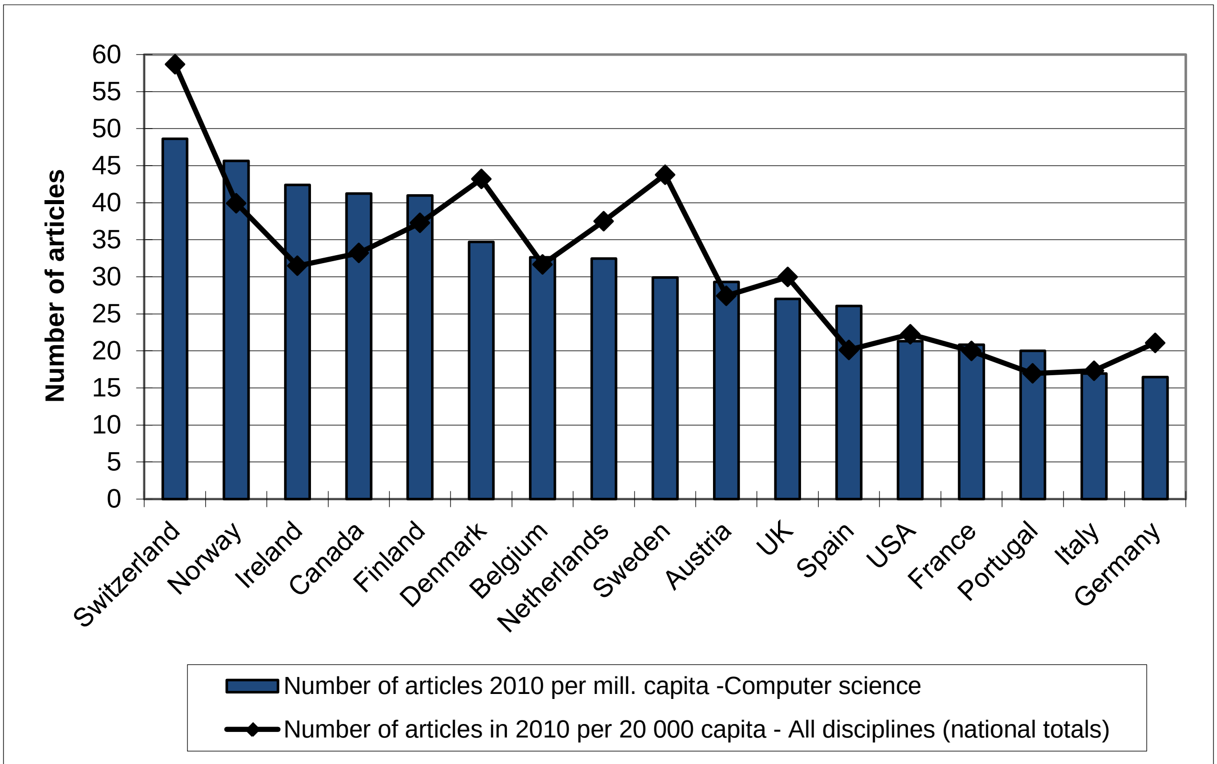
As described in Chapter 2 many publications are multi-authored, and are the results of collaborative efforts involving researchers from more than one country. In the figure we have used the “whole” counting method, i.e. a country is credited an article if it has at least one author address from the respective country.

In a global context Norway is a very small country science-wise. In Computer science, the Norwegian publication output amounts to 0.69 % of the world production of scientific publications in 2010 (measured as the sum of all countries’ publication output). In comparison, Norway has an overall publication share of 0.61 % (national total, all fields). This means that Norway contributes slightly more to the global scientific output in Computer science than it does in other fields.

There are no international data available that makes it possible to compare the output in terms of publications to the input in terms of number of researchers. Instead, the publication output is usually compared with the size of the population of the different countries – although differences in population do not necessarily reflect differences in research efforts. Measured as number of articles per million capita, Norwegian scientists published 46 articles in Computer science in 2010. In Figure 3.2 we have shown the corresponding publication output for a selection of other countries (blue bars). Here Norway ranks as number two, and has a larger relative publication output than most other countries. Switzerland has the highest number with 49 articles, and Ireland ranks as number three with 42 articles per million capita.

In Figure 3.2 we have also shown the production (per 20,000 capita) for all disciplines (national totals) (black line). This can be used as an indication of whether Computer science has a higher or lower relative position in the science system of the countries than the average. For example, for Ireland, Computer science clearly ranks above the national average, while the opposite is the case for Sweden.

Figure 3.2 Scientific publishing per capita in 2010 in selected countries, Computer science and all disciplines.



In order to provide further insight into the profile of Norwegian Computer science we have analysed the distribution of the articles at subfield levels. This is based on the classification system of Thomson Reuters where the journals have been assigned to different categories according to their content (journal-based research field delineation). There is a separate category for journals covering multidisciplinary (computer science) topics. Some journals are assigned to more than one category (double counts). Although such a classification method is not particularly accurate, it nevertheless provides a basis for profiling and comparing the publication output of countries at subfield levels. We have also included the social science subfield Information Science & Library Science in this overview, which includes certain topics covered by the evaluation.

Category descriptions – Computer Science

Computer Science, Artificial Intelligence: Covers journals that focus on research and techniques to create machines that attempt to efficiently reason, problem-solve, use knowledge representation, and perform analysis of contradictory or ambiguous information. This category includes journals on artificial intelligence technologies such as expert systems, fuzzy systems, natural language processing, speech recognition, pattern recognition, computer vision, decision-support systems, knowledge bases, and neural networks.

Computer Science, Cybernetics: Includes journals that focus on the control and information flows within and between artificial (machine) and biological systems. Journals in this category draw from the fields of artificial intelligence, automatic control, and robotics.

Computer Science, Hardware & Architecture: Covers journals on the physical components of a computer system: main and logic boards, internal buses and interfaces, static and dynamic memory, storage devices and storage media, power supplies, input and output devices, networking interfaces, and networking hardware such as routers and bridges. Journals in this category also cover the architecture of computing devices, such as SPARC, RISC, and CISC designs, as well as scalable, parallel, and multi-processor computing architectures.

Computer Science, Information Systems: Covers journals that focus on the acquisition, processing, storage, management, and dissemination of electronic information that can be read by humans, machines, or both. This category also includes journals for telecommunications systems and discipline-specific subjects such as medical informatics, chemical information processing systems, geographical information systems, and some library science.

Computer Science, Interdisciplinary Applications: Includes journals concerned with the application of computer technology and methodology to other disciplines, such as information management, engineering, biology, medicine, environmental studies, geosciences, arts and humanities, agriculture, chemistry, and physics.

Computer Science, Software Engineering: Includes journals that are concerned with the programs, routines, and symbolic languages that control the functioning of the hardware and direct its operation. Also covered in this category are computer graphics, digital signal processing, and programming languages.

Computer Science, Theory & Methods: Includes journals that emphasize experimental computer processing methods or programming techniques such as parallel computing, distributed computing, logic programming, object-oriented programming, high-speed computing, and supercomputing.

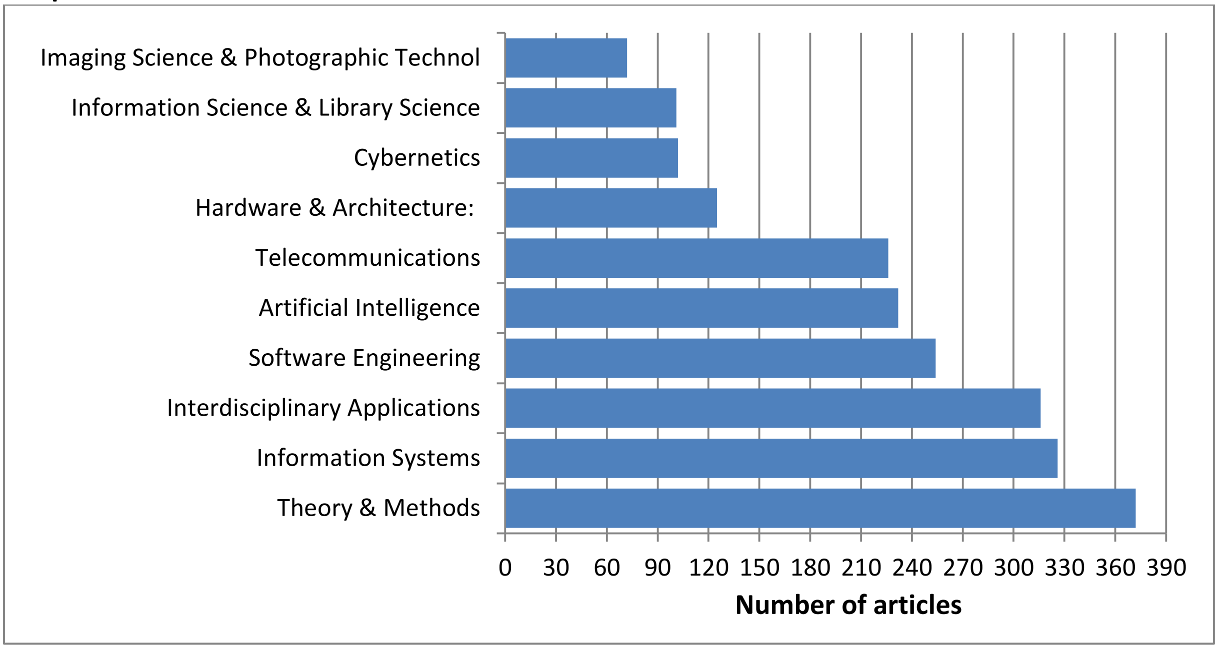
Imaging Science & Photographic Technology: Includes journals that cover pattern recognition, analog and digital signal processing, remote sensing, and optical technology. This category also covers journals on the photographic process (the engineering of photographic devices and the chemistry of photography) as well as machine-aided imaging, recording materials and media, and visual communication and image representation.

Telecommunications: Covers journals on the technical and engineering aspects of communications over long distances via telephone, television, cable, fiber optics, radio, computer networks, telegraph, satellites, and so on. Other relevant topics include electronics, opto-electronics, radar and sonar navigation, communications systems, microwaves, antennas, and wave propagation.

Information Science & Library Science: Covers journals on a wide variety of topics, including bibliographic studies, cataloguing, categorization, database construction and maintenance, electronic libraries, information ethics, information processing and management, interlending, preservation, scientometrics, serials librarianship, and special libraries.

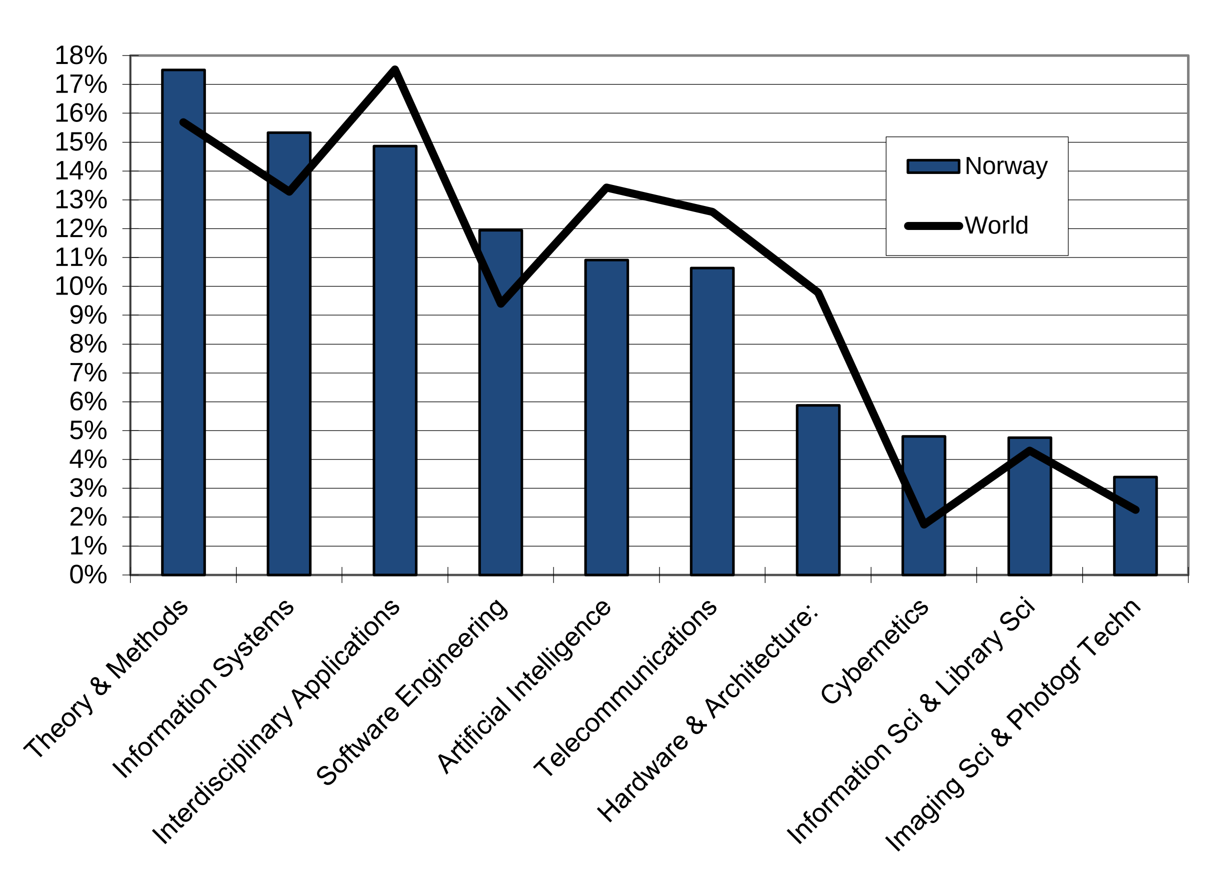
Figure 3.3 shows the distribution of articles for the 5-year period 2006–2010. We note that Computer science, Theory & Methods is the largest category, and 370 articles have been published within this field by Norwegian researchers during the period. Next follows Computer Science, Information Systems with almost 330 articles and Computer Science, Interdisciplinary Applications with approximately 320 articles. As described above, the method underlying the field-classification is not very accurate. For example, the field Cybernetics is rather narrowly defined in terms of journals included. Several journals publishing cybernetics research are not included. Therefore, the "real" Norwegian production in this field is significantly higher than what appears from the figure.

Figure 3.3 Scientific publishing in Computer science subfields, Norway, total number of articles for the period 2006–2010.



The particular distribution of articles by subfields can be considered as the specialisation profile of Norwegian Computer science. In order to further assess its characteristics, we have compared the Norwegian profile with the global average distribution of articles. The results are shown in Figure 3.4. As can be seen, Norway has a distribution of articles that is quite similar to the world distribution of articles. One exception is Computer Science, Hardware & Architecture where Norway has relatively fewer articles.

Figure 3.4 Relative distributions of articles on Computer science subfields, Norway and the world average, based on publication counts for the period 2006–2010.



The Norwegian contributions in the field of Computer science are distributed on a large number of different journals (480 during the period 2006–2010). However, the frequency distribution is skewed, and a limited number of journals account for a substantial amount of the publication output. Table 3.3 gives the annual publication counts for the most frequently used journals in Computer science and related fields for the period 2006–2010. In this table also proceedings papers published in the journals are included in the figures. The 54 most frequently used journals shown in the table account for almost 50 % of the Norwegian publication output in Computer science.

On top of the list we find the *Modelling Identification and Control,* which traditionally has published results of research carried out in Norway, with 69 articles. Then follows *IEEE Transactions on Information Theory* with 48 articles. The table shows how the Norwegian contribution in the various journals has developed during the time period. From the list of journals one also gets an impression of the overall research profile of Norwegian research within Computer science.

Table 3.2 The most frequently used journals for the period 2006–2010, number of publications* from Norway, Computer science.

	2006	2007	2008	2009	2010	Total
MODELING IDENTIFICATION AND CONTROL	20	12		14	22	68
IEEE TRANSACTIONS ON INFORMATION THEORY	11	7	10	11	9	48
BMC BIOINFORMATICS	5	3	5	9	9	31
IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	2	7	8	6	6	29
INFORMATION AND SOFTWARE TECHNOLOGY	5	1	2	11	8	27
BIOINFORMATICS	2	5	6	7	6	26
JOURNAL OF COMPUTATIONAL PHYSICS	2	4	8	5	5	24
COMPUTATIONAL GEOSCIENCES	4	4	4	5	6	23
IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	1	4	5	8	4	22
COMPUTERS & CHEMICAL ENGINEERING	1	2	5	5	6	19
IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	4	2	5	3	4	18
THEORETICAL COMPUTER SCIENCE	4	2	3	4	5	18
JOURNAL OF SYSTEMS AND SOFTWARE	1	3	3	5	6	18
COMPUTERS & OPERATIONS RESEARCH	2		6	3	5	16
INTERNATION JOUR FOR NUMERICAL METHODS IN FLUIDS	4		2	5	4	15
COMPUTATIONAL STATISTICS & DATA ANALYSIS	2	4	3	3	3	15
COMPUTERS & GEOSCIENCES	2	2		6	5	15
COMPUTER NETWORKS	2	1	3	6	3	15
IEEE TRANSAC ON VISUALIZATION & COMPUTER GRAPHICS	2	4	5	2	2	15
EURASIP JOUR ON WIRELESS COMMUNICAT &NETWORKING	1	3	3	3	4	14
IEEE TRANSACTIONS ON SIGNAL PROCESSING		7	1	2	3	13
IEEE TRANSACTIONS ON COMMUNICATIONS	4			7	2	13
BIT NUMERICAL MATHEMATICS	5		2	2	4	13
WIRELESS PERSONAL COMMUNICATIONS		2	1	4	6	13
INTERNATIONAL JOURNAL OF MEDICAL INFORMATICS	1	3	1	2	4	11
IEEE TRANSACT SYSTEMS MAN & CYBERN PART B CYBERNET		3	1	6	1	11
COMPUTER GRAPHICS FORUM			6	2	3	11
DESIGNS CODES AND CRYPTOGRAPHY		3	6	1		10
ELECTRONICS LETTERS	1	2	1	5		9
COMPUTER PHYSICS COMMUNICATIONS	1	2		3	3	9
IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION	2		1	3	3	9
COMPUTER AIDED GEOMETRIC DESIGN	1		1	5	2	9
INDUSTRIAL MANAGEMENT & DATA SYSTEMS	3		2	1	3	9
IEEE COMMUNICATIONS LETTERS			6	2	1	9
INFORMATION PROCESSING LETTERS	2	1		3	3	9
EXPERT SYSTEMS WITH APPLICATIONS	1		3	5		9
COMPUTERS & FLUIDS		4		4		8
IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS	1	1	2	3	1	8
KYBERNETES		1	2	4	1	8
ACM TRANSACTIONS ON MATHEMATICAL SOFTWARE		3	1	1	3	8
ALGORITHMICA	1		2	4	1	8
IEICE TRANSACTIONS ON FUNDAMENTALS OF ELECTRONICS COMMUNICATIONS AND COMPUTER SCIENCES	4	2	1		1	8
PATTERN RECOGNITION	2	2	1	2	1	8
MATHEMATICS AND COMPUTERS IN SIMULATION		1		6	1	8
JOURNAL OF INFORMATION TECHNOLOGY	2		1	2	3	8
GROUP COORDINATION AND COOPERATIVE CONTROL	8					8
EMPIRICAL SOFTWARE ENGINEERING	1	3		1	2	7
IEEE COMMUNICATIONS MAGAZINE	2	1	3	1		7
IEEE SOFTWARE	2	1	2	2		7
COMPUTER COMMUNICATIONS	1	2	2	1	1	7
MATHEMATICAL & COMPUTER MODEL OF DYNAMICAL SYST		1		3	3	7
WIRELESS COMMUNICATIONS & MOBILE COMPUTING			3	2	2	7
TELECOMMUNICATION SYSTEMS		1	2	1	3	7
FOUNDATIONS OF COMPUTATIONAL MATHEMATICS			4		3	7

*) Includes the following publication types: articles, review papers and proceedings papers.

Conference proceedings are important as publication channels in Computer science. Some important conference proceedings relevant for Norwegian ICT-researchers are shown in Table 3.3. As can be seen there is a large number of articles published in *Lecture Notes in Computer Science,* and altogether almost 700 articles have been published by Norwegian researchers during the time period 2006-2010 in this series.

Table 3.3 Number of publications* in conference proceedings series (most frequent), for the period 2006–2010, from Norway, Computer science.**

	2006	2007	2008	2009	2010	Total
Lecture Notes in Computer Science	157	156	121	137	126	697
Lecture Notes in Artificial Intelligence	14	12	19	11	12	68
International Federation for Information Processing	20	8	20	7		55
Lecture Notes in Business Information Processing,			5	10	18	33
IEEE International Conference on Communications (ICC)	7	5	5	4	11	32
Global Telecommunication Conference	5	3	10	9	4	31
Communications in Computer and Information Science		1	7	4	13	25
Computer Aided Chemical Engineering	10	3		4	2	19

*) Includes the following publication types: articles, review papers and proceedings papers.

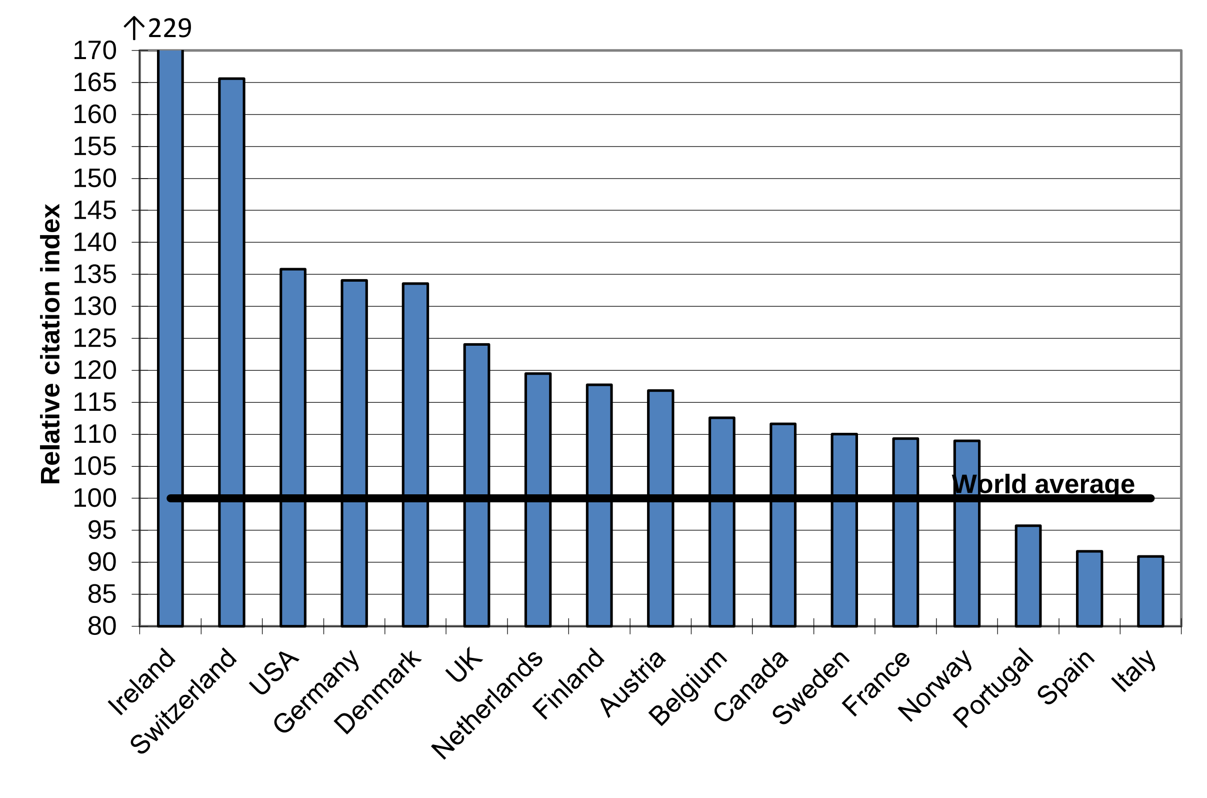
**) Only proceedings that are part of series are shown in the table. Conference proceedings series covering several disciplines are not shown in the table.

3.2 Citation indicators

The extent to which the articles have been referred to or cited in the subsequent scientific literature is often used as an indicator of scientific impact and international visibility. In absolute numbers the countries with the largest number of articles also receive the highest numbers of citations. It is however common to use a size-independent measure to assess whether a country's articles have been highly or poorly cited. One such indicator is the relative citation index showing whether a country's scientific publications have been cited above or below the world average (=100).

Figure 3.5 shows the relative citation index in Computer science for a selection of countries, based on the citations to the publications from the three year period 2006–2008. The publications from Ireland and Switzerland are most highly cited. Ireland has a citation index of 228, far above the world average. This is due to an outlier value in 2007 (probably caused by one or a few extremely highly cited papers), and is not typical for the citation rates of the country the recent years. Norway ranks as number 14 among the 17 countries shown in this figure, with a citation index of 109. In other words, the performance of Norwegian Computer science in terms of citations is somewhat below that of the leading countries. Still, the Norwegian citation index is above world average, although this average does not constitute a very ambitious reference standard as it includes publications from countries with less developed science systems (for example China, which is the second largest producer of publications in the world with a citation index of 90 in Computer science). The Norwegian index in Computer science is also lower than the Norwegian total (all disciplines) for this period, which is approximately 125.

Figure 3.5 Relative citation index in Computer science for selected countries (2006–2008).*

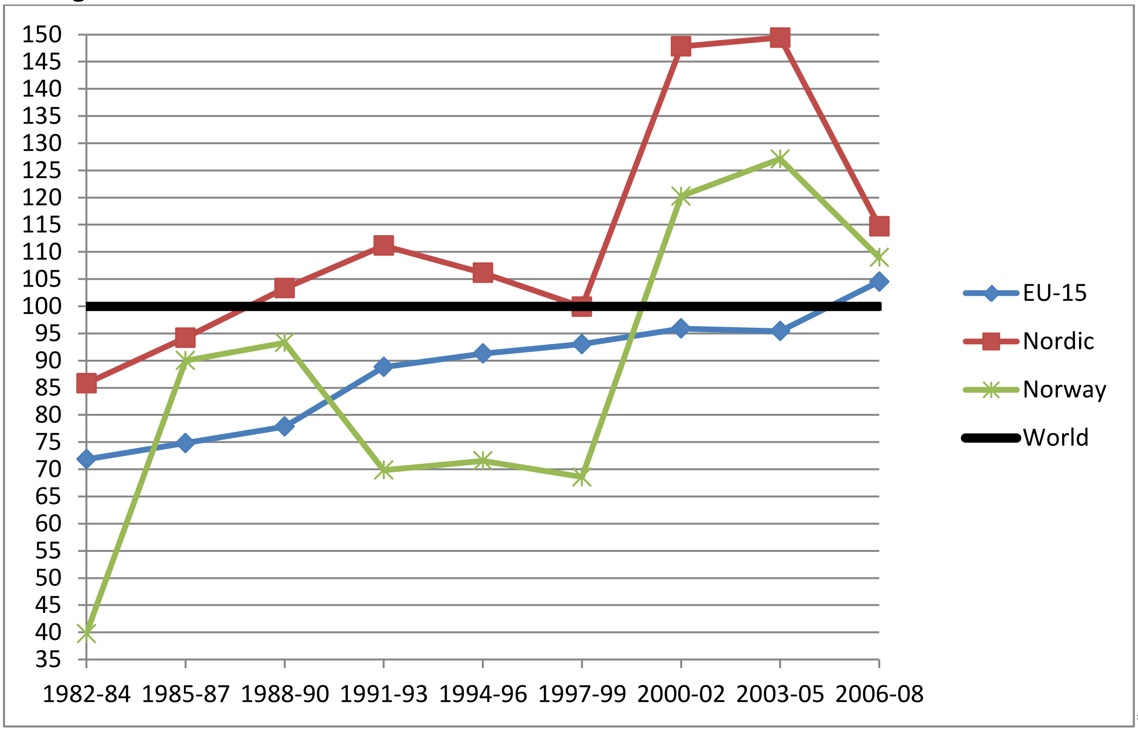


*) Based on the publications from the period 2006-2008 and accumulated citations to these publications through 2010.

We have also analysed how the citation rate of the Norwegian publications within Computer science has developed over the period 1982–2008. The results are shown in Figure 3.6 (using three-year periods). Also the respective averages for the Nordic countries, the EU-15 and the world (=100) have been included in this figure. As can be seen, there are significant variations in the Norwegian citation index. [5] However, there is a strong positive trend. While the Norwegian articles published during the 80ies and 90ies were cited below and often significantly below the world average, the citation rate has been much higher during the 00ies.

[5] It is a general phenomenon that annual citation indicators, particularly at subfield levels, may show large annual fluctuations. In particular, this may be due to variations in the importance of highly cited papers.

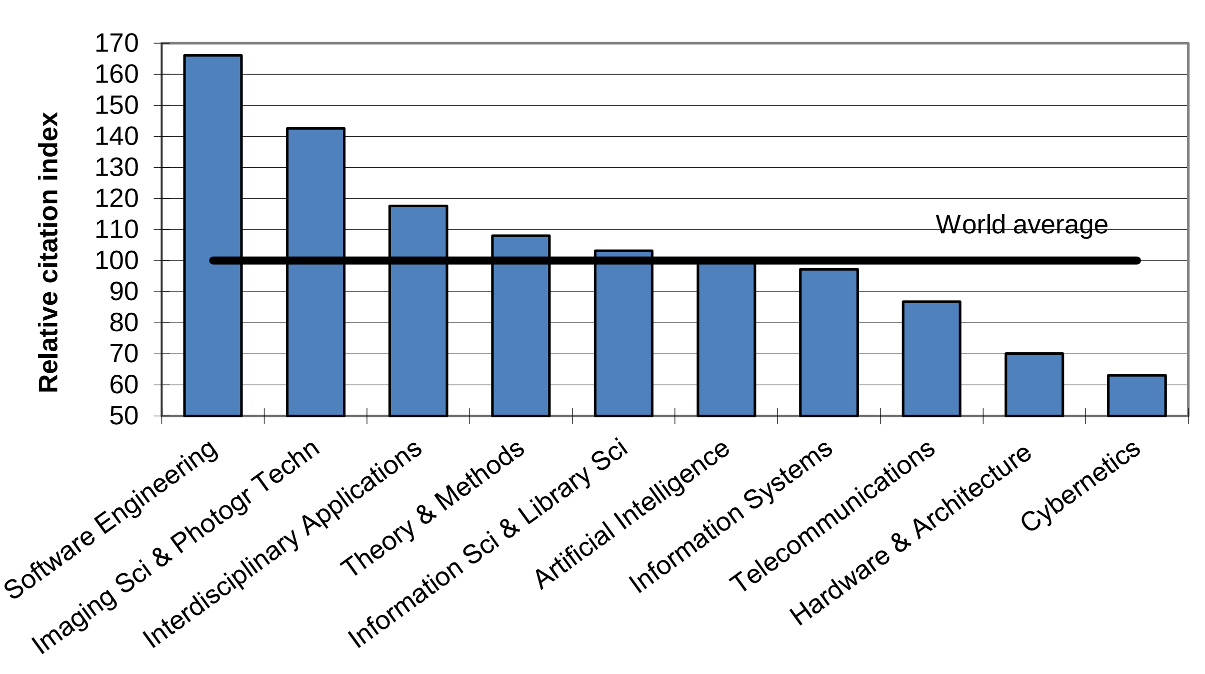
Figure 3.6 Relative citation index* in Computer science for Norway compared with the average for the Nordic countries, the EU-15 countries and the world for the period 1982–2008, 3-years averages.



*) Based on annual publication windows and accumulated citations to these publications.

The overall citation index for Computer science does, however, disguise important differences at subfield levels. This can be seen in figure 3.7 where a citation index has been calculated for each of the subfields within Computer science for the 2006–2008 publications. Norway performs very well in two subfields, Software Engineering and Imaging Science & Photographic Technology, with citation indexes of 166 and 143, respectively. Lowest citation rate is found for Hardware & Architecture (70) and Cybernetics (63). Thus, in these fields the citation indexes is far below the world-average.

Figure 3.7 Relative citation index in Computer science subfields (2006–2008).*



*) Based on the publications from the period 2006–2008 and accumulated citations to these publications through 2010.

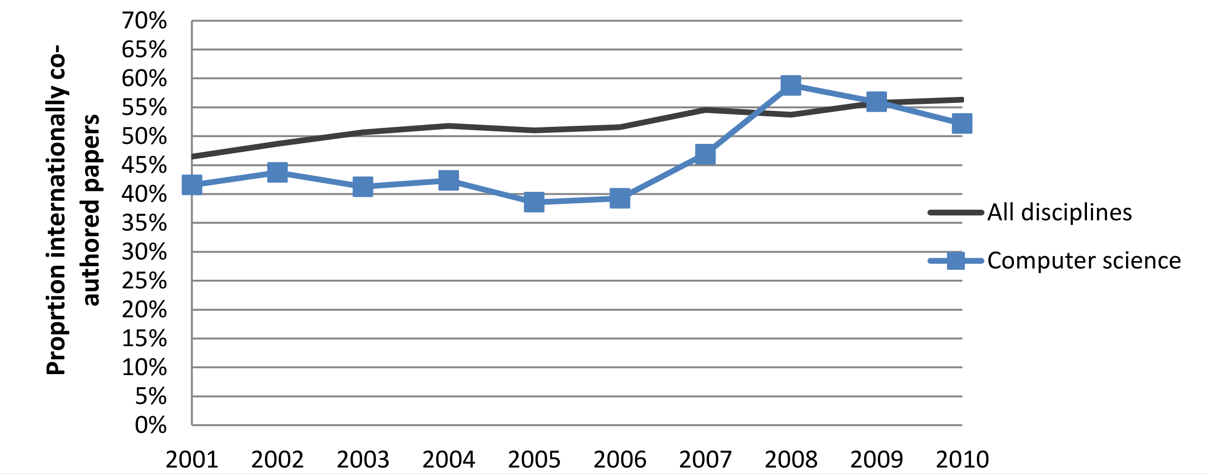
3.3 Collaboration indicators

This chapter explores the Norwegian publications involving international collaboration (publications having both Norwegian and foreign author addresses). Increasing collaboration in publications is an international phenomenon and is one of the most important changes in publication behaviour among scientists during the last decades.

In Figure 3.8 we have shown the development in the extent of international co-authorship for Norway in Computer science (including Information Science & Library Science) and for all disciplines (national total). In Computer science, 52 % of the articles had co-authors from other countries in 2010. In other words, one out of two publications was internationally co-authored. This is close to the national average (56 %).

The proportion of international collaboration in Computer science has increased from 42 % to 52 % during the 10 year period (with a peak of 59 % in 200). The national total has increased during the period from 46 % in 2001 to 56 % in 2010.

Figure 3.8 The proportion of international co-authorship, 2001–2010, Norway.



Which countries are the most important collaboration partners for Norway in Computer science? In order to answer this question we analysed the distribution of co-authorship. Table 3.4 shows the frequencies of co-authorship for the countries that comprise Norway's main collaboration partners from 2001 to 2010.

The USA is the most important collaboration partner. And 10 % of the "Norwegian" articles within Computer science also had co-authors from this nation. Next follow France and UK – 6 % of the "Norwegian" articles were co-authored with French and British scientists.

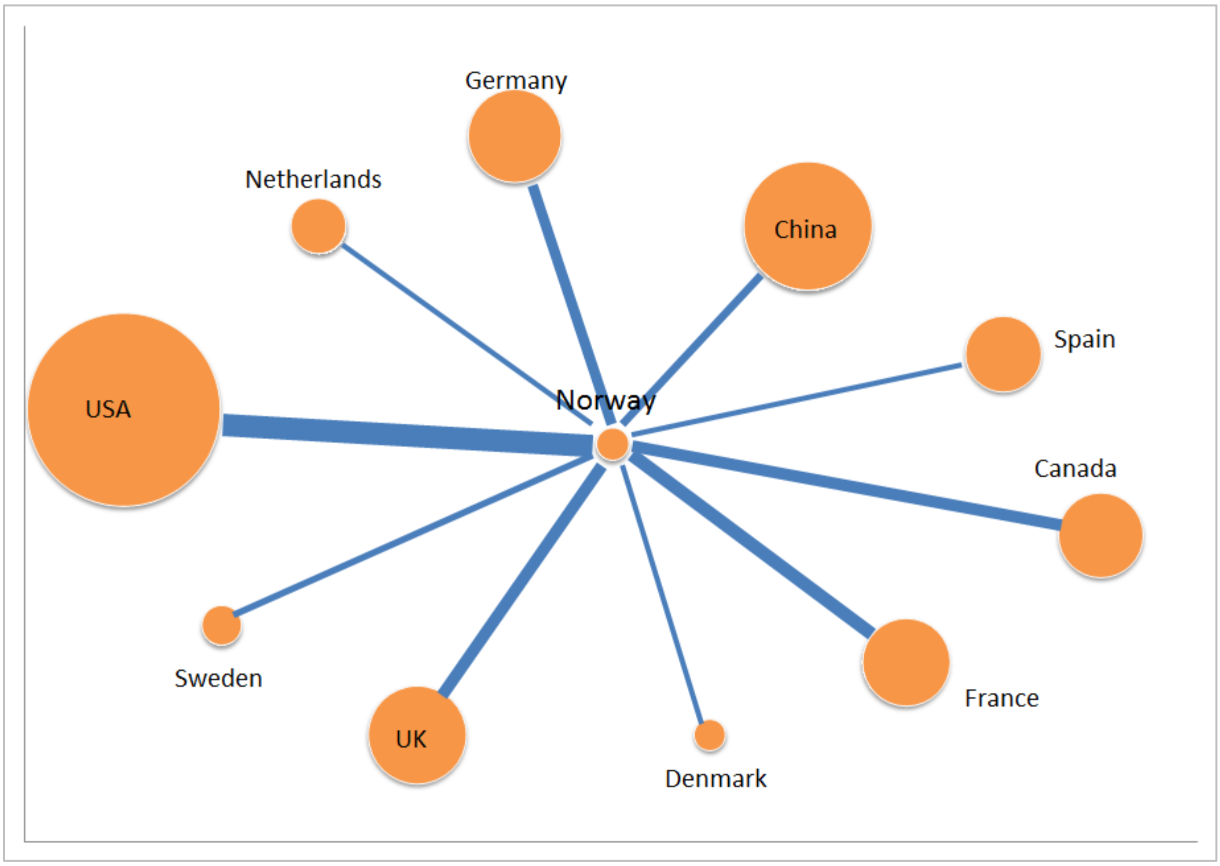
Table 3.4 Collaboration by country* 2006–2010. Number and proportion of the Norwegian article production in Computer science with co-authors from the respective countries.

Country	Num. articles	Proportion	Country	Num. articles	Proportion
USA	173	10 %	Australia	29	2 %
France	103	6 %	Austria	28	2 %
UK	98	6 %	Taiwan	23	1 %
Canada	92	5 %	Finland	22	1 %
Germany	82	5 %	Greece	19	1 %
China	62	4 %	Switzerland	19	1 %
Sweden	51	3 %	Belgium	19	1 %
Netherlands	46	3 %	Japan	18	1 %
Denmark	45	3 %	South Korea	18	1 %
Spain	43	3 %	Singapore	16	1 %
Italy	42	2 %	Romania	13	1 %
India	31	2 %			

*) Only countries with more than 10 collaborative articles are shown in the table.

In Figure 3.9 we have illustrated the international collaboration profile of Norwegian Computer science graphically for the 11 most important collaborative partners.

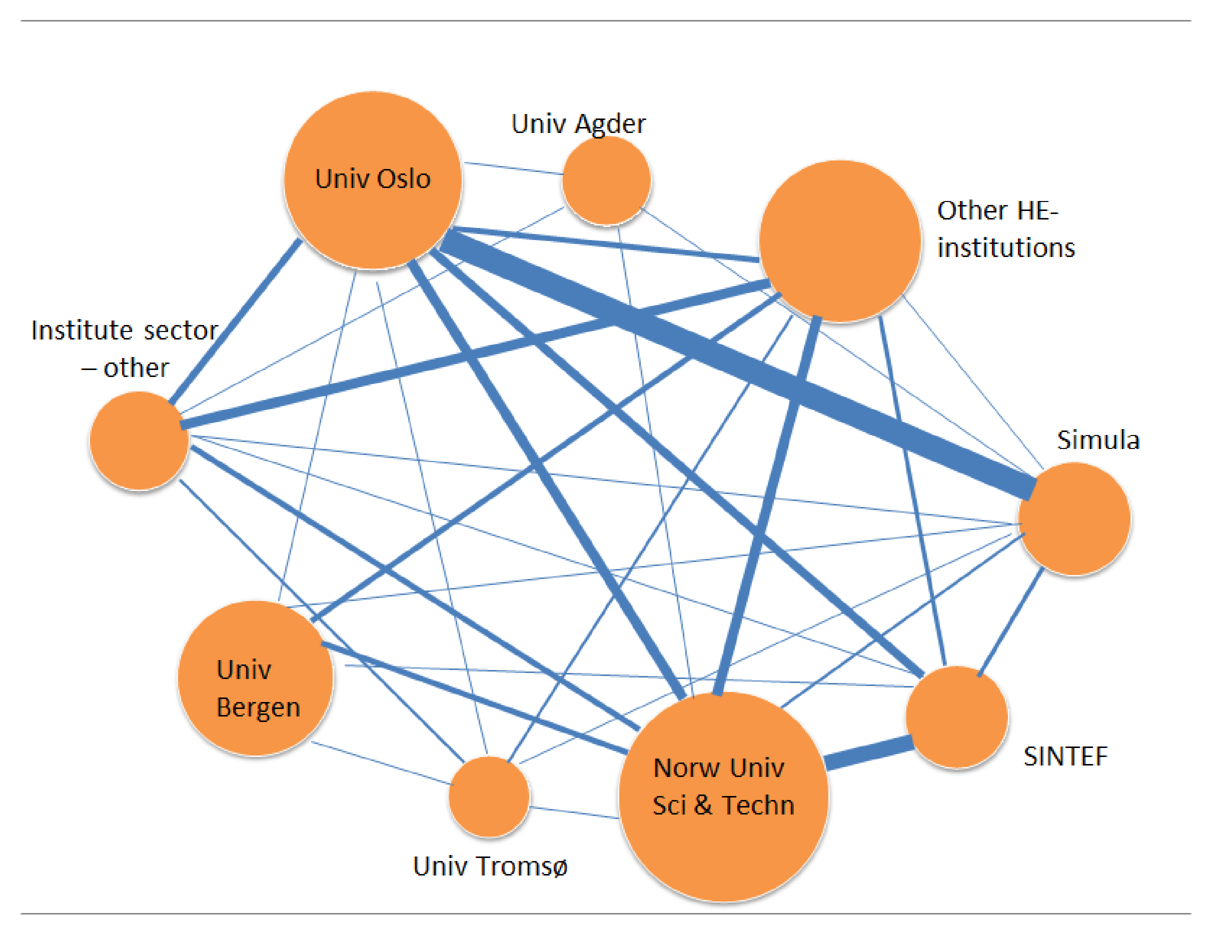
Figure 3.9 Graphical illustration of the international collaboration profile* of Norwegian Computer science (2001-2010).



*) Only the 11 most important collaborative countries are shown in the figure. The surface area of the circles is proportional to the total publication output in Computer science of the countries, while the breadth of the lines is proportional to the number of collaborative articles with Norway.

In similar way we have analysed the national collaboration based on co-authorship, and the results (based on the 2006-2010 publications) for the largest institutions/institutes are illustrated in Figure 3.10. In the figure, the surface area of the circles is proportional to the total publication output in Computer science, while the breadth of the lines is proportional to the number of collaborative articles. As can be seen, there are strong collaborative links between the University of Oslo (UiO) and Simula and between the Norwegian University of Science and Technology (NTNU) and SINTEF. Of the universities, UiO has significantly more external national collaboration in relative terms than the universities in Bergen and Agder, while NTNU and the University of Tromsø have intermediate positions. The research profile of the units in the institute sector, including SINTEF and Simula, is characterised by extensive external national collaboration.

Figure 3.10 Graphical illustration of the national collaboration profile* of Norwegian Computer Science (2006-2010).



*) Only the largest institutions/institutes in terms of publication output are shown in the figure. The surface area of the circles is proportional to the total publication output in Computer science, while the breadth of the lines is proportional to the number of collaborative articles.

4 Institutional analyses

4.1 Norwegian University of Science and Technology (NTNU)

There are four departments at the Norwegian University of Science and Technology (NTNU) included in the evaluation:

- Department of Computer and Information Science
- Department of Electronics and Telecommunications
- Department of Engineering Cybernetics
- Department of Telematics

Table 4.1.1 shows various publication indicators for the departments and their research groups for the period 2006-2010. The Department of Computer and Information Science is the largest both in terms of persons included in the evaluation and total publication output. The productivity measured as number of publications per man year (full time equivalent (FTE)) is highest at the Department of Engineering Cybernetics with 5.5 publications. For the other departments the productivity varies from 3.0 to 3.5 which is above the average for all units covered by this evaluation (2.9). At group levels, however, we find large variations (1.5-7.6).

Table 4.1.1 Number of publications, 2006–2010, NTNU.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
TOTAL - Department of Computer and Information Science	49	200	600	157	3.0
Algorithms, HPC and Graphics (AHG)	4	19	42	23	2.2
Computer Architecture and Design (CARD)	4	15	39	4	2.6
Data and Information Management (DIF)	11	49	116	14	2.4
Information Systems (IS)	10	39	180	53	4.7
Intelligent Systems (AI)	9	41	82	30	2.0
Software Engineering (SE)	9	35	148	34	4.2
TOTAL - Department of electronics and telecommunications	37	154	465	203	3.0
AK	5	13	34	18	2.7
EO	4	15	41	25	2.7
KS	7	35	75	27	2.1
KT	6	23	65	56	2.8
RA	5	22	34	17	1.5
SI	10	46	221	58	4.8
Total - Department of Engineering Cybernetics	19	68	378	144	5.5
Control Systems (CS)	13	47	353	127	7.6
Industrial Computer and Instrumentation Systems (ICIS)	6	22	40	22	1.9
Total - Department of Telematics	19	75	260	55	3.5
Information Security (IS)	3	13	58	17	4.5
Networked Systems (NS)	8	31	67	6	2.2
Networks (NET)	8	32	151	36	4.8

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.1.2a and b give the most frequently used journals – limited to journals with at least three publications during the period 2006–2010 for the departments and the research groups. Therefore, for some of the groups, there are no journals on this list.

Table 4.1.2a The most frequently used journals*, number of publications 2006–2010 by department. NTNU.

Department	Journal	Numb. of articles
Department of Computer and Information Science	INFORMATION AND SOFTWARE TECHNOLOGY	7
	STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS	7
	IFIP ADVANCES IN INFORMATION & COMMUNICATION TECHNOLOGY	5
	ADVANCES IN PARALLEL COMPUTING	4
	BMC BIOINFORMATICS	4
	SOFTWARE PROCESS IMPROVEMENT AND PRACTICE	4
	EMPIRICAL SOFTWARE ENGINEERING	3
	KNOWLEDGE ENGINEERING REVIEW	3
	NUCLEIC ACIDS RESEARCH	3
Department of electronics and telecommunications	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	15
	APPLIED PHYSICS LETTERS	8
	IEEE TRANSACTIONS ON COMMUNICATIONS	7
	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	7
	JOURNAL OF APPLIED PHYSICS	7
	EURASIP JOURNAL ON WIRELESS COMMUNICATIONS & NETWORKING	6
	IEEE COMMUNICATIONS LETTERS	5
	IEEE TRANSACTIONS ON INFORMATION THEORY	5
	MODERN PHYSICS LETTERS B	5
	NANOTECHNOLOGY	5
	ACTA ACUSTICA UNITED WITH ACUSTICA	4
	JOURNAL OF CRYSTAL GROWTH	4
	JOURNAL OF VACUUM SCIENCE & TECHNOLOGY B	4
	NANO LETTERS	4
	OPTICS EXPRESS	4
	PHYSICA SCRIPTA	4
	IEEE TRANSACTIONS ON AUDIO, SPEECH & LANGUAGE PROCESSING	3
	IEEE TRANSACTIONS ON ELECTRON DEVICES	3
	JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA	3
Department of Engineering Cybernetics	MODELING IDENTIFICATION AND CONTROL	26
	AUTOMATICA	16
	IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY	8
	GROUP COORDINATION AND COOPERATIVE CONTROL	6
	CONTROL ENGINEERING PRACTICE	5
	IEEE TRANSACTIONS ON ROBOTICS	5
	IEEE TRANSACTIONS ON AUTOMATIC CONTROL	4
	INTERNATIONAL JOURNAL OF CONTROL	4
	JOURNAL OF PROCESS CONTROL	4
	SPE PRODUCTION & OPERATIONS	3
Department of Telematics	COMPUTER NETWORKS	7
	INTERNATIONAL JOURNAL OF COMPUTER SCI & NETWORK SECURITY	5
	COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE	3

*) Limited to journals with at least three publications during the time period.

Table 4.1.2b The most frequently used journals, number of publications 2006–2010 by groups* NTNU.

Department	Group	Journal	Numb. of articles
Department of Computer and Information Science	Algorithms, HPC and Graphics (AHG)	ADVANCES IN PARALLEL COMPUTING	4
		BMC BIOINFORMATICS	3
		NUCLEIC ACIDS RESEARCH	3
	Information Systems (IS)	STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS	7
		INFORMATION AND SOFTWARE TECHNOLOGY	3
	Intelligent Systems (AI)	KNOWLEDGE ENGINEERING REVIEW	3
	Software Engineering (SE)	INFORMATION AND SOFTWARE TECHNOLOGY	4
		SOFTWARE PROCESS IMPROVEMENT AND PRACTICE	4
		EMPIRICAL SOFTWARE ENGINEERING	3
Department of electronics and telecommunications	AK	ACTA ACUSTICA UNITED WITH ACUSTICA	4
		JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA	3
	EO	OPTICS EXPRESS	4
	KS	IEEE TRANSACTIONS ON ELECTRON DEVICES	3
	KT	APPLIED PHYSICS LETTERS	8
		JOURNAL OF APPLIED PHYSICS	7
		JOURNAL OF VACUUM SCIENCE & TECHNOLOGY B	4
		NANO LETTERS	4
		NANOTECHNOLOGY	4
		JOURNAL OF CRYSTAL GROWTH	3
	RA	MODERN PHYSICS LETTERS B	5
	SI	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	13
		IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	7
		EURASIP JOURNAL ON WIRELESS COMMUNICATIONS AND NETWORKING	5
		IEEE COMMUNICATIONS LETTERS	5
		IEEE TRANSACTIONS ON COMMUNICATIONS	5
		IEEE TRANSACTIONS ON INFORMATION THEORY	5
Department of Engineering Cybernetics	Control Systems (CS)	MODELING IDENTIFICATION AND CONTROL	26
		AUTOMATICA	16
		IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOL	8
		GROUP COORDINATION AND COOPERATIVE CONTROL	6
		IEEE TRANSACTIONS ON ROBOTICS	5
		CONTROL ENGINEERING PRACTICE	4
		IEEE TRANSACTIONS ON AUTOMATIC CONTROL	4
		INTERNATIONAL JOURNAL OF CONTROL	4
		JOURNAL OF PROCESS CONTROL	4
		SPE PRODUCTION & OPERATIONS	3
Department of Telematics	Information Security (IS)	INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND NETWORK SECURITY	5
		COMMUNICATIONS IN COMPUTER & INFORMATION SCI	3
	Networks (NET)	COMPUTER NETWORKS	6

*) Limited to journals with at least three publications during the time period.

Table 4.1.3 contains a citation and journal profile of the departments and groups based on the journal articles index in the NCR-database and published in the period 2006–2009. However, due to the small number of articles we have not calculated relative citation indexes for some of the groups (cf. Method section). The Department of Computer and Information Science obtains the highest citation rates with a field normalized citation rate of 139. In other words, the articles are cited 39 % above the world average, moreover 22 % above the corresponding Norwegian average. It should be noted, however, that one article with a very high citation count influences strongly on these index values. Then follows Department of Electronics and Telecommunications with citation rates close to the field normalised world and Norwegian averages. The two other departments perform less well in terms of citation rates. Particularly, this holds for the Department of Telematics with a field normalized citation index of only 45.

At group level, the Algorithms, HPC and Graphics (AHG) group obtains very high citation indexes, an important reason being the highly cited article described above. This group also publishes in journals that are relatively highly cited (i.e. have high impact factor), which is reflected by a journal profile of approximately 160. Several groups do not perform very well in terms of citation rates, for example, the Data and Information Management (DIF) group, the Software Engineering (SE) group and the Radio Systems (RA) group with field normalised citation indexed in the range of 40-60. These groups also tend to publish in journals with low impact factors.

Table 4.1.3 Citation and journal indicators, 2006–2009 publications indexed in NCR*. NTNU.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
Dep of Computer and Information Science - TOTAL	92	413 (10)	71	139	135	122	128	102
Algorithms, HPC and Graphics (AHG)	13	265 (20)	71	251	156	237	224	160
Computer Architecture and Design (CARD)	4	0	0	-	-	-	-	-
Data and Information Management (DIF)	12	10 (1)	2	40	56	37	38	71
Information Systems (IS)	22	36 (3)	10	86	108	70	82	80
Intelligent Systems (AI)	25	84 (5)	20	92	129	78	85	72
Software Engineering (SE)	18	18 (2)	6	58	104	47	55	56
Dep of electronics and telecommunications - TOTAL	134	468 (5)	28	109	113	102	95	96
AK	9	18 (2)	6	-	-	-	-	-
EO	17	132 (8)	28	154	123	137	134	126
KS	21	42 (5)	21	77	108	71	67	71
KT	31	155 (6)	25	119	110	112	99	109
RA	11	19 (1)	5	53	102	52	48	51
SI	43	88 (3)	16	102	104	105	94	98
Dep of Engineering Cybernetics - TOTAL	106	243 (5)	38	80	98	83	73	82
Control Systems (CS)	97	220 (5)	38	83	102	89	76	81
Industrial Computer and Instrumentation Systems (ICIS)	13	35 (4)	11	68	91	57	60	75
Department of Telematics - TOTAL	30	33 (2)	9	45	61	45	47	74
Information Security (IS)	2	2	2	-	-	-	-	-
Networked Systems (NS)	7	1	1	-	-	-	-	-
Networks (NET)	22	30 (2)	9	52	62	52	54	83

*) Based on the publications indexed in NCR from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.1.3. However, Table 4.1.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited. In correspondence with the results of Table 4.1.3, the Department of Computer and Information Science also obtains the highest citation rates of proceedings papers. The Department of Electronics and Telecommunications, on the other hand, has the lowest average number of citations per proceedings paper of the four departments.

Table 4.1.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. NTNU.

Unit	Number of articles	Number of citations	Number of citations per article
Dep. of Computer and Information Science - TOTAL	185	125	0.7
Algorithms, HPC and Graphics (AHG)	9	1	0.1
Computer Architecture and Design (CARD)	17	11	0.6
Data and Information Management (DIF)	34	9	0.3
Information Systems (IS)	58	40	0.7
Intelligent Systems (AI)	23	20	0.9
Software Engineering (SE)	47	38	0.8
Dep. of electronics and telecommunications - TOTAL	166	33	0.2
AK	8	0	0.0
EO	14	9	0.6
KS	33	9	0.3
KT	4	1	0.3
RA	10	5	0.5
SI	102	9	0.1
Department of Engineering Cybernetics - TOTAL	68	39	0.6
Control Systems (CS)	62	38	0.6
Industrial Computer and Instrumentation Systems (ICIS)	11	1	0.1
Department of Telematics - TOTAL	93	35	0.4
Information Security (IS)	18	8	0.4
Networked Systems (NS)	35	24	0.7
Networks (NET)	49	9	0.2

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all articles indexed in NCR and proceedings articles indexed in Web of Science Conference Proceedings Citation Index where the departments are listed as an author address are included. This analysis covers the period 2001-2009. Based on this analysis we have calculated citation indicators for two periods: 2001-2005 and 2006-2009. The results are given in the table below.

Table 4.1.5 Citation and journal indicators, 2001–2009 publications. NTNU.

Department	Publication type/ period	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
Department of Computer and Information Science	Journ art 2001-05*	160	1197	311	114	111	105	103
	Journ art 2006-09**	125	445	71	112	112	100	100
	Proc art 2001-05*	106	83	15				
	Proc art 2006-09**	213	121	6				
Department of electronics and telecommunica-tions	Journ art 2001-05*	103	1102	188	104	96	83	108
	Journ art 2006-09**	171	542	28	94	92	88	102
	Proc art 2001-05*	82	58	9				
	Proc art 2006-09**	190	38	4				
Department of Engineering Cybernetics	Journ art 2001-05*	87	691	59	105	109	92	97
	Journ art 2006-09**	123	288	38	82	91	83	90
	Proc art 2001-05*	59	128	42				
	Proc art 2006-09**	81	39	11				
Department of Telematics	Journ art 2001-05*	36	61	10	42	51	39	83
	Journ art 2006-09**	33	31	9	43	56	43	77
	Proc art 2001-05*	37	17	7				
	Proc art 2006-09**	97	41	7				

The indicators for journal articles are based on articles indexed in NCR, while the figures for proceedings papers are based on proceedings papers indexed in Web of Science Conference Proceedings Citation Index.
*) Based on the publications from the period 2001–2005 and the accumulated citations to these publications through 2010.
**) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.2 University of Agder (UiA)

At the University of Agder there are research groups at two departments included in the evaluation: Department of ICT and Department of Information System. Table 4.2.1 shows various publication indicators for the departments and their research groups.
The Department of ICT has a very high productivity: 4.8 publications per full time equivalent (FTE), significantly above the average for all units covered by this evaluation (2.9). One group at the department contributes significantly to this high productivity: Mobile Communication Systems Group (MC). The productivity at the Department of Information System is lower: 1.8. This department has recently (2009) obtained a new PhD-programme and it takes time before the results of this programme appear as publications.

Table 4.2.1 Number of publications, 2006–2010, UiA.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
Department of ICT	11	49	237	44	4.8
Mobile Communication Systems Group (MC)	2	8	120	25	14.3
Multimedia group (MM)	2	10	15		1.5
System Development and Security Group (SYS)	7	31	109	19	3.5
Department of Information Systems	10	45	83	33	1.8
Centre for Enterprise Systems (CENS)	4	19	38	15	2.0
Centre on e-Government (e-Gov)	4	19	40	18	2.1
Information Systems Development (ISD)	2	7	16	6	2.3

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.2.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006–2010. Therefore, for some of the groups there are no journals on this list.

Table 4.2.2 The most frequently used journals*, number of publications 2006–2010 by unit, UiA.

Unit	Journal	Numb. of articles
Department of ICT -TOTAL	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	5
	WIRELESS PERSONAL COMMUNICATIONS	4
	WIRELESS COMMUNICATIONS & MOBILE COMPUTING	3
Mobile Communication Systems Group (MC)	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	5
	WIRELESS PERSONAL COMMUNICATIONS	4
	WIRELESS COMMUNICATIONS & MOBILE COMPUTING	3
Department of Information Systems - TOTAL	SCANDINAVIAN JOURNAL OF INFORMATION SYSTEMS	4
Centre on e-Government (e-Gov)	SCANDINAVIAN JOURNAL OF INFORMATION SYSTEMS	3

*) Limited to journals with at least three publications during the time period.

Table 4.2.3 contains a citation and journal profile of the departments and groups based on the journal articles (indexed in NCR) published in the period 2006–2009. However, for several groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). Both departments have a rather poor performance measured in terms of citations. Their publications are little cited compared to corresponding world and Norwegian averages.

Table 4.2.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. UiA.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
Department of ICT - TOTAL	24	37 (2)	6	69	82	72	66	84
Mobile Communication Systems Group (MC)	15	25 (2)	6	72	98	79	71	74
Multimedia group (MM)	2	0	0	-	-	-	-	-
System Development and Security Group (SYS)	7	12	4	-	-	-	-	-
Department of Information Systems - TOTAL	11	21 (2)	5	65	67	67	63	96
Centre for Enterprise Systems (CENS)	7	13	5	-	-	-	-	-
Centre on e-Government (e-Gov)	2	4	4	-	-	-	-	-
Information Systems Development (ISD)	2	4	2	-	-	-	-	-

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.2.3. However, Table 4.2.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited, and this also holds for the departments at University of Agder.

Table 4.2.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. UiA.

Unit	Number of articles	Number of citations	Number of citations per article
Department of ICT - TOTAL	71	13	0.2
Mobile Communication Systems Group (MC)	43	5	0.1
Multimedia group (MM)	3	0	0.0
System Development and Security Group (SYS)	26	8	0.3
Department of Information Systems - TOTAL	14	7	0.5
Centre for Enterprise Systems (CENS)	3	1	0.3
Centre on e-Government (e-Gov)	8	5	0.6
Information Systems Development (ISD)	3	1	0.3

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

4.3 University of Bergen (UiB)

At the University of Bergen, two departments are included in the evaluation: Department of Informatics and Department of Information Science and Media Studies.
Table 4.3.1 shows various publication indicators for the departments and their research groups. The scientific productivity at the Department of Informatics is high. In total almost 500 publications, of which 221 were in journals, have been published during the period 2006-2010. The overall productivity is 3.7 publications per full time equivalent (FTE), which is above the average for all units covered by this evaluation (2.9). With one exception, all groups at the department have productivity-levels above the national average. The productivity is particularly high for the Algorithms research group (ALG) and the Visualization (VIS) group. The productivity at the Department of Information Science and Media Studies is significantly lower with 1.9 publications per full time equivalent (FTE).

Table 4.3.1 Number of publications, 2006–2010, UiB.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
TOTAL - Department of Informatics	36	134	499	221	3.7
ALG	8	30	202	80	6.7
OPT	3	10	32	17	3.1
PUT	7	28	56	22	2.0
SEL	14	52	170	80	3.3
VIS	3	9	49	24	5.4
TOTAL - Department of Information Science and Media Studies	11	41	79	22	1.9
Interaction	3	9	5	2	0.6
LII	3	12	22	10	1.8
SSIS	5	20	52	10	2.7

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.3.1 a and b give the most frequently used journals for the departments and their groups – limited to journals with at least three publications during the period 2006-2010. Therefore, for two of the groups at the Department of Information Science and Media Studies there are no journals listed.

Table 4.3.2a The most frequently used journals*, number of publications 2006–2010 by department. UiB.

Department	Journal	Numb. of articles
Department of Informatics	IEEE TRANSACTIONS ON INFORMATION THEORY	37
	DISCRETE APPLIED MATHEMATICS	20
	IEEE TRANSACTIONS ON VISUALIZATION & COMPUTER GRAPHICS	11
	THEORETICAL COMPUTER SCIENCE	9
	ALGORITHMICA	8
	DESIGNS CODES AND CRYPTOGRAPHY	8
	DISCRETE MATHEMATICS	8
	INFORMATION PROCESSING LETTERS	6
	SIAM JOURNAL ON COMPUTING	6
	ALGORITHMS	5
	COMPUTER GRAPHICS FORUM	5
	IEEE SECURITY & PRIVACY	5
	FINITE FIELDS AND THEIR APPLICATIONS	4
	JOURNAL OF COMBINATORIAL THEORY SERIES A	3
	JOURNAL OF GRAPH THEORY	3
	OPTIMIZATION METHODS & SOFTWARE	3
	SIAM JOURNAL ON DISCRETE MATHEMATICS	3
Department of Information Science and Media Studies	LOGIC JOURNAL OF THE IGPL	3

Table 4.3.2b The most frequently used journals*, number of publications 2006–2010 by group, UiB.

Department	Group	Journal	Numb. of articles
Department of Informatics	ALG	DISCRETE APPLIED MATHEMATICS	15
		ALGORITHMICA	8
		THEORETICAL COMPUTER SCIENCE	8
		ALGORITHMS	5
		DISCRETE MATHEMATICS	5
		SIAM JOURNAL ON COMPUTING	5
		INFORMATION PROCESSING LETTERS	4
		JOURNAL OF GRAPH THEORY	3
	OPT	OPTIMIZATION METHODS & SOFTWARE	3
	PUT	DISCRETE APPLIED MATHEMATICS	6
	SEL	IEEE TRANSACTIONS ON INFORMATION THEORY	37
		DESIGNS CODES AND CRYPTOGRAPHY	8
		IEEE SECURITY & PRIVACY	5
		FINITE FIELDS AND THEIR APPLICATIONS	4
		JOURNAL OF COMBINATORIAL THEORY SERIES A	3
	VIS	IEEE TRANSACTIONS ON VISUALIZATION & COMPUTER GRAPHICS	11
		COMPUTER GRAPHICS FORUM	5
Dep of Information Science and Media Studies	LII	LOGIC JOURNAL OF THE IGPL	3

*) Limited to journals with at least three publications during the time period.

Table 4.3.3 contains a citation and journal profile of the departments and groups based on the journal articles (indexed in NCR) published in the period 2006–2009. However, for the Department of Information Science and Media Studies we have not calculated relative citation indexes at group level due to the small number of articles (cf. Method section). The Department of Informatics performs quite well in terms of citation rates, with a field normalized citation index of 129. In other words, the articles have been cited 29 % above the world average. Also compared to the citation rate of the corresponding Norwegian articles, the publications of the department are more highly cited (index 111). However, there are large differences in citation rates among the groups, as shown in the table. Particularly, the Algorithms research group (ALG) and the Visualization (VIS) group have high citation indexes. The Optimization group (OPT) and the Programming Technology group (PUT) perform less well in terms of citations. These groups also publish in journals that are relatively little cited (i.e. have low impact factor), which is reflected by a journal profile of approximately 60. The few journal articles (index in NCR) of the Department of Information Science and Media Studies are little cited.

Table 4.3.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. UiB.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
TOTAL - Department of Informatics	170	439 (4)	23	129	114	111	122	114
ALG	63	174 (4)	16	162	208	125	152	78
OPT	10	12 (1)	4	53	80	57	55	66
PUT	16	16 (2)	6	65	135	59	65	48
SEL	68	164 (4)	23	107	72	100	101	149
VIS	15	74 (5)	20	229	162	174	206	141
TOTAL - Dep of Information Science and Media Studies	11	7 (1)	2	31	61	30	31	51

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.3.3. However, Table 4.3.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited. Nevertheless, the ALG group has a high citation rate of the proceedings paper.

Table 4.3.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. UiB.

Unit	Number of articles	Number of citations	Number of citations per article
TOTAL - Department of Informatics	109	149	1.4
ALG	50	110	2.2
OPT	8	2	0.3
PUT	14	14	1.0
SEL	40	26	0.7
VIS	1	0	0.0
TOTAL - Dep of Information Science and Media Studies	21	4	0.2

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all journal articles and proceedings articles where the department is listed as an author address are included. This analysis covers the period 2001-2009. Based on this analysis we have calculated citation indicators for two periods: 2001-2005 and 2006-2009. The results are given in the table below.

Table 4.3.4 Citation and journal indicators, 2001–2009 publications. UiB.

Unit	Publication type/ period	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
Department of Informatics	Journ art 2001-05*	223	2359	483	144	97	121	147
	Journ art 2006-09**	236	830	52	108	104	96	104
	Proc art 2001-05*	38	31	8				
	Proc art 2006-09**	131	213	31				
Dep of Information Science and Media Studies	Journ art 2001-05*	20	90	25	89	115	73	78
	Journ art 2006-09**	19	11	3	35	67	34	52
	Proc art 2001-05*	8	1	1				
	Proc art 2006-09**	22	1	1				

The indicators for journal articles are based on articles indexed in NCR, while the figures for proceedings paper are based on proceedings papers indexed in Web of Science Conference Proceedings Citation Index.
*) Based on the publications from the period 2001–2005 and the accumulated citations to these publications through 2010.
**) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.4 University of Oslo (UiO)

One department at the University of Oslo is included in the evaluation: Department of Informatics. The department is the largest of the units encompassed by the evaluation both in terms of persons included and total publication output. Table 4.4.1 shows various publication indicators for the department and its research groups. In the period 2006-2010, 211journal articles have been published, in addition to 473 other scientific publications. Overall the department has a productivity of 2.6 publications per full time equivalent (FTE), which is below the average for all units covered by this evaluation (2.9). There are large variations between the groups, and three of the groups have a scientific productivity of less than 1.0 publication per FTE.

Table 4.4.1 Number of publications, 2006–2010, UiO.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
TOTAL - Department of informatics	67	263	684	211	2.6
BMI	5	21	48	45	2.3
Design	5	21	16	2	0.8
DMMS	5	20	45	6	2.3
DSB	7	25	51	25	2.0
GI	7	30	68	42	2.3
LC	4	18	17	8	0.9
LTG	4	12	10	3	0.9
NANO	6	28	139	19	5.0
ND	6	18	97	23	5.4
OMS	6	29	62	18	2.1
PMA	7	23	79	18	3.2
ROBIN	4	13	56	2	4.5

*) The dividing line between journals and book series is not always distinct. For example, “Lecture note” series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.4.2a and b give the most frequently used journals for the department and its research groups – limited to journals with at least three publications during the period 2006-2010. Therefore, for some of the groups there are no journals on this list.

Table 4.4.2a The most frequently used journals*, number of publications 2006–2010 by department. UiO.

Department	Journal	Numb. of articles
Department of informatics	INFORMATION TECHNOLOGY FOR DEVELOPMENT	11
	IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	5
	IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL	5
	INFORMATION AND SOFTWARE TECHNOLOGY	5
	JOURNAL OF LOGIC AND ALGEBRAIC PROGRAMMING	4
	IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	4
	BMC GENOMICS	3
	FUNDAMENTA INFORMATICAE	3
	IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS	3
	IEEE TRANSACTIONS ON COMPUTERS	3
	IEEE TRANSACTIONS ON NEURAL NETWORKS	3
	JOURNAL OF INFORMATION TECHNOLOGY	3
	NUCLEIC ACIDS RESEARCH	3
	PLOS ONE	3

*) Limited to journals with at least three publications during the time period.

Table 4.4.2b The most frequently used journals*, number of publications 2006–2010 by group. UiO.

Group	Journal	Numb. of articles
BMI	BMC GENOMICS	3
	NUCLEIC ACIDS RESEARCH	3
	PLOS ONE	3
DSB	IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	5
	IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL	5
GI	INFORMATION TECHNOLOGY FOR DEVELOPMENT	11
	JOURNAL OF INFORMATION TECHNOLOGY	3
NANO	IEEE TRANSACTIONS ON NEURAL NETWORKS	3
	IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS	3
OMS	INFORMATION AND SOFTWARE TECHNOLOGY	5
	IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	4
PMA	JOURNAL OF LOGIC AND ALGEBRAIC PROGRAMMING	4
	FUNDAMENTA INFORMATICAE	3

*) Limited to journals with at least three publications during the time period.

Table 4.4.3 contains a citation and journal profile of the department and its groups based on the journal articles (indexed in NCR) published in the period 2006–2009. For some of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). Overall the publications are cited almost equal to the field normalized world average (citation index 104) but lower than the corresponding Norwegian average (index 89). At group levels, there are distinct variations in the performance measured in terms of citation rates. The majority of the groups are, however, cited below the Norwegian average.

Table 4.4.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. UiO.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
TOTAL - Department of informatics	121	483 (8)	51	104	99	89	98	105
BMI	28	272 (14)	51	121	108	95	114	112
DMMS	4	6	4	-	-	-		-
DSB	19	62 (5)	17	87	92	82	77	94
GI	14	47 (3)	13	77	73	77	76	105
LC	4	2	1	-	-	-		-
LTG	1	2	2	-	-	-		-
NANO	12	21 (2)	6	73	70	74	69	104
ND	14	21 (3)	9	95	135	90	89	70
OMS	11	39 (5)	15	190	104	154	178	183
PMA	13	11 (2)	6	59	89	47	58	67

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.4.3. However, Table 4.4.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited, and this also holds for the department at the University of Oslo, although there are some variations among the groups.

Table 4.4.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. UiO.

Unit	Number of articles	Number of citations	Number of citations per article
TOTAL - Department of informatics	172	111	0.6
DMMS	12	4	0.3
DSB	14	7	0.5
GI	1	0	0.0
LC	1	0	0.0
NANO	58	13	0.2
ND	32	30	0.9
OMS	16	10	0.6
PMA	16	27	1.7
ROBIN	21	20	1.0

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all journal articles and proceedings articles where the department is listed as an author address are included. This analysis covers the period 2001-2009. Based on this analysis we have calculated citation indicators for two periods: 2001-2005 and 2006-2009. The results are given in the table below. Overall, the department performed somewhat better in terms of citation rates in the first period analysed than in the latter.

Table 4.4.5 Citation and journal indicators, 2001–2009 publications*. UiO.

Publication type/ period	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
Journ art 2001-05*	183	2036	273	120	94	102	127
Journ art 2006-09**	235	765	46	97	89	84	108
Proc art 2001-05*	128	182	131				
Proc art 2006-09**	181	111	11				

The indicators for journal articles are based on articles indexed in NCR, while the figures for proceedings paper are based on proceedings papers indexed in Web of Science Conference Proceedings Citation Index.
*) Based on the publications from the period 2001–2005 and the accumulated citations to these publications through 2010.
**) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.5 University of Stavanger (UiS)

There are two research groups at Department of Computer Science and Electrical Engineering at the University of Stavanger included in the evaluation. Table 4.5.1 shows various publication indicators for the department and its research groups. In the period 2006-2010, approximately 70 journal articles have been published by the personnel encompassed in the evaluation, in addition to more than 100 other publications. Overall the department has a productivity of 2.3 publications per full time equivalent (FTE), which is somewhat below the average for all units covered by this evaluation (2.9).

Table 4.5.1 Number of publications, 2006–2010, UiS.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
Department of Computer Science and Electrical Engineering (CSEE) - TOTAL	18	78	177	71	2.3
CSG	9	34	120	31	3.5
SP&CG	9	44	60	40	1.4

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.5.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006-2010.

Table 4.5.2 The most frequently used journals*, number of publications 2006–2010 by unit. UiS.

Unit	Journal	Numb. of articles
Department of Computer Science and Electrical Engineering (CSEE) - TOTAL	RESUSCITATION	12
	IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING	3
	ISSUES IN INFORMATION SYSTEMS	3
	SIGNAL PROCESSING	3
	COMMUNICATIONS OF THE IIMA	3
CSG	ISSUES IN INFORMATION SYSTEMS	3
SP&CG	RESUSCITATION	12
	COMMUNICATIONS OF THE IIMA	3
	SIGNAL PROCESSING	3
	IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING	3

*) Limited to journals with at least three publications during the time period.

We have also analysed the citation rate of the journal publications (indexed in NCR). The results are given in Table 4.5.3. The Signal Processing and Control (SP & CG) group has a field normalized citation index of 118, meaning that the articles are cited 18 % more than the corresponding world average. This corresponds to a citation rate slightly below the Norwegian average (citation index 88). The publications of the Research group Computer Science (CSG) are rather poorly cited.

Table 4.5.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. UiS.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
TOTAL	39	167 (5)	24	112	113	84	103	100
CSG	10	10 (1)	3	64	149	50	58	43
SP&CG	29	157 (5)	24	118	111	88	109	106

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.5.3. However, Table 4.5.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited, and this also holds for the research groups at the University of Stavanger.

Table 4.5.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. UiS.

Unit	Number of articles	Number of citations	Number of citations per article
TOTAL	51	7	0.1
CSG	41	6	0.1
SP&CG	13	1	0.1

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

4.6 University of Tromsø (UiT)

At the University of Tromsø, the evaluation encompasses the Department of Computer Science. Table 4.6.1 shows various publication indicators for the department and its research groups. The overall productivity measured in terms of publications per full-time equivalents (FTE) is 2.1, which is below the average for the units encompassed by the evaluation (2.9). The productivity rate is lowest for the High Performance Distributed Systems (HPDS) group (1.6), but is below the national average for all the research groups. The HPDS groups has two newly appointed staff members who so far have spent time on establishing a basis for their future research at the department, with a reduced number of publications as a result.

Table 4.6.1 Number of publications, 2006–2010, UiT.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
Department of Computer Science - TOTAL	14	56	120	42	2.1
HPDS	6	22	35	8	1.6
IA	2	9	25	5	2.1
MI&T	3	11	36	25	3.3
ODS	3	15	26	3	1.7

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.6.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006-2010. Therefore, for some of the groups there are no journals listed.

Table 4.6.2 The most frequently used journals*, number of publications 2006–2010 by unit. UiT.

Unit	Journal	Numb. of articles
Department of Computer Science -TOTAL	STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS	12
	JOURNAL OF TELEMEDICINE AND TELECARE	4
MI&T	STUDIES IN HEALTH TECHNOLOGY AND INFORMATICS	12
	JOURNAL OF TELEMEDICINE AND TELECARE	4

*) Limited to journals with at least three publications during the time period.

Table 4.6.3 contains a citation and journal profile of the department based on the journal articles (indexed in NCR) published in the period 2006–2009. However, for all of the groups, we have not calculated relative citation indexes due to the small number of journal articles (cf. Method section). The department has a poor performance measured in terms of citations. Its publications are little cited compared to corresponding world and Norwegian averages. The staff also tend to publish in journals that are relatively little cited (i.e. have low impact factor), which is reflected by a journal profile of approximately 60. It is important to take into consideration, however, that the department has very few of its publications in NCR-indexed journals (only 12 publication during the period 2006-2009). The analysis is accordingly based on a very limited part of the research output of the department.

Table 4.6.3 Citation and journal indicators, 2006–2009 publications indexed in NCR*. UiT.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
TOTAL	12	15 (2)	8	47	82	49	45	57
HPDS	2	0	0	-	-	-	-	-
IA	1	0	0	-	-	-	-	-
MI&T	7	14	8	-	-	-	-	-
ODS	2	1	1	-	-	-	-	-

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.6.3. However, Table 4.6.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited, and this also holds for the research groups at the University of Tromsø.

Table 4.6.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index , 2006–2009 publications*. UiT.

Unit	Number of articles	Number of citations	Number of citations per article
TOTAL	43	8	0.2
HPDS	15	5	0.3
IA	7	1	0.1
MI&T	11	3	0.3
ODS	11	0	0.0

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all journal articles and proceedings articles where the department is listed as an author address are included. This analysis covers the period 2001-2009. Based on this analysis we have calculated citation indicators for two periods: 2001-

2005 and 2006-2009. The results are given in the table below. As can be seen, the citation rates are low in both periods.

Table 4.6.4 Citation and journal indicators, 2001–2009 publications*. UiT.

Publication type/ period	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
Journ art 2001-05*	16	57	18	58	95	52	61
Journ art 2006-09**	14	27	8	69	96	67	72
Proc art 2001-05*	21	0	0				
Proc art 2006-09**	42	8	1				

The indicators for journal articles are based on articles indexed in NCR, while the figures for proceedings paper are based on proceedings papers indexed in Web of Science Conference Proceedings Citation Index.
*) Based on the publications from the period 2001–2005 and the accumulated citations to these publications through 2010.
**) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.7 Gjøvik University College (HiG)

Three research groups at the Gjøvik University College (HiG) are included in the evaluation. Table 4.7.1 provides some overall publication indicators for the groups. In the period 2006-2010, almost 30 journal articles have been published, in addition to 180 other publications. Overall the groups have a productivity of 3.3 publications per full time equivalent (FTE), which is slightly higher than the average for all units covered by this evaluation (2.9). The productivity is particularly high at the Norwegian Color Lab.

Table 4.7.1 Number of publications, 2006–2010, HiG.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
HiG - TOTAL	16	63	208	29	3.3
Norwegian Color Lab	3	15	75	16	5.0
Norwegian Information Security Lab (NISlab)	11	42	132	14	3.2
Norwegian Media Technology Lab (MTL)	2	7	3		0.5

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.7.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006-2010. Therefore, for two of the groups there are no journals listed.

Table 4.7.2 The most frequently used journals*, number of publications 2006–2010 by unit. HiG.

Department	Journal	Numb. of articles
HiG -TOTAL	JOURNAL OF IMAGING SCIENCE AND TECHNOLOGY	4
	COLOR RESEARCH AND APPLICATION	4
Norwegian Color Lab	JOURNAL OF IMAGING SCIENCE AND TECHNOLOGY	4
	COLOR RESEARCH AND APPLICATION	4

*) Limited to journals with at least three publications during the time period.

Table 4.7.3 contains a citation and journal profile of the department and groups based on the journal articles (indexed in NCR) published in the period 2006–2009. The department has a rather poor performance measured in terms of citations. Their publications are little cited compared to corresponding world and Norwegian averages. The staff also tend to publish in journals that are relatively little cited (i.e. have low impact factor), which is reflected by a journal profile of 66.

Table 4.7.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. HiG.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
HiG - TOTAL	14	23 (2)	5	53	80	41	46	66
Norwegian Color Lab	11	19 (2)	5	50	84	37	43	59
Norwegian Information Security Lab (NISlab)	5	4	2	-	-	-		-

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.7.3. However, Table 4.7.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited and this also holds for the research groups at Gjøvik University College.

Table 4.7.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. HiG.

Unit	Number of articles	Number of citations	Max cited article
HiG - TOTAL	45	10	0.2
Norwegian Color Lab	16	4	0.3
Norwegian Information Security Lab (NISlab)	29	6	0.2

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

4.8 Vestfold University College (HiVe)

At the Vestfold University College (HiVe) one department is included in the evaluation: Department of Micro- and Nano Systems Technology. The department is organised in different research groups. However, as there is considerable overlap among the research groups in terms of personnel included, we have not calculated indicators for the individual research groups. Table 4.8.1 shows various publication indicators for the department. In total, more than 50 journal articles and 80 other publications have been published. The department has a scientific productivity of 2.0 publications per full time equivalent (FTE), which is below the average for all units covered by this evaluation (2.9). However, it should be noted that the department is rather young and has been gradually expanding both in terms of staff members and publication output. It takes some time before the research results of works carried out by newly appointed appear as publications, and the number of publications output has increased significantly during the period.

Table 4.8.1 Number of publications, 2006–2010, HiVe.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
HiVe	18	69	138	53	2.0

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.8.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006-2010.

Table 4.8.2 The most frequently used journals*, number of publications 2006–2010 by department. HiVe.

Department	Journal	Numb. of articles
HiVe - TOTAL	APPLIED OPTICS	4
	JOURNAL OF MICROMECHANICS AND MICROENGINEERING	4
	PHYSICAL REVIEW A	3
	JOURNAL OF APPLIED PHYSICS	3

*) Limited to journals with at least three publications during the time period.

Table 4.8.3 contains a citation and journal profile of the department based on the journal articles (indexed in NCR) published in the period 2006–2009. The department has a rather poor performance measured in terms of citations. Its publications are little cited compared to corresponding world and Norwegian averages.

Table 4.8.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. HiVe.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
HiVe	21	49 (2)	8	55	64	51	50	85

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.8.3. However, Table 4.8.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited and this also holds for department at Vestfold University College.

Table 4.8.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. HiVe.

Unit	Number of articles	Number of citations	Number of citations per aticle
HiVe	28	8	0.3

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

4.9 Østfold University College (HiØ)

At the Østfold University College, Faculty of Information Technology is included in the evaluation. There are no formally organised research groups at the faculty. Table 4.9.1 shows various publication indicators for HiØ. The included personnel has a scientific productivity of 1.4 publications per full time equivalent (FTE), which is significantly below the average for all units covered by this evaluation (2.9).

Table 4.9.1 Number of publications, 2006–2010, HiØ.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
HiØ	7	29	42	9	1.4

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.9.2 contains citation numbers for the journal articles (indexed in NCR) published in the period 2006–2009. Only two uncited journal articles have been published.

Table 4.9.2 Citation and journal indicators, 2006–2009 publications indexed in NCR *. HiØ.

Unit	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
HiØ	2	0	0	-	-	-	-

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.9.3. Table 4.9.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index.

Table 4.9.3 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. HiØ.

Unit	Number of articles	Number of citations	Number of citations per article
HiØ	6	2	0.3

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

4.10 University Graduate Center at Kjeller (UNIK)

Table 4.10.1 shows various publication indicators for the University Graduate Center at Kjeller (UNIK). In total, almost 110 journal articles and 190 other publications have been published in the period 2006-2010. The scientific productivity at UNIK is very high. The number of publications per number of full time equivalents (FTE) is 6.2 which is far above the average for all units covered by this evaluation (2.9). The productivity is particularly high for the Cybernetics and Communication group.

Table 4.10.1 Number of publications, 2006–2010, UNIK.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
TOTAL - UNIK	13	48	297	107	6.2
Cybernetics and Communication	9	32	223	62	7.0
Electronics and Photonics	4	16	74	45	4.6

*) The dividing line between journals and book series is not always distinct. For example, “Lecture note” series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.10.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006-2010.

Table 4.10.2 The most frequently used journals*, number of publications 2006–2010 by unit. UNIK.

Unit	Journal	Numb. of articles
UNIK - TOTAL	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	11
	OPTICS EXPRESS	8
	IEEE PHOTONICS TECHNOLOGY LETTERS	4
	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	4
	ELECTRONICS LETTERS	3
	EURASIP JOURNAL ON ADVANCES IN SIGNAL PROCESSING	3
	EURASIP JOURNAL ON WIRELESS COMMUNICATIONS AND NETWORKING	3
	IEEE COMMUNICATIONS LETTERS	3
	IEEE TRANSACTIONS ON ELECTRON DEVICES	3
	IEEE TRANSACTIONS ON SIGNAL PROCESSING	3
Cybernetics and Communication	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	11
	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	4
	EURASIP JOURNAL ON ADVANCES IN SIGNAL PROCESSING	3
	EURASIP JOURNAL ON WIRELESS COMMUNICATIONS AND NETWORKING	3
	IEEE COMMUNICATIONS LETTERS	3
	IEEE TRANSACTIONS ON SIGNAL PROCESSING	3
Electronics and Photonics	OPTICS EXPRESS	8
	IEEE PHOTONICS TECHNOLOGY LETTERS	4
	IEEE TRANSACTIONS ON ELECTRON DEVICES	3

*) Limited to journals with at least three publications during the time period.

Table 4.10.3 contains a citation and journal profile of the groups based on the articles (indexed in NCR) published in the period 2006–2010. The institute performs well in terms of citation rates. Both groups have a field normalized citation index significantly above average: 163 for the Cybernetics and Communication groups and 137 for the Electronics and Photonics. In other words, the publications are 63 and 37% more cited than the corresponding world average. The citation rates are also clearly above the corresponding Norwegian average.

Table 4.10.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. UNIK.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
TOTAL	56	220 (6)	28	145	137	143	128	106
Cybernetics and Communication	30	77 (5)	22	163	164	164	156	99
Electronics and Photonics	26	143 (8)	28	137	125	134	117	109

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.10.3. However, Table 4.10.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited, and this also holds for the publications of UNIK.

Table 4.10.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. UNIK.

Unit	Number of articles	Number of citations	Number of citations per article
TOTAL	94	17	0.2
Cybernetics and Communication	83	16	0.2
Electronics and Photonics	11	1	0.1

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

4.11 Norwegian Defence Research Establishment (FFI)

Five research groups at three different divisions at Norwegian Defence Research Establishment (FFI) are included in the evaluation. Table 4.11.1 shows various publication indicators for the divisions and their research groups. Overall, the research groups at FFI have a productivity of 1.5 publications per full time equivalent (FTE), which is clearly below the average for all units covered by this evaluation (2.9). In terms of productivity there are only minor differences among the research groups.

Table 4.11.1 Number of publications, 2006–2010, FFI.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
TOTAL - Information Management division	13	62	90	26	1.5
Information security	5	24	30	12	1.3
Wireless communication networks and services	8	38	62	14	1.6
TOTAL -Land- and Air Systems division	11	48	61	20	1.3
Hyperspectral imaging	5	23	25	9	1.1
Radar	6	25	36	11	1.4
TOTAL - Maritime system division	13	58	78	11	1.4
Underwater robotics and sensors group	13	58	78	11	1.4

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.11.2 gives the most frequently used journals for the institute and the research groups – limited to journals with at least three publications during the period 2006–2010. Therefore, for two of the groups there are no journals on this list.

Table 4.11.2 The most frequently used journals*, number of publications 2006–2010 by unit. FFI.

Unit	Journal	Numb. of articles
FFI - TOTAL	IEEE COMMUNICATIONS MAGAZINE	6
	IEEE COMMUNICATIONS SURVEYS & TUTORIAL	3
	IEEE JOURNAL OF OCEANIC ENGINEERING	3
	IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	3
Wireless communication networks and services	IEEE COMMUNICATIONS MAGAZINE	5
Radar	IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	3
Underwater robotics and sensors group	IEEE JOURNAL OF OCEANIC ENGINEERING	3

*) Limited to journals with at least three publications during the time period.

Table 4.11.3 contains a citation and journal profile of the divisions/groups based on the journal articles (indexed in NCR) published in the period 2006–2009. For all of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). Despite a limited production, the institute performs reasonably well in terms of citation rates. The institute has a field normalized citation index at 123. In other words, the articles are cited 28 % more than the world average. The citation rate is also higher than the corresponding Norwegian average. However, one highly cited article contributes significantly to the citation index. Moreover, as can be seen from the table the journal publications of some of the groups are hardly cited at all.

Table 4.11.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. FFI.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
FFI - TOTAL	28	128 (10)	47	123	108	120	104	113
Information Management division	6	3	2	-	-	-	-	-
Information security	1	0	0	-	-	-	-	-
Wireless communication networks and services	5	3	2	-	-	-	-	-
Land- and Air Systems division	14	96 (12)	47	143	112	136	118	128
Hyperspectral imaging	7	77	47	-	-	-	-	-
Radar	7	19	9	-	-	-	-	-
Maritime system division Underwater robotics and sensors group	8	29	23	-	-	-	-	-

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.11.3. However, Table 4.11.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited, and this also holds for the publications of FFI.

Table 4.11.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. FFI.

Unit	Number of articles	Number of citations	Number of citations per article
FFI - TOTAL	33	17	0.5
Information Management division	15	13	0.9
Information security	5	10	2.0
Wireless communication networks and services	10	3	0.3
Land- and Air Systems division	9	2	0.2
Hyperspectral imaging	4	2	0.5
Radar	5	0	0.0
Maritime system division Underwater robotics and sensors group	9	2	0.2

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

4.12 Simula Research Laboratory AS

There are three research groups at Simula Research Laboratory included in the evaluation. Table 4.12.1 shows various publication indicators for the three research groups. Overall, the number of fractionalised publications per number of full time equivalents (FTE) is 3.7, which is above to the average for all units covered by this evaluation (2.9). The productivity rate is particularly high for the Communication Systems group and the Software Engineering group (5.0, and 4.3, respectively). In the analysis we have no separate category for book publishing. It should be noted, however, that the Scientific Computing group in particular has several publications in books on prestigious publishers.

Table 4.12.1 Number of publications, 2006-2010, Simula.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
TOTAL - Simula Research Laboratory	33	115	427	217	3.7
Communication Systems (CS)	10	37	187	71	5.0
Scientific Computing (SC)	14	53	135	79	2.5
Software Engineering (SE)	9	25	108	60	4.3

*) The dividing line between journals and book series is not always distinct. For example, “Lecture note” series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.12.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006–2010.

Table 4.12.2 The most frequently used journals*, number of publications 2006–2010 by unit. Simula.

Unit	Journal	Numb. of articles
Simula - TOTAL	IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	14
	INFORMATION AND SOFTWARE TECHNOLOGY	11
	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	10
	MOBILE NETWORKS & APPLICATIONS	7
	JOURNAL OF SYSTEMS AND SOFTWARE	7
	MATHEMATICAL BIOSCIENCES	6
	IEEE SOFTWARE	5
	ACM TRANSACTIONS ON MATHEMATICAL SOFTWARE	5
	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	4
	IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING	3
	PHYSICAL REVIEW B	3
	AMERICAN JOURNAL OF NEURORADIOLOGY	3
	ACM TRANSACTIONS ON SOFTWARE ENGINEERING AND METHODOLOGY	3
	IEEE COMMUNICATIONS MAGAZINE	3
	COMMUNICATIONS IN COMPUTATIONAL PHYSICS	3
	BIOPHYSICAL JOURNAL	3
	SIAM JOURNAL ON SCIENTIFIC COMPUTING	3
	WIRELESS COMMUNICATIONS & MOBILE COMPUTING	3
Communication Systems (CS)	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY	10
	MOBILE NETWORKS & APPLICATIONS	7
	IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS	4
	IEEE COMMUNICATIONS MAGAZINE	3
	WIRELESS COMMUNICATIONS & MOBILE COMPUTING	3
Scientific Computing (SC)	MATHEMATICAL BIOSCIENCES	6
	ACM TRANSACTIONS ON MATHEMATICAL SOFTWARE	5
	AMERICAN JOURNAL OF NEURORADIOLOGY	3
	BIOPHYSICAL JOURNAL	3
	COMMUNICATIONS IN COMPUTATIONAL PHYSICS	3
	IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING	3
	PHYSICAL REVIEW B	3
	SIAM JOURNAL ON SCIENTIFIC COMPUTING	3
Software Engineering (SE)	IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	14
	INFORMATION AND SOFTWARE TECHNOLOGY	11
	JOURNAL OF SYSTEMS AND SOFTWARE	7
	IEEE SOFTWARE	5
	ACM TRANSACTIONS ON SOFTWARE ENGINEERING AND METHODOLOGY	3

*) Limited to journals with at least three publications during the time period.

Table 4.12.3 contains a citation and journal profile of the institute and its groups based on the journal articles (indexed in NCR) published in the period 2006–2009. Overall, the institute has a field normalized citation index of 114. In other words, the publications are 14 per cent more cited than the world average. The publications of the institute are cited almost equal with the corresponding Norwegian average (index 102). Particularly the Software Engineering group performs very well, with a field normalized citation rate of 250. This group also tends to publish in journals that are relatively highly cited (i.e. have high impact factor), which is reflected by a journal profile of 186.

Table 4.12.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. Simula.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
TOTAL	106	328 (5)	34	114	101	102	104	116
Communication Systems (CS)	26	40 (2)	9	108	137	110	101	78
Scientific Computing (SC)	52	176 (5)	21	85	83	75	78	102
Software Engineering (SE)	28	115 (7)	34	250	135	209	239	186

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.12.3. However, Table 4.12.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index. Generally, proceedings papers are little cited, and this also holds for the publications of Simula although there are some variations among the groups.

Table 4.12.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. Simula.

Unit	Number of articles	Number of citations	Number of citations per article
TOTAL	61	31	0.5
Communication Systems (CS)	37	8	0.2
Scientific Computing (SC)	10	5	0.5
Software Engineering (SE)	16	19	1.2

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

While the tables above include the persons encompassed by the evaluation only, we have made an additional analysis where all journal articles where Simula is listed as an author address are included. This analysis covers the period 2001-2009. Based on this analysis we have calculated citation indicators for two periods: 2001-2005 and 2006-2009. The results are given in the table below. As can be seen, the publications from the first period obtained even higher citation indexes than the publications from the latter period.

Table 4.12.4 Citation and journal indicators, 2006–2009 publications*. Simula.

Publication type/ period	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
Journ art 2001-05*	79	627	50	145	132	109	110
Journ art 2006-09**	164	484	34	109	105	96	104
Proc art 2001-05*	30	25	4				
Proc art 2006-09**	73	42	14				

*) Based on the publications from the period 2001–2005 and the accumulated citations to these publications through 2010.

**) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010

1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.13 SINTEF ICT

At SINTEF ICT there are two research groups included in the evaluation. Table 4.13.1 shows various publication indicators for the two research groups. The groups have a productivity level corresponding to 2.2 and 1.6 publications per number of full time equivalents (FTE), which is below the average for all units covered by this evaluation (2.9).

Table 4.13.1 Number of publications, 2006–2010, SINTEF ICT.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals*	Total number of publications per number of FTE
TOTAL - SINTEF ICT	13	60	113	49	1.9
Human Computer Interaction Group (HCI)	7	30	48	20	1.6
Software Process Improvement and Knowledge Management Group (SPI)	6	30	65	29	2.2

*) The dividing line between journals and book series is not always distinct. For example, "Lecture note" series and various IEEE series publishing proceeding papers are not included under journals in the analysis.

Table 4.13.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006–2010.

Table 4.13.2 The most frequently used journals*, number of publications 2006–2010 by unit. SINTEF ICT.

Unit	Journal	Numb. of articles
SINTEF ICT - TOTAL	SOFTWARE PROCESS IMPROVEMENT AND PRACTICE	9
	INFORMATION AND SOFTWARE TECHNOLOGY	8
	NEW MEDIA & SOCIETY	4
	PROFESSIONAL KNOWLEDGE MANAGEMENT	3
	IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	3
	IEEE SOFTWARE	3
Human Computer Interaction Group (HCI)	NEW MEDIA & SOCIETY	4
Software Process Improvement and Knowledge Management Group (SPI)	SOFTWARE PROCESS IMPROVEMENT AND PRACTICE	9
	INFORMATION AND SOFTWARE TECHNOLOGY	8
	IEEE SOFTWARE	3
	IEEE TRANSACTIONS ON SOFTWARE ENGINEERING	3
	PROFESSIONAL KNOWLEDGE MANAGEMENT	3

*) Limited to journals with at least three publications during the time period.

Table 4.13.3 contains a citation and journal profile of the groups based on the journal articles (indexed in NCR) published in the period 2006–2009. The Software Process Improvement and Knowledge Management Group (SPI) performs very well in terms of citation rates with a field normalized citation index of 233. In other words, the articles have been cited 133 % above the corresponding world average. The group also publishes in journals that are higher than average cited (i.e. have high impact factor), which is reflected by a journal profile of 152.

Table 4.13.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. SINTEF ICT.

Unit	Number of articles	Number of citations[1]	Max cited article	Citation index – field[2]	Citation index – journal[3]	Citation index – Norway[4]	Citation index – EU-15[5]	Journal profile[6]
TOTAL	29	111 (6)	22	188	141	169	181	133
Human Computer Interaction Group (HCI)	8	17 (2)	5	-	-	-	-	-
Software Process Improvement and Knowledge Management Group (SPI)	21	94 (7)	22	233	154	191	219	152

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.
1) Standard deviations are given in brackets. 2) World average field = 100. 3) Journal average = 100.
4) Norwegian average field = 100. 5) Average of EU-15 countries = 100. 6) Average journal profile = 100.

Proceedings papers are not included in the figures in Table 4.13.3. However, Table 4.13.4 shows the number of proceedings papers (2006-2009) indexed in the Web of Science Conference Proceedings Citation Index.

Table 4.13.4 Citations to proceedings papers indexed in Web of Science Conference Proceedings Citation Index, 2006–2009 publications*. SINTEF ICT.

Unit	Number of articles	Number of citations	Number of citations per article
TOTAL	22	22	1.0
Human Computer Interaction Group (HCI)	8	2	0.3
Software Process Improvement and Knowledge Management Group (SPI)	14	20	1.4

*) Based on the publications from the period 2006–2009 and the accumulated citations to these publications through 2010.

5 Appendix: General introduction to bibliometric indicators

Publication and citation data have increasingly been applied as performance indicators in the context of science policy and research evaluation. The basis for the use of bibliometric indicators is that new knowledge – the principal objective of basic and applied research – is disseminated to the research community through publications. Publications can thereby be used as indirect measures of knowledge production. Data on how much the publications have been referred to or cited in the subsequent scientific literature can in turn be regarded as an indirect measure of the scientific impact of the research. In this chapter we will provide a general introduction to bibliometric indicators, particularly focusing on analyses based on the Thomson Reauters (ISI)-database.[6]

5.1 The ISI (Thomson Reuter)-database

The ISI database covers a large number of specialised and multidisciplinary journals within the natural sciences, medicine, technology, the social sciences and the humanities. The coverage varies between the different database products. According to the website of the Thomson Scientific company, the most well-known product, the *Science Citation Index* today covers 7,100 journals (*Science Citation Index Expanded*). The online product *Web of Science* covering the three citation indexes *Science Citation Expanded*, *Social Sciences Citation Index*, and *Arts & Humanities Citation Index* includes more than 10,000 journals. Compared to the large volume of scientific and scholarly journals that exist today, this represents a limited part. The selection of journals is based on a careful examination procedure in which a journal must meet particular requirements in order to be included (Testa, 1997). Even if its coverage is not complete, the ISI database will include all major journals within the natural sciences, medicine and psychology and technology and is generally regarded as constituting a satisfactory representation of international mainstream scientific research (Katz & Hicks, 1998). With respect to the social sciences and humanities the coverage is more limited, and this issue will be further discussed below.

From a bibliometric perspective, a main advantage of the ISI database is that it fully indexes the journals that are included. Moreover, all author names, author addresses and references are indexed. Through its construction it is also well adapted for bibliometric analysis. For example, country names and journal names are standardised, controlled terms. It is also an advantage that it is multidisciplinary in contrast to most other similar databases which cover just one or a few scientific disciplines.

[6] This introduction is based on Aksnes (2005).

5.2 Citation indicators

Citations represent an important component of scientific communication. Already prior to the 19th century it was a convention that scientists referred to earlier literature relating to the theme of the study (Egghe & Rousseau, 1990). The references are intended to identify earlier contributions (concepts, methods, theory, empirical findings, etc.) upon which the present contribution was built, and against which it positions itself. Thus, it is a basic feature of the scientific article that it contains a number of such references and that these references are attached to specific points in the text.

This ISI-database was originally developed for information retrieval purposes, to aid researchers in locating papers of interest in the vast research literature archives (Welljams-Dorof, 1997). As a subsidiary property it enabled scientific literature to be analysed quantitatively. Since the 1960s the *Science Citation Index* and similar bibliographic databases have been applied in a large number of studies and in a variety of fields. The possibility for citation analyses has been an important reason for this popularity. As part of the indexing process, ISI systematically registers all the references of the indexed publications. These references are organised according to the publications they point to. On this basis each publication can be attributed a citation count showing how many times each paper has been cited by later publications indexed in the database. Citation counts can then be calculated for aggregated publications representing, for example, research units, departments, or scientific fields.

5.3 What is measured through citations?

Because citations may be regarded as the mirror images of the references, the use of citations as indicators of research performance needs to be justified or grounded in the referencing behaviour of the scientists (Wouters, 1999). If scientists cite the work they find useful, frequently cited papers are assumed to have been more useful than publications which are hardly cited at all, and possibly be more useful and thus important in their own right. Thus, the number of citations may be regarded as a measure of the article's usefulness, impact, or influence. The same reasoning can be used for aggregated levels of articles. The more citations they draw, the greater their influence must be. Robert K. Merton has provided the original theoretical basis for this link between citations and the use and quality of scientific contribution. In Merton's traditional account of science, the norms of science oblige researchers to cite the work upon which they draw, and in this way acknowledge or credit contributions by others (Merton, 1979). Such norms are upheld through informal interaction in scientific communities and through peer review of manuscripts submitted to scientific journals.

Empirical studies have shown that the Mertonian account of the normative structure of science covers only part of the dynamics. For the citation process, this implies that other incentives occur, like the importance of creating visibility for one's work, and being selective in referencing to create a distance between oneself and others. Merton himself already pointed out the ambivalence of the norms, for example that one should not hide one's results from colleagues in one's community, but also not rush into print before one's findings are robust. Merton also identified system level phenomena like the "Matthew effect": to whom who has shall be given more. Clearly, a work may be cited for a large number of reasons including tactical ones such as citing a journal editor's work as an attempt to enhance the chances of acceptance for publication. Whether this affects the use of citations as performance indicators is a matter of debate (Aksnes, 2003b).

The concept of quality has often been used in the interpretation of citation indicators. Today, however, other concepts – particularly that of "impact" – are usually applied. One reason is that quality is often considered as a diffuse or at least multidimensional concept. For example, the following description is given by Martin and Irvine (1983): "'Quality' is a property of the publication and the research described in it. It describes how well the research has been done, whether it is free from obvious 'error' […] how original the conclusions are, and so on." Here, one sees reference to the craft of doing scientific research, and to the contribution that is made to the advance of science.

The impact of a publication, on the other hand, is defined as the "actual influence on surrounding research activities at a given time." According to Martin and Irvine it is the impact of a publication that is most closely linked to the notion of scientific progress – a paper creating a great impact represents a major contribution to knowledge at the time it is published. If these definitions are used as the basis it is also apparent that impact would be a more suitable interpretation of citations than quality. For example, a 'mistaken' paper can nonetheless have a significant impact by stimulating further research. Moreover, a paper by a recognised scientist may be more visible and therefore have more impact, earning more citations, even if its quality is no greater than those by lesser known authors (Martin, 1996).

5.4 Some basic citation patterns

De Solla Price showed quite early that recent papers are more cited than older ones (Price, 1965). Nevertheless, there are large individual as well as disciplinary differences. The citation counts of an article may vary from year to year. Citation distributions are extremely skewed. This skewness was also early identified by Solla Price (Price, 1965). The large majority of the scientific papers are never or seldom cited in the subsequent scientific literature. On the other hand some papers have an extremely large number of citations (Aksnes, 2003a; Aksnes & Sivertsen, 2004).

Citation rates vary considerably between different subject areas. For example, on average papers in molecular biology contain many more references than mathematics papers (Garfield, 1979b). Accordingly, one observes a much higher citation level in molecular biology than in mathematics. Generally, the average citation rate of a scientific field is determined by different factors, most importantly the average number of references per paper. In addition, the percentage of these references that appears in ISI-indexed journals, the average age of the references, and the ratio between new publications in the field and the total number of publications, are relevant.

5.5 Limitations

In addition to the fundamental problems related to the multifaceted referencing behaviour of scientists, there are also more specific problems and limitations of citation indicators. Some of these are due to the way the ISI database is constructed. First of all, it is important to emphasise that only references in ISI-indexed literature count as "citations". For example, when articles are cited in non-indexed literature (e.g. a trade journal) these are not counted. This has important consequences. Research of mainly national or local interest, for example, will usually not be cited in international journals. Moreover, societal relevance, such as contributions of importance for technological or industrial development, may not be reflected by such counts. Because it is references in (mainly) international journals which are indexed, it might be more appropriate to restrict the notion of impact in respect to citation indicators to impact on international or "mainstream" knowledge development.

There is also a corresponding field dimension. For example, LePair (1995) has emphasised that "In technology or practicable research bibliometrics is an insufficient means of evaluation. It may help a little, but just as often it may lead to erroneous conclusions." For similar reasons the limitations of citation indicators in the social sciences and humanities are generally more severe due to a less centralised or a different pattern of communication. For example, the role of international journals is less important, and publishing in books is more common: older literature has a more dominant role and many of the research fields have a "local" orientation. In conclusion, citation analyses are considered to be most fair as an evaluation tool in the scientific fields where publishing in the international journal literature is the main mode of communication.

Then there are problems caused by more technical factors such as discrepancies between target articles and cited references (misspellings of author names, journal names, errors in the reference lists, etc.), and mistakes in the indexing process carried out by Thomson Scientific (see Moed, 2002; Moed & Vriens, 1989). Such errors affect the accuracy of the citation counts to individual articles but are nevertheless usually not taken into account in bibliometric analyses (although their effect to some extent might "average out" at aggregated levels).

While some of the problems are of a fundamental nature, inherent in any use of citations as indicators, other may be handled by the construction of more advanced indicators. In particular, because of the large differences in the citation patterns between different scientific disciplines and subfields, it has long been argued by bibliometricians that relative indicators and not absolute citation counts should be used in cross-field comparisons (Schubert & Braun, 1986; Schubert & Braun, 1996; Schubert, Glänzel, & Braun, 1988; Vinkler, 1986). For example, it was early emphasised by Garfield that: "Instead of directly comparing the citation counts of, say, a mathematician against that of a biochemist, both should be ranked with their peers, and the comparison should be made between rankings" (Garfield, 1979a). Moed et al. (1985) similarly stressed that: "if one performs an impact evaluation of publications from various fields by comparing the citation counts to these publications, differences between the citation counts can not be merely interpreted in terms of (differences between) impact, since the citation counts are partly determined by certain field-dependent citation characteristics that can vary from one field to another".

A fundamental limitation of citation indicators in the context of research assessments is that a certain time period is necessary for such indicators to be reliable, particularly when considering smaller number of publications. Frequently, in the sciences a three-year period is considered as appropriate (see e.g. Moed et al., 1985). But for the purpose of long-term assessments more years are required. At the same time, an excessively long period makes the results less usable for evaluation purposes. This is because one then only has citation data for articles published many years previously. Citation indicators are not very useful when it comes to publications published very recently, a principal limitation of such indicators being that they cannot provide an indication of present or future performance except indirectly: past performance correlates with future performance (Luukkonen, 1997). It should be added, however, that this time limitation does not apply to the bibliometric indicators based on publication counts.

5.6 Bibliometric indicators versus peer reviews

Over the years a large number of studies have been carried out to ascertain the extent to which the number of citations can be regarded as a measure of scientific quality or impact. Many studies have also found that citation indicators correspond fairly well, especially in the aggregate, with various measures of research performance or scientific recognition which are taken as reflecting quality. On the other hand, there have been several studies challenging or criticising such use of citations.

One approach to the question is represented by studies analysing how citations correlate with peer reviews. In these studies judgements by peers have been typically regarded as a kind of standard by which citation indicators can be validated. The idea is that one should find a correlation if citations legitimately can be used as indicators of scientific performance (which assumes that peer assessment can indeed identify quality and performance without bias – a dubious assumption). Generally, most of the studies seem to have found an overall positive correspondence although the correlations identified have been far from perfect and have varied among the studies (see e.g. Aksnes & Taxt, 2004, Aksnes, 2006).

Today most bibliometricians emphasise that a bibliometric analysis can never function as a substitute for a peer review. Thus, a bibliometric analysis should not replace an evaluation carried out by peers. First a peer-evaluation will usually consider a much broader set of factors than those reflected through bibliometric indicators. Second, this is due to the many problems and biases attached to such analyses. As a general principle, it has been argued that the greater the variety of measures and qualitative processes used to evaluate research, the greater is the likelihood that a composite measure offers a reliable understanding of the knowledge produced (Martin, 1996).

At the same time, it is generally recognised that peer reviews also have various limitations and shortcomings (Chubin & Hackett, 1990). For example, van Raan (2000) argues that subjectivity is a major problem of peer reviews: The opinions of experts may be influenced by subjective elements, narrow mindedness and limited cognitive horizons. An argument for the use of citation indicators and other bibliometric indicators is that they can counteract shortcomings and mistakes in the peers' judgements. That is, they may contribute to fairness of research evaluations by representing "objective" and impartial information to judgements by peers, which would otherwise depend more on the personal views and experiences of the scientists appointed as referees (Sivertsen, 1997). Moreover, peer assessments alone do not provide sufficient information on important aspects of research productivity and the impact of the research activities (van Raan, 1993).

Citations and other bibliometric indicators have been applied in various ways in research evaluation. For example, such indicators are used to provide information on the performance of research groups, departments, institutions or fields. According to van Raan (2000), "the application of citation analysis to the work – the oeuvre – of a group as a whole over a longer period of time, does yield in many situations a strong indicator of scientific performance, and, in particular, of scientific quality". As a qualifying premise it is emphasised, however, that the citation analysis should adopt an advanced, technically highly developed bibliometric method. In this view, a high citation index means that the assessed unit can be considered as a scientifically strong organisation with a high probability of producing very good to excellent research.

In this way a bibliometric study is usually considered as complementary to a peer evaluation. Van Raan has accordingly suggested that in cases where there is significant deviation between the peers' qualitative assessments and the bibliometric performance measures, the panel should investigate the reasons for these discrepancies. They might then find that their own judgements have been mistaken or that the bibliometric indicators did not reflect the unit's performance (van Raan, 1996).[7]

In conclusion, the use of citations as performance measures have their limitations, as all bibliometric indicators have. But a citation analysis when well designed and well

[7] Van Raan (1996) suggests that in cases were conflicting results appear, the conclusion may depend on the type of discrepancy. If the bibliometric indicators show a poor performance but the peer's judgement is positive, then the communication practices of the group involved may be such that bibliometric assessments do not work well. By contrast, if the bibliometric indicators show a good performance and the peers' judgement is negative, then it is more likely that the peers are wrong.

interpreted will still provide valuable information in the context of research evaluation. Performance, quality and excellence can also be assessed through peer review, but in spite of their widespread use, these have problems as well. A combination of methods, or better, mutual interplay on the basis of findings of each of the methods, is more likely to provide reliable evaluation results.

5.7 Co-authorship as an indicator of collaboration[8]

The fact that researchers co-author a scientific paper reflects collaboration, and co-authorship may be used as an indicator of such collaboration. Computerised bibliographic databases make it possible to conduct large-scale analyses of scientific co-authorship. Of particular importance for the study of scientific collaboration is the fact that the ISI (Thomson Scientific) indexes all authors and addresses that appear in papers, including country as a controlled term.

By definition a publication is co-authored if it has more than one author, internationally co-authored if it has authors from more than one country. Compared to other methodologies, bibliometrics provides unique and systematic insight into the extent and structure of scientific collaboration. A main advantage is that the size of the sample that can be analysed with this technique can be very large and render results that are more reliable than those from case studies. Also, the technique captures non-formalised types of collaboration that can be difficult to identify with other methodologies.

Still, there are limitations. Research collaboration sometimes leads to other types of output than publications. Moreover, co-authorship can only be used as a measure of collaboration if the collaborators have put their names on a joint paper. Not all collaboration ends up in co-authorship and the writing of co-authored papers does not necessarily imply close collaboration (Katz & Martin, 1997; Luukkonen, Persson, & Sivertsen, 1992; Melin & Persson, 1996). Thus, international co-authorship should only be used as a partial indicator of international collaboration (Katz and Martin 1997). As described above there are also particular limitations with the ISI database, represented by the fact that regional or domestic journals, books, reports etc. are not included.

Smith (1958) was among the first to observe an increase in the incidence of multi-authored papers and to suggest that such papers could be used as a rough measure of collaboration among groups of researchers (Katz and Martin 1997). In a pioneering work, Derek de Solla Price also showed that multiple authorship had been increasing (Price, 1986). These findings have later been confirmed by a large number of similar studies (e.g. (Merton & Zuckerman, 1973; National Science Board, 2002). In the natural sciences and medicine the single-author paper is, in fact, becoming an exception to the norm. In the case of Norway, 86 % of ISI-indexed papers were co-authored in 2000, compared to 66 % in 1981.

[8] This section is based on Wendt, Slipersæter, & Aksnes (2003).

Scientific collaboration across national borders has also significantly increased over the last decades. According to Melin and Persson (1996) the number of internationally co-authored papers has doubled in about fifteen years. In Norway every second paper published by Norwegian researchers now has foreign co-authors compared to 16 % in 1981. Similar patterns can be found in most countries. Bibliometric analysis thus provides evidence to the effect that there is a strong move towards internationalisation in science and that the research efforts of nations are becoming more and more entwined.

The move toward internationalisation is also reflected in the publishing practices of scientists: English has increasingly become the lingua franca of scientific research, and publishing in international journals is becoming more and more important, also in the areas of social science and the humanities.

As might be expected, nations with big scientific communities have far more collaborative articles than have smaller countries (Luukkonen, Tijssen, Persson, & Sivertsen, 1993), though one finds a trend to the effect that the proportion of internationally co-authored papers increases along with decreasing national volume of publications (see e.g. Luukkonen, Persson et al. 1992, National Science Board 2002), hence international collaboration is relatively more important in smaller countries. This is probably a consequence of researchers from small countries often having to look abroad for colleagues and partners within their own speciality. Size is, however, not the only factor with bearing on the extent of international collaboration; access to funding, geographical location, and cultural, linguistic and political barriers are other important factors (Luukkonen, Persson et al. 1992, Melin and Persson 1996).

Bibliometric techniques allow analysis of structures of international collaboration. For almost all other countries, the United States is the most important partner country; this reflects this country’s pre-eminent role in science. In 1999, 43 % of all published papers with at least one international co-author had one or more U.S. authors. For Western Europe the share of U.S. co-authorship ranged from 23 % to 35 % of each country's internationally co-authored papers (National Science Board 2002). Generally, one also finds that most countries have much collaboration with their neighbouring countries (e.g. collaboration among the Nordic countries). Over the last decade we find a marked increase in co-authorship among western European countries; this probably mainly reflects the EU framework programmes.

6 Appendix – "Level 2"* journals in informatics

ACM Computing Surveys	IEEE Micro
ACM Transactions on Computer Systems	IEEE Software
ACM Transactions on Graphics	IEEE Transactions on Information Theory
ACM Transactions on Programming Languages and Systems	IEEE Transactions on Visualization and Computer Graphics
Applied intelligence (Boston)	Information and Computation
Artificial Intelligence	Interacting with computers
Artificial Intelligence in Medicine	International Journal of Approximate Reasoning
Bioinformatics	International Journal of Computer Vision
BIT Numerical Mathematics	Journal of automated reasoning
Communications of the ACM	Journal of computer and system sciences (Print)
Computer	Journal of Heuristics
Computer graphics forum (Print)	Journal of Logic and Algebraic Programming
Computer Networks	Journal of machine learning research
Computer speech & language (Print)	Journal of Parallel and Distributed Computing
Computer-Aided Design	Journal of Software Maintenance: Research and Practice
Computers & structures	Journal of Systems and Software
Computers and education	Knowledge engineering review (Print)
Concurrency	Language and Computers
Data & Knowledge Engineering	Neural Computation
Data mining and knowledge discovery	Neural Networks
Decision Support Systems	Parallel Computing
Distributed computing	Performance evaluation (Print)
Distributed Computing Systems	Proceedings / International Conference of Software Engineering
Eurographics	Proceedings / International Conference on Data Engeenering
Evolutionary Computation	Proceedings of the VLDB Endowment
Formal methods in system design	Science of Computer Programming
Geoinformatica	The international journal of high performance computing applications
High-Performance Computer Architecture	The journal of artificial intelligence research
Human-Computer Interaction	Theoretical Computer Science
IEEE Computer Graphics and Applications	User modeling and user-adapted interaction
IEEE Internet Computing	

*) Journals accredited as level 2 journals by UHR's National Councils (ref. 01.01. 2011). In the analysis also "level 2" journals in other subjects are included.

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Cover design: Design et cetera AS
Cover photo: Shutterstock
Print: 07 Gruppen AS
Number of copies: 200

Oslo, March 2012

ISBN 978-82-12-03064-0 (printed version)
ISBN 978-82-12-03065-7 (pdf)