The Research Council of Norway

Research in Mathematics at Norwegian Universities

Bibliometric analysis

Evaluation
Division for Science

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NIFU

Nordic Institute for Studies in
Innovation, Research and Education

Evaluation of Mathematics – Publication and Citation Analysis

National Indicators and International Comparisons

Institutional Analyses

Dag W. Aksnes

15.01 2012

Preface

This report presents a bibliometric analysis of research in mathematics 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 mathematics in Norway. Both the institution/department level and the research group level are analysed. In addition the report contains a macro analysis of Norwegian mathematics 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 mathematics 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:

Norwegian University of Life Sciences (UMB)

- Department of Chemistry, Biotechnology and Food Science
  - Biostatistics
- Department of Mathematical Sciences and Technology
  - Applied Mathematics/Computational Biology

Norwegian University of Science and Technology (NTNU)

- Faculty of Information Technology, Mathematics and Electrical Engineering
  - Department of Mathematical Sciences

University of Agder (UiA)

- Faculty of Engineering and Science
  - Department of Mathematical Sciences

University of Bergen (UiB)

- Faculty of Mathematics and Natural Sciences
  - Department of Mathematics

University of Oslo (UiO)

- Faculty of Mathematics and Natural Sciences
  - Department of Mathematics

University of Stavanger (UiS)

- Faculty of Science and Technology
  - Department of Mathematics and Natural Science, Section of Mathematics

University of Tromsø (UiT)

- Faculty of Science and Technology
    - Department of mathematics and statistics

The general chapter on Norwegian mathematics (chapter 3) is, however, not limited to these units. Here, all Norwegian publishing in journals within mathematics 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 and groups. 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 mathematics (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

[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.

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.

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 mathematics. 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.

2.3.1 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 employed at the unit and adjusted the productivity indicator accordingly.

[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.

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.

2.3.2 Citation indicators

Only publications published in journals indexed in the Thomson Reuters database NCR are included in the citation analyses. In mathematics, the database covers the large majority of the journals where the original research results are published.

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

[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.

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.

Relative citation index – journal

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.

Relative citation index – field

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.

Relative citation index – Norway

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.

Example

The following example can illustrate the principle for calculating relative citation indexes: A scientist has published a regular journal article in *Mathematics of Computation* in 2006. This article has been cited 6 times. The articles published in *Mathematics of Computation* were in contrast cited 4.00 times on average this year. The Relative citation index – journal is: (6/4.00)*100 = 150. The world-average citation rate for the subfield which this journal is assigned to is 3.69 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: (6/3.69)*100 = 162. 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 picture of the research performance. Moreover, the unit may have good and weak years. In mathematics the citation rates are generally low compared to for example biomedicine. This weakens the validity of citations rates as performance measure in mathematics. 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.

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 mathematics in an international context

This chapter presents various bibliometric indicators on the performance of Norwegian research within mathematics. The chapter is based on *all* publications within mathematics, 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 *Mathematics* is a separate field category and where there also are categories for particular subfields within mathematics. In the analysis we have both analysed mathematics as a collective discipline and subfields. The category for Mathematics 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 Mathematics: Mechanics. 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 a large majority (71 %) of the Norwegian scientific journal publishing within Mathematics. 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. The University of Oslo and the Norwegian University of Science and Technology are by far the largest universities with respect to publication output in Mathematics, with proportions of 27 and 25 %, respectively, of the national total. Then follows University of Bergen with 16 %. In the Institute sector (private and public research institutes), Simula Research Laboratory is the largest single contributor with 3 % 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).

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

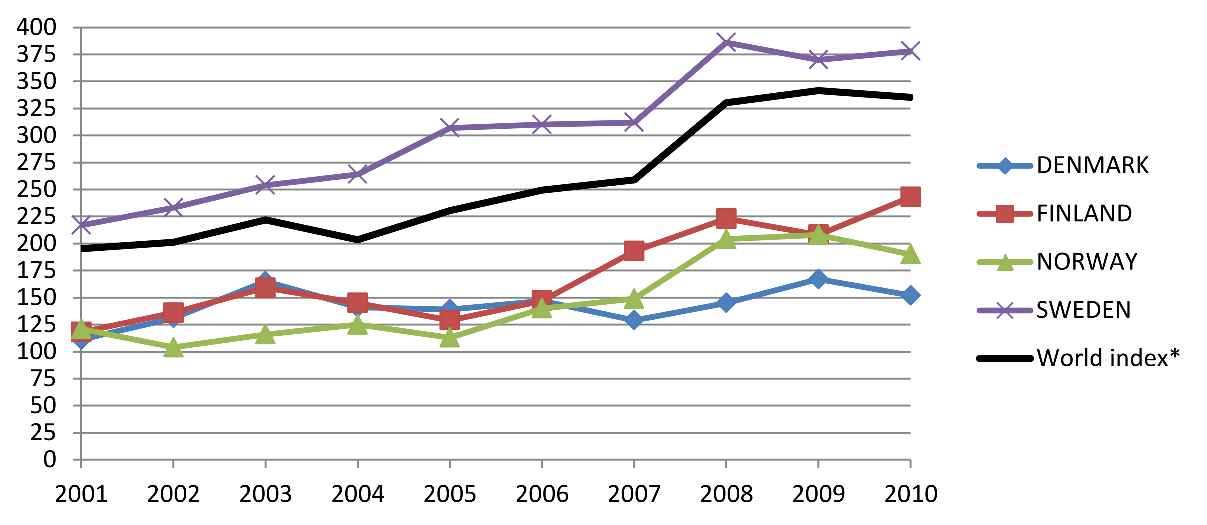
	Number of articles	Proportion
University of Oslo	444	27 %
Norwegian University of Science and Technology	411	25 %
University of Bergen	267	16 %
Norwegian University of Life Sciences	63	4 %
University of Tromsø	43	3 %
Narvik University College	40	2 %
University of Stavanger	33	2 %
Norwegian School of Economics	26	2 %
University of Agder	21	1 %
Other Higher Education institutions	57	3 %
Simula	45	3 %
Nofima	22	1 %
Institute sector - other institutes	133	8 %
Hospitals	21	1 %
Industry	42	3 %

*) Only institutions/institutes with more than 20 publications within the Mathematics category (as defined by Thomson Reuters) during the time period are shown separately in the table.

In Figure 3.1 we have shown the development in the annual production of articles in Mathematics 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 190 articles in 2010. Sweden is the largest country and has twice as large production as Norway (380 articles) followed by Finland with 240 articles.

In terms of productivity there is a notable positive trend the recent years. This holds for all the Nordic countries. In 2001, 120 articles were published by Norwegian researchers, and particularly after 2005 the production has been increasing, albeit with reduction from 2009 to 2010.

Figure 3.1 Scientific publishing in Mathematics 2001-2010 in four Nordic countries.



*) The "world index" is a reference line, calculated as the world production of articles in Mathematics divided by 100.

In Table 3.2 we have shown the increase in the number of papers from the year 2001 to the year 2010 for the same set of countries. As can be seen, the number of papers published by Norwegian researchers in Mathematics in 2010 is 57 % higher than the one in 2001. The corresponding figures for Sweden, Denmark and Finland are 74 %, 37 %, and 106 %, respectively.

As a reference, Table 3.2 also shows the increase for all fields, i.e. the national totals. The overall Norwegian publication output increased by 77 % from 2001 to 2010. In other words, there has been a strong increase in the national publication output, and even stronger than the one for Mathematics.[4] As another reference parameter, Table 3.2 and Figure 3.1 also include figures for the world development. As can be seen there has been a significant increase also in the global publication output during the period both for Mathematics (72 %) and overall (48 %). [5]

[4] The reason for this increase is outside the scope of the report. A main factor is obviously the increase in the resources and personnel devoted to R&D. In 2004 Norway implemented a new funding model for the higher education institutions. The funding of these institutions is now partially based on the measurement of their scientific and scholarly publishing. It is likely that the model has contributed to part of the increase by having incentive impacts, although the actual contribution of this effect is hard to establish.

[5] The figures are for the universe represented by the Thomson Reuters' database. We do not have independent measures to assess the "real" global development. It is clear that the global science system is expanding from year to year. More money is being spent on research activities, which involves an increasing number of persons. This is also reflected in the publication counts. In addition, the coverage of the database in terms of the number of journals indexed has grown during the period. Particularly from 2007 to 2008 the number of journals indexed increased significantly. Whether this increase in the database coverage correlates with the increase in the total scientific literature globally, is hard to assess. But at least part of the increase can be seen as a database artifact (cf. Aksnes & Hessen 2009).

Table 3.2 Increase in the scientific publishing during the period 2001–2010 in four Nordic countries and the World, Mathematics and all fields.

		Norway	Sweden	Denmark	Finland	World
Mathematics	Increase, per cent	57 %	74 %	37 %	106 %	72 %
	Increase, number of articles	69	161	41	125	14 015
All fields (national totals)	Increase, per cent	77 %	23 %	45 %	26 %	48 %
	Increase, number of articles	4 027	3 684	3 615	2 026	373 560

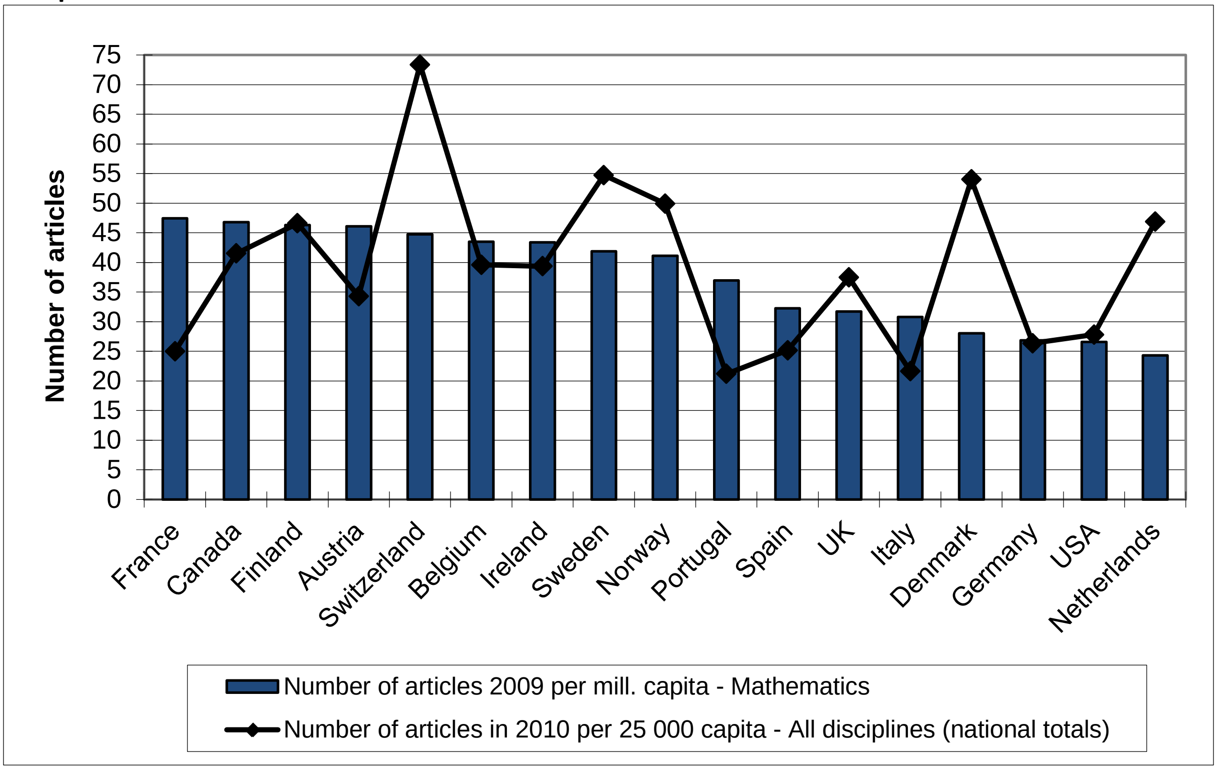
As described in Chapter 2 many publications are multi-authored, and are the results of collaborative efforts involving researchers from more than one country. In the figure we have used the "whole" counting method, i.e. a country is credited an article if it has at least one author address from the respective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

In a global context Norway is a very small country science-wise. In Mathematics, the Norwegian publication output amounts to 0.43 % 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 less to the global scientific output in Mathematics 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 41 articles in Mathematics 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 nine. France, Canada, Finland and Austria are the countries with the highest per capita production of articles in Mathematics (46-47 articles per million capita).

In Figure 3.2 we have also shown the production (per 25,000 capita) for all disciplines (national totals) (black line). This can be used as an indication of whether Mathematics has a higher or lower relative position in the science system of the countries than the average. For example, for Norway, Mathematics ranks below the national average, while the opposite is the case for France.

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



In order to provide further insight into the profile of Norwegian Mathematics 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 broad and general (mathematics) 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 subfield Mechanics in this overview, which includes certain topics covered by the evaluation.

Category descriptions Mathematics and related disciplines

Mathematical & Computational Biology: Includes journals concerning the use of mathematical, statistical and computational methods to address data analysis, modeling, and information management in biological problems, processes and systems. Among the areas covered are biostatistics, bioinformatics, biometrics, modeling of biological systems, and computational biology.

Mathematics: Mathematics covers journals having a broad, general approach to the field. The category also includes journals focusing on specific fields of basic research in Mathematics such as topology, algebra, functional analysis, combinatorial theory, differential geometry and number theory.

Mathematics, Applied: Covers journals concerned with areas of mathematics that may be applied to other fields of science. It includes areas such as differential equations, numerical analysis, nonlinearity, control, software, systems analysis, computational mathematics and mathematical modeling. Journals that are concerned with mathematical methods and whose primary focus is on a specific non-mathematics discipline (except biology) such as psychology, history, economics etc., are covered in the MATHEMATICS, INTERDISCIPLINARY APPLICATIONS category. Journals focusing on mathematical biology are covered in the MATHEMATICAL & COMPUTATIONAL BIOLOGY category.

Mathematics, Interdisciplinary Applications: Includes journals concerned with mathematical methods whose primary focus is on a specific non-mathematics discipline (except biology) such as psychology, history, economics, etc. Journals that deal with mathematical biology are covered in the MATHEMATICAL AND COMPUTATIONAL BIOLOGY category. Journals that focus on specific mathematical topics such as differential equations, numerical analysis, nonlinearity, etc., are covered in the MATHEMATICS, APPLIED category.

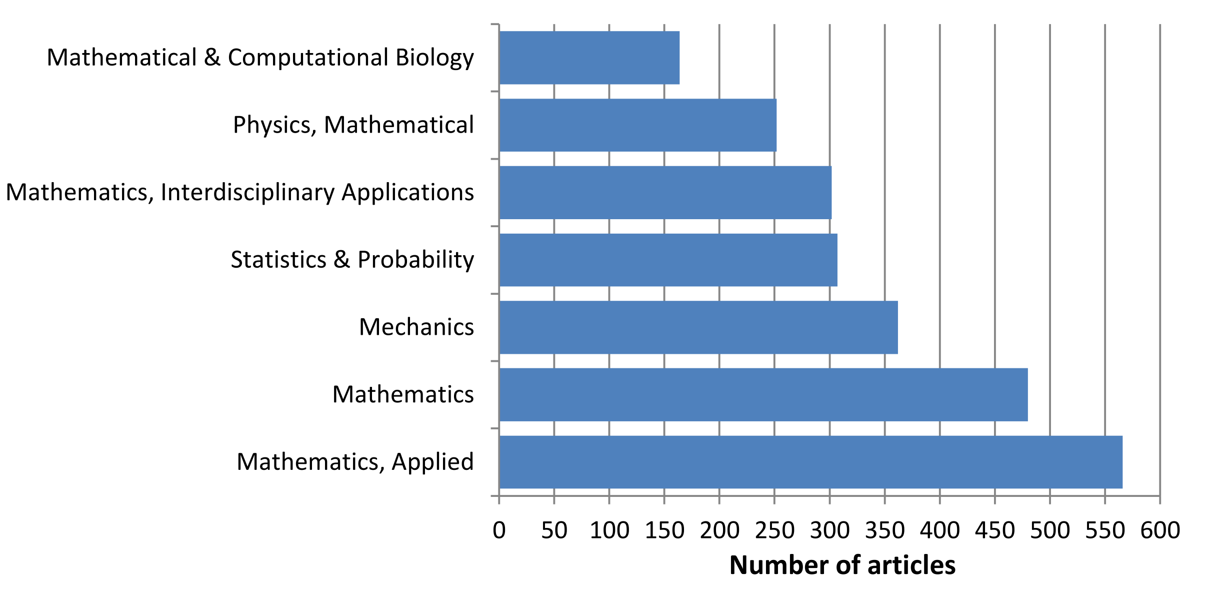
Physics, Mathematical: Includes journals that focus on mathematical methods in physics. It includes journals on logic, set theory, algebra, group theory, function theory, analysis, geometry, topology, and probability theory that have applications in physics.

Statistics & Probability: Covers journals concerned with methods of obtaining, analyzing, summarizing, and interpreting numerical or quantitative data. Journals on the study of the mathematical structures and constructions used to analyze the probability of a given set of events from a family of outcomes are also covered.

Mechanics: Includes journals that cover the study of the behavior of physical systems under the action of forces. Relevant topics in this category include fluid mechanics, solid mechanics, gas mechanics, mathematical modeling (chaos and fractals, finite element analysis), thermal engineering, fracture mechanics, heat and mass flow and transfer, phase equilibria studies, plasticity, adhesion, rheology, gravity effects, vibration effects, and wave motion analysis.

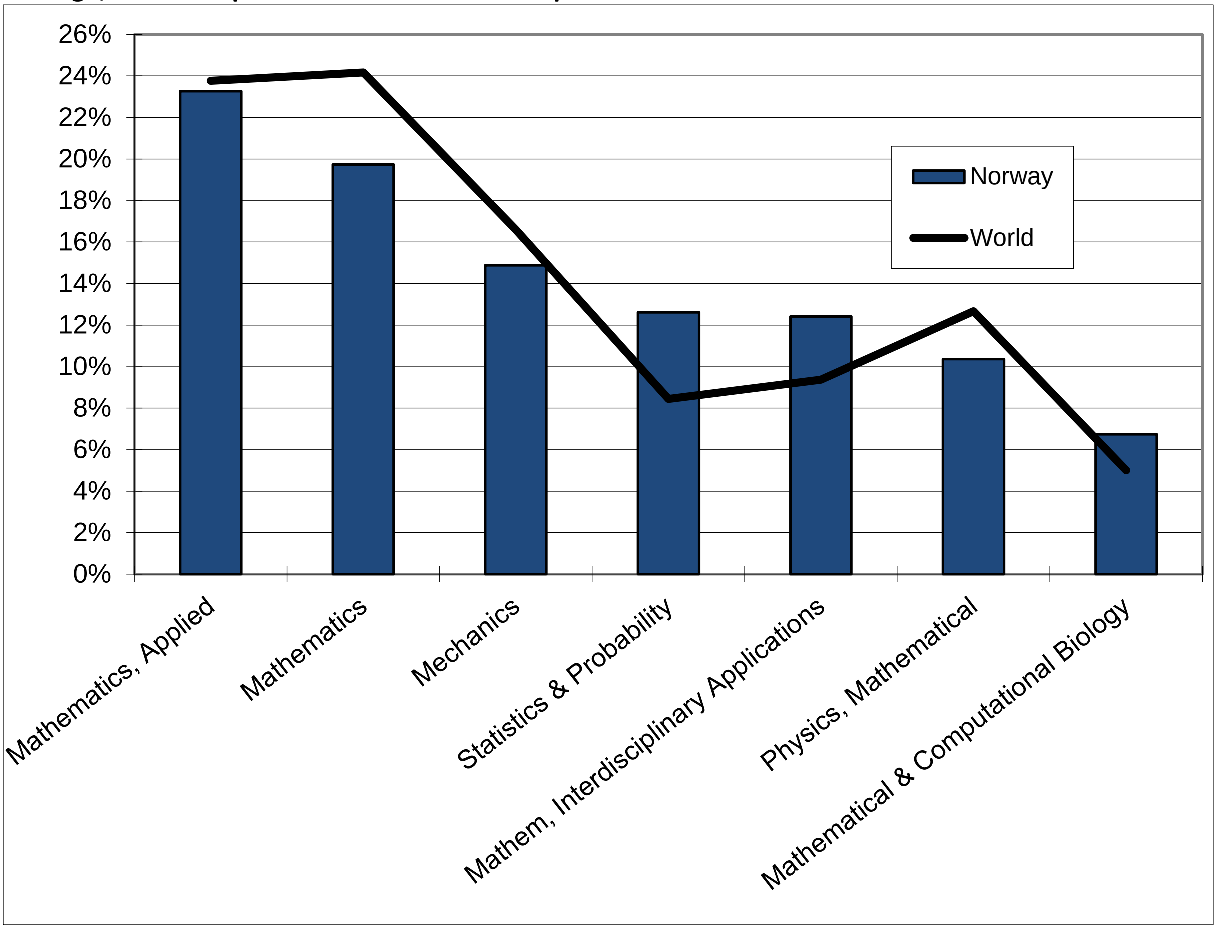
Figure 3.3 shows the distribution of articles for the 5-year period 2006–2010. We note that Mathematics, Applied by far is the largest category, and more than 560 articles have been published within this field by Norwegian researchers during the period. Next follows the general category Mathematics with 480 articles, and Mechanics with 360 articles.

Figure 3.3 Scientific publishing in Mathematics 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 Mathematics. 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 higher proportion of articles in Statistics and Probability and Interdisciplinary Applications than the world average (13 vs. 8 % and 12 vs. 9 %, respectively). On the other hand, Norway has lower proportions in Mathematics and Physics, Mathematical. It should be noted, however, that the world average should not be considered as a normative reference standard. For a country, particularly a small one like Norway, there may be strong reasons for specialising in some fields and not in others. With limited resources it is difficult to cover all fields equally. Thus, the analysis is primarily interesting for providing insight into the particular characteristics of Norwegian Mathematics.

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



The Norwegian contributions in the field of Mathematics (including Mechanics) are distributed on a large number of different journals (438 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 Mathematics and related fields for the period 2006–2010. The 56 most frequently used journals shown in the table account for 44 % of the Norwegian publication output in Mathematics.

On top of the list we find journals which are outside the core fields of Mathematics: fluid mechanics/physics and bioinformatics journals. Then follow *Journal of Computational and Applied Mathematics* and *Discrete applied Mathematics* where Norwegian researchers have published 22 and 20 articles, respectively, during the time period. 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 Mathematics.

Table 3.3 The most frequently used journals for the period 2006–2010, number of publications* from Norway, Mathematics (including Mechanics).

	2006	2007	2008	2009	2010	Total
PHYSICS OF FLUIDS	8	6	6	8	4	32
BMC BIOINFORMATICS	5	3	5	9	9	31
INTERNATIONAL JOURN FOR NUMERICAL METHO IN FLUIDS	8		4	10	8	30
JOURNAL OF FLUID MECHANICS	5	3	5	6	9	28
BIOINFORMATICS	2	5	6	7	6	26
JOURNAL OF COMPUTATIONAL PHYSICS	2	4	8	5	5	24
JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMAT	3	4	4	5	6	22
ENGINEERING FRACTURE MECHANICS	4	2	9	4	3	22
DISCRETE APPLIED MATHEMATICS		1	2	9	8	20
JOURNAL OF PHYSICS A-MATHEMATICAL AND THEORETICAL		10	3	1	6	20
INTERNATIONAL JOURNAL OF IMPACT ENGINEERING	3	2	3	7	4	19
JOURNAL OF ALGEBRA	1	3	6	4	4	18
MATHEMATICS OF COMPUTATION	5	7	4		1	17
JOURNAL OF FUNCTIONAL ANALYSIS	2	4	4	3	4	17
SIAM JOURNAL ON SCIENTIFIC COMPUTING	2	2	3	6	3	16
SCANDINAVIAN JOURNAL OF STATISTICS		4	7	4		15
MATHEMATICA SCANDINAVICA	3	3	1	6	2	15
COMPUTATIONAL STATISTICS & DATA ANALYSIS	2	4	3	3	3	15
STATISTICS IN MEDICINE	1	2	5	4	2	14
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES	2	3	3	3	3	14
PROBABILISTIC ENGINEERING MECHANICS			10		4	14
TRANSACTIONS OF THE AMERICAN MATHEMATICAL SOC	6		4	1	2	13
BIT NUMERICAL MATHEMATICS	5		2	2	4	13
ADVANCES IN MATHEMATICS	2	1	5	1	4	13
COMPUTER METHODS IN APPLIED MECHANICS AND ENGINE		2	4	2	4	12
DISCRETE MATHEMATICS	6			4	2	12
APPLIED NUMERICAL MATHEMATICS	3	2	2	3	2	12
PROCEEDINGS OF THE AMERICAN MATHEMATICAL SOCIETY	3	2	3	1	3	12
SIAM JOURNAL ON NUMERICAL ANALYSIS	2		3	5	2	12
JOURNAL OF ENGINEERING MATHEMATICS	1	3	4	1	3	12
JOURNAL OF PURE AND APPLIED ALGEBRA	1	2	5	1	3	12
APPLIED MATHEMATICAL MODELLING		2	2	4	4	12
PHILOSOPHICAL MAGAZINE	3	1	3	4	1	12
ACTA APPLICANDAE MATHEMATICAE	1	1	5	1	4	12
STOCHASTIC ENVIRONMENTAL RESEARCH AND RISK ASSESS	1		1	5	5	12
COMPTES RENDUS MATHEMATIQUE	3	2	2	1	3	11
MATHEMATICAL BIOSCIENCES		4	3	3	1	11
NETWORKS AND HETEROGENEOUS MEDIA		3	3	1	4	11
JOURNAL OF HYPERBOLIC DIFFERENTIAL EQUATIONS	2	2	4	2	1	11
DESIGNS CODES AND CRYPTOGRAPHY		3	6	1		10
JOURNAL OF MICROMECHANICS AND MICROENGINEERING	1		1	1	7	10
RISK ANALYSIS		1	2	2	5	10
INTERNAT JOURN OF NUMERICAL ANALYSIS & MODELING	3	2	1	3	1	10
PLOS COMPUTATIONAL BIOLOGY	2	1	3	3	1	10
NUMERISCHE MATHEMATIK	2	3	2	2		9
COMPUTER AIDED GEOMETRIC DESIGN	1		1	5	2	9
INTERNATIONAL JOURNAL OF MULTIPHASE FLOW	1	1	2	3	2	9
JOURNAL OF DIFFERENTIAL EQUATIONS	1	2	3	3		9
EUROPEAN JOURNAL OF MECHANICS A-SOLIDS	1		2	3	3	9
BULLETIN OF THE LONDON MATHEMATICAL SOCIETY	1	1		6	1	9
DISCRETE AND CONTINUOUS DYNAMICAL SYSTEMS	2		3	3	1	9
ESAIM-MATHEMATICAL MODELLING AND NUMERICAL ANAL	2	1		5	1	9
JOURNAL OF STATISTICAL PLANNING AND INFERENCE	3	1	1	2	2	9
COMMUNICATIONS IN COMPUTATIONAL PHYSICS	1	1	1	3	3	9
NATURAL RESOURCE MODELING		2	4	1	2	9
PROGRESS IN COMPUTATIONAL FLUID DYNAMICS	1	3		4	1	9

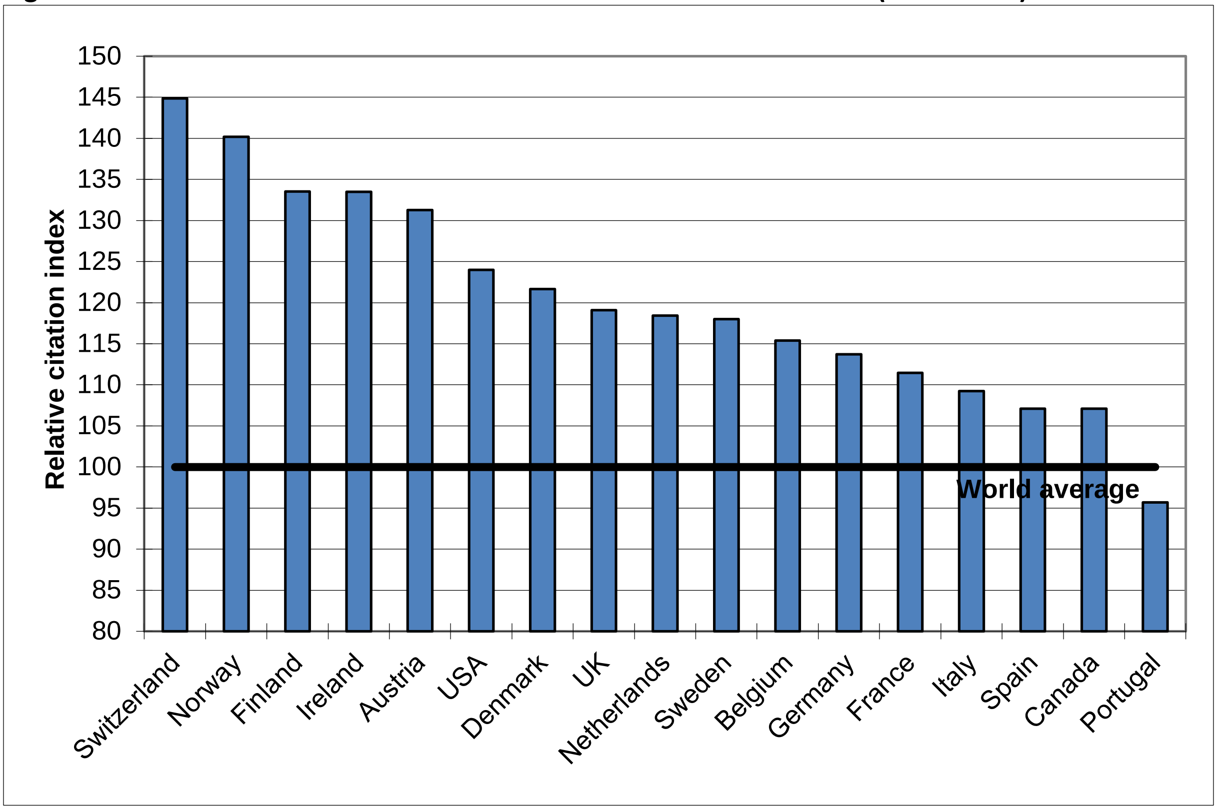
*) Includes the following publication types: articles, review papers and proceedings papers.

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 Mathematics for a selection of countries, based on the citations to the publications from the three year period 2006–2008. The publications from Switzerland are most highly cited, approximately 45 per cent above world average. Norway ranks as number 2 among the 17 countries shown in this figure, with a citation index of 140. In other words, Norway performs very well in terms of citation rates, and Norway is among the leading countries in the world. The Norwegian index in Mathematics is also higher than the Norwegian total (all disciplines) for this period, which is approximately 125. It should be added that the world average does not constitute a very ambitious reference standard as it includes publications from countries with less developed science systems.

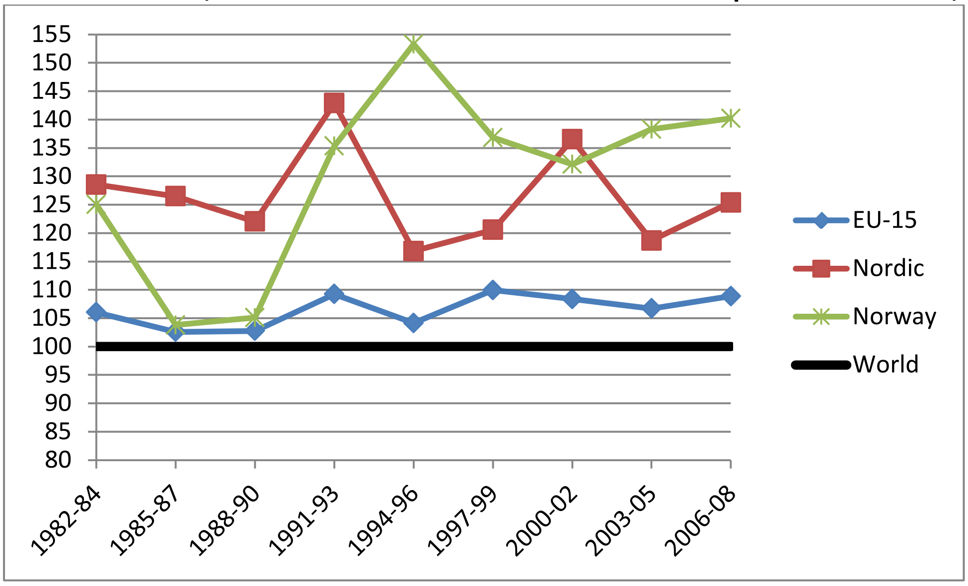
Figure 3.5 Relative citation index in Mathematics for selected countries (2006–2008).*



*) 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 Mathematics 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. [6] However, there is a positive trend and from 1994 and onwards, the Norwegian publications have been significantly more frequently cited than the EU-15 publications and also the Nordic publications (with an exception of the 2000-2002 publications where there is a peak for the Nordic publications). Thus, the high citation rate of the 2006-08 publications is not an isolated case, and Norway has performed very well for many years in terms of citation rates in Mathematics.

Figure 3.6 Relative citation index* in Mathematics 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.



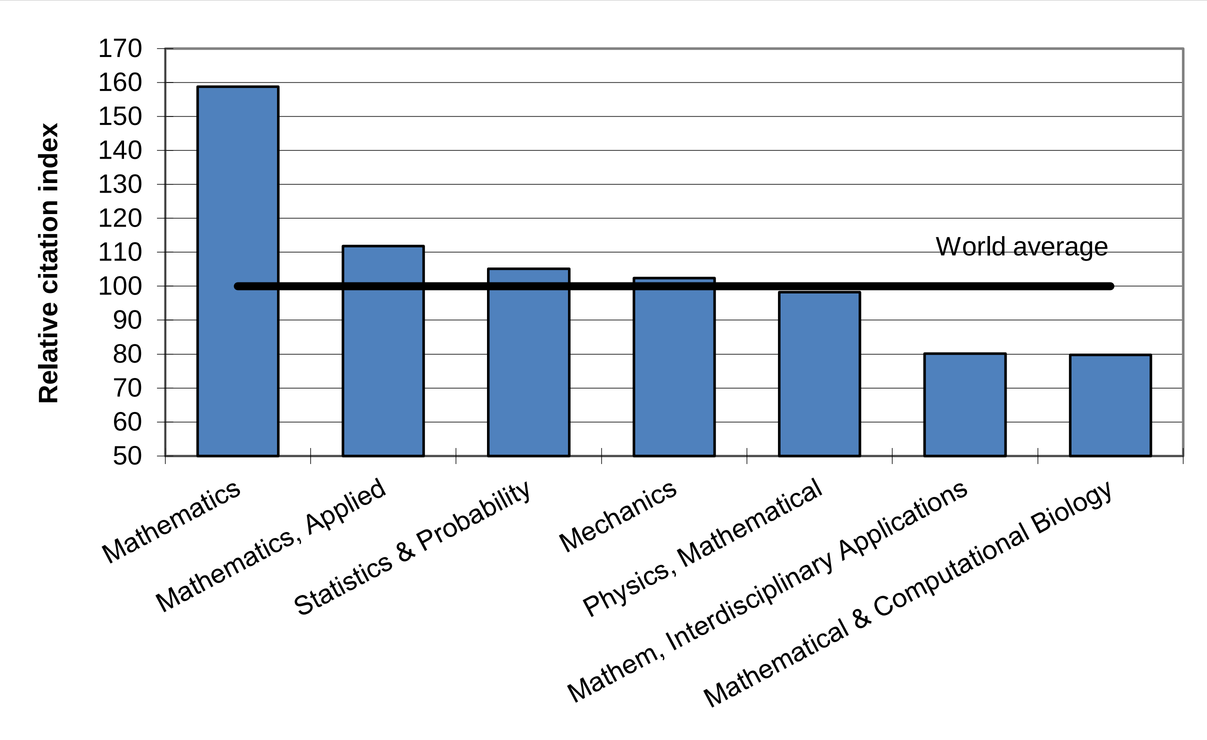
*) Based on annual publication windows and accumulated citations to these publications.

The overall citation index for Mathematics 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 Mathematics for the 2006–2008 publications. Norway performs very well in the broad field Mathematics where the publications are cited almost 60 per cent above the world average (citation index 159). Then follows Applied Mathematics with citation index of 112. In Statistics & Probability, Mechanics, and Physics, Mathematical the citation index is close to the world average (105-98), while the publications in Mathematics, Interdisciplinary and Mathematical & Computational Biology do not even reach the world-average with a citation index of 80. In other words, the picture is mixed at subfield level,

[6] 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.

and the publications in the subfield Mathematics contribute significantly to the high citation rate of the field as a whole.

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



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

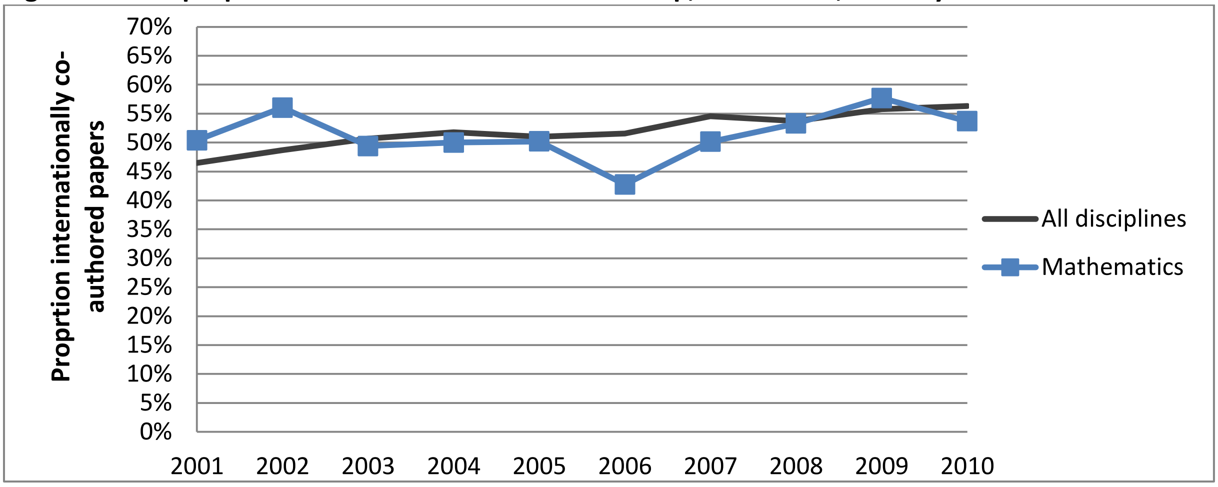
3.3 Collaboration indicators

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 Mathematics (including Mechanics) and for all disciplines (national total). In Mathematics, 54 % 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 Mathematics has varied from 43 % to 56 % during the 10 year period. 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 Mathematics? 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 13 % of the "Norwegian" articles within Mathematics also had co-authors from this nation. Next follows France – 7 % of the "Norwegian" articles were co-authored with French scientists – and UK and Germany (6 %).

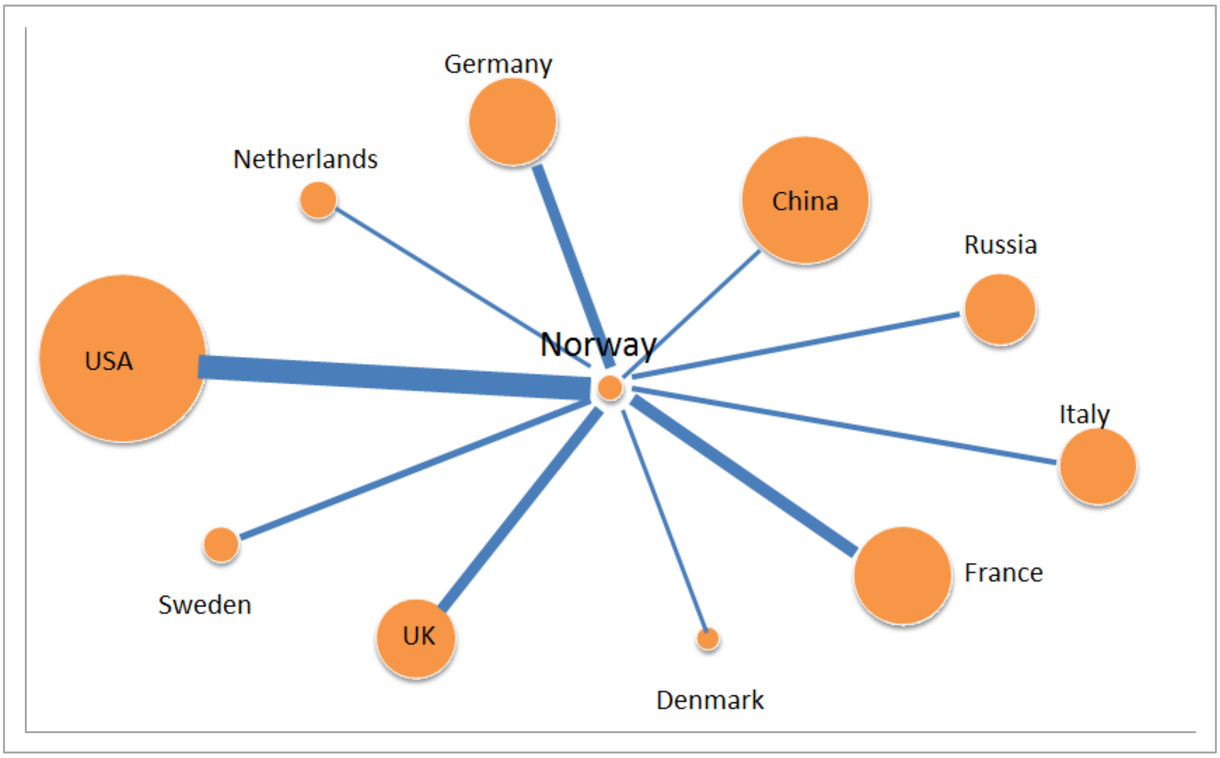
Table 3.4 Collaboration by country* 2001–2010. Number and proportion of the Norwegian article production in Mathematics with co-authors from the respective countries.

Country	Num. articles	Proportion	Country	Num. articles	Proportion
USA	254	13 %	Spain	30	2 %
France	141	7 %	India	23	1 %
UK	121	6 %	Austria	22	1 %
Germany	119	6 %	Finland	21	1 %
Sweden	71	4 %	Belgium	21	1 %
Italy	66	3 %	Japan	20	1 %
Russia	65	3 %	Singapore	19	1 %
China	50	3 %	Israel	19	1 %
Denmark	44	2 %	Ukraine	19	1 %
Netherlands	43	2 %	Poland	18	1 %
Canada	39	2 %	Czech Repub	16	1 %
Australia	32	2 %	Switzerland	15	1 %

*) 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 Mathematics graphically for the 11 most important collaborative partners.

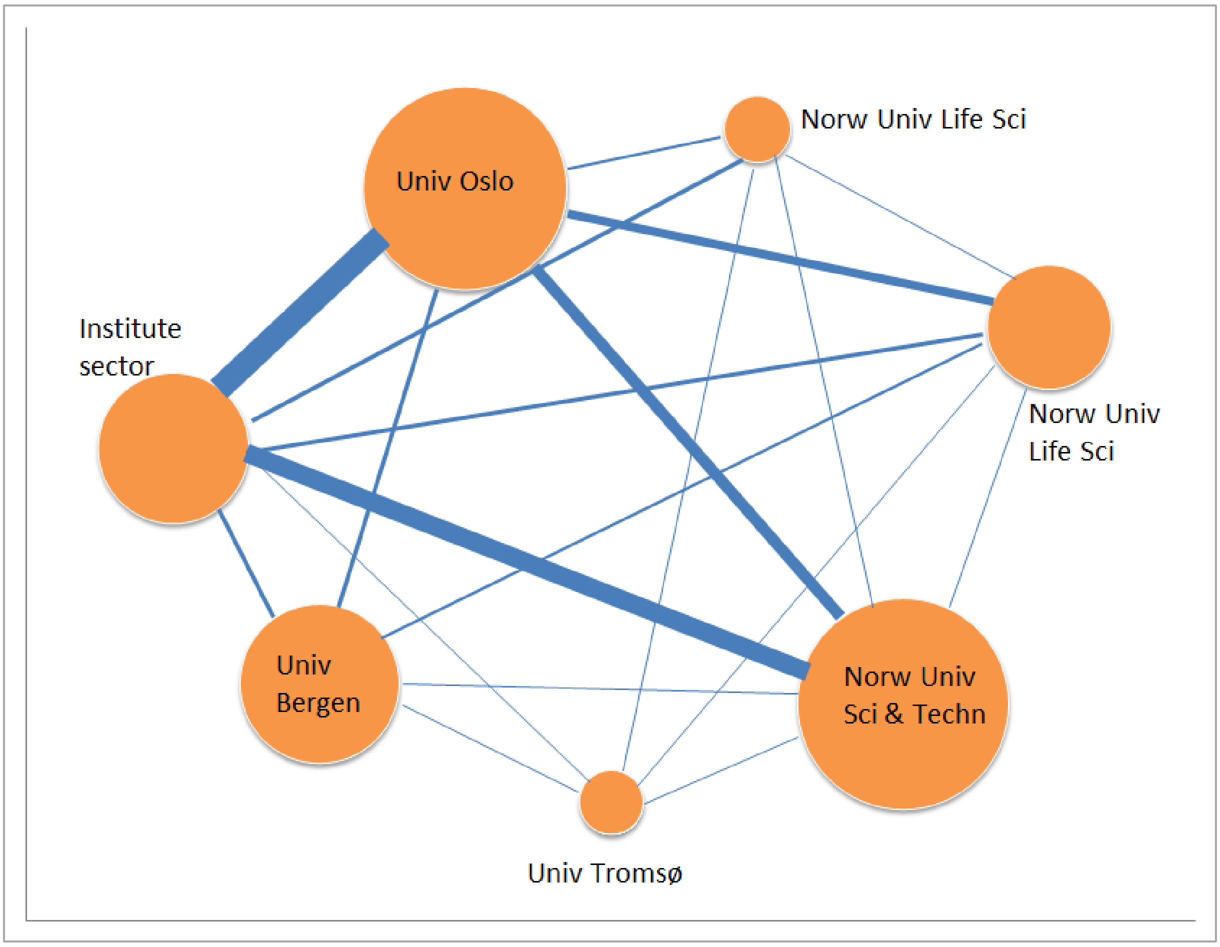
Figure 3.9 Graphical illustration of the international collaboration profile* of Norwegian Mathematics (2001-2010).



*) 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 Mathematics 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 are illustrated in Figure 3.10. In the figure, the surface area of the circles is proportional to the total publication output in Mathematics, 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 the Norwegian University of Science and Technology (NTNU) as well as institutes in the institute sector. Also NTNU has much collaboration with the institute sector. Of the universities, the University of Life Sciences (UMB) and UiO have significantly more external national collaboration in relative terms than the universities in Bergen and Tromsø, while NTNU has an intermediate position. The research profile of the units in the institute sector is characterised by extensive external national collaboration.

Figure 3.9 Graphical illustration of the national collaboration profile* of Norwegian Mathematics (2006-2010).



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

4 Institutional analyses

4.1 Norwegian University of Life Sciences (UMB)

Two research groups at the Norwegian University of Life Sciences are included in the evaluation: The Research Group Applied Mathematics/Computational Biology at the Department of Mathematical Sciences and Technology and the Biostatistics Group at the Department of Chemistry, Biotechnology and Food Science. Both groups are quite small both in terms of staff members and publication output.

Table 4.1.1 shows various publication indicators for the research groups. The research group Biostatistics has published 2.0 publications per full time equivalent (FTE) which is close to the average for all units covered by this evaluation (1.9). The corresponding figure for the Applied Mathematics/Computational Biology is 2.4.

Table 4.1.1 Number of publications, 2006–2010, Norwegian University of Life Sciences.

Unit	Number of persons	Number of man years (FTE)	Total number of publications	Publications in journals	Total number of publications per number of FTE
Biostatistics	3	11	22	19	2.0
Applied Mathematics/Computa-tional Biology	4	16	38	33	2.4

Table 4.1.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006–2010.

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

Unit	Journal	Numb. of articles
TOTAL - UMB	CHEMOMETRICS AND INTELLIGENT LABORATORY SYSTEMS	6
	JOURNAL OF CHEMOMETRICS	6
	PHYSICA D-NONLINEAR PHENOMENA	3
Biostatistics Group	CHEMOMETRICS AND INTELLIGENT LABORATORY SYSTEMS	4
	JOURNAL OF CHEMOMETRICS	3
Applied Mathematics/Computational Biology	JOURNAL OF CHEMOMETRICS	4
	PHYSICA D-NONLINEAR PHENOMENA	3

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

Table 4.1.3 contains a citation and journal profile of the groups based on the journal articles (indexed in NCR) published in the period 2006–2009. Of the two groups the Biostatistics group obtains higher scores than the Applied Mathematics/Computational Biology group, although it should be considered that the number of articles underlying this analysis is quite limited. The Biostatistics Research Group has a field normalized citation index of 98. In other words, the articles are almost equal to the corresponding world average. The field normalized index for the Applied Mathematics/Computational Biology group is 74. Compared to the corresponding Norwegian average the groups obtain even lower citation indexes (88 and 66, respectively).

Table 4.1.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. Norwegian University of Life Sciences.

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]
TOTAL - UMB	28	112	18	90	88	80	103
Biostatistics	13	67	18	106	106	94	100
Applied Mathematics/Computa-tional Biology	15	45	11	74	70	66	106

*) 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 Norwegian University of Science and Technology (NTNU)

At the Norwegian University of Science and Technology (NTNU) the evaluation encompasses the Department of Mathematical Sciences.

Table 4.2.1 shows various publication indicators for the department and its research groups. In the period 2006-2010, almost 400 journal articles have been published, in addition to more than 60 other scientific publications such as proceeding articles. Overall the department has a productivity of 2.0 publications per full time equivalent (FTE), which is close to the average for all units covered by this evaluation (1.9). However, the productivity varies considerably between the groups, and the B2 and B4 groups have a productivity of only 0.9 and 1.0, respectively.

Table 4.2.1 Number of publications, 2006–2010, Norwegian University of Science and Technology.

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 Mathematical Sciences	53	228	449	383	2.0
B1	8	34	77	66	2.3
B2	9	41	36	34	0.9
B3	15	63	123	103	2.0
B4	5	24	23	19	1.0
B5	16	66	190	161	2.9

Table 4.2.2 a and b give the most frequently used journals for the department and the research groups – limited to journals with at least three publications during the period 2006–2010. Therefore, for one of the groups there are no journals on this list.

Table 4.2.2a The most frequently used journals*, number of publications 2006–2010 by department. NTNU.

Journal	Numb. of articles
JOURNAL OF ALGEBRA	11
GEOPHYSICS	8
JOURNAL OF ENGINEERING MECHANICS-ASCE	8
DISCRETE AND CONTINUOUS DYNAMICAL SYSTEMS	7
JOURNAL OF ANIMAL ECOLOGY	7
JOURNAL OF OFFSHORE MECHANICS AND ARCTIC ENGINEERING-TRANSACTIONS OF ASME	7
JOURNAL OF PURE AND APPLIED ALGEBRA	7
INTERNATIONAL MATHEMATICS RESEARCH NOTICES	6
JOURNAL OF HYPERBOLIC DIFFERENTIAL EQUATIONS	6
ADVANCES IN MATHEMATICS	5
APPLIED OCEAN RESEARCH	5
COLLOQUIUM MATHEMATICUM	5
COMPUTATIONAL STATISTICS & DATA ANALYSIS	5
IMA JOURNAL OF NUMERICAL ANALYSIS	5
PROBABILISTIC ENGINEERING MECHANICS	5
PROCEEDINGS OF THE AMERICAN MATHEMATICAL SOCIETY	5
AMERICAN NATURALIST	4
COMMUNICATIONS IN ALGEBRA	4
COMMUNICATIONS IN PARTIAL DIFFERENTIAL EQUATIONS	4
EVOLUTION	4
JOURNAL OF STATISTICAL PLANNING AND INFERENCE	4
SIAM JOURNAL ON NUMERICAL ANALYSIS	4
BULLETIN OF THE LONDON MATHEMATICAL SOCIETY	3
COMPUTER METHODS IN APPLIED MECHANICS AND ENGINEERING	3
ESAIM-MATHEMATICAL MODELLING AND NUMERICAL ANALYSIS	3
EXPOSITIONES MATHEMATICAE	3
FOUNDATIONS OF COMPUTATIONAL MATHEMATICS	3
HOMOLOGY HOMOTOPY AND APPLICATIONS	3
INTERNATIONAL JOURNAL OF NON-LINEAR MECHANICS	3
JOURNAL OF APPLIED MECHANICS-TRANSACTIONS OF THE ASME	3
JOURNAL OF DIFFERENTIAL EQUATIONS	3
JOURNAL OF SOUND AND VIBRATION	3
JOURNAL OF THEORETICAL BIOLOGY	3
MATHEMATICS OF COMPUTATION	3
MATHEMATISCHE ZEITSCHRIFT	3
RAMANUJAN JOURNAL	3
SCANDINAVIAN JOURNAL OF STATISTICS	3
STRUCTURAL SAFETY	3

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

Table 4.2.2b The most frequently used journals*, number of publications 2006–2010 by group. NTNU.

Group	Journal	Numb. of articles
B1	JOURNAL OF ALGEBRA	11
	JOURNAL OF PURE AND APPLIED ALGEBRA	7
	ADVANCES IN MATHEMATICS	5
	COLLOQUIUM MATHEMATICUM	5
	COMMUNICATIONS IN ALGEBRA	4
	MATHEMATISCHE ZEITSCHRIFT	3
B2	RAMANUJAN JOURNAL	3
B3	DISCRETE AND CONTINUOUS DYNAMICAL SYSTEMS	7
	JOURNAL OF HYPERBOLIC DIFFERENTIAL EQUATIONS	6
	IMA JOURNAL OF NUMERICAL ANALYSIS	5
	COMMUNICATIONS IN PARTIAL DIFFERENTIAL EQUATIONS	4
	INTERNATIONAL MATHEMATICS RESEARCH NOTICES	4
	SIAM JOURNAL ON NUMERICAL ANALYSIS	4
	COMPUTER METHODS IN APPLIED MECHANICS AND ENGINEERING	3
	ESAIM-MATHEMATICAL MODELLING AND NUMERICAL ANALYSIS-MODELISATION MATHEMATIQUE ET ANALYSE NUMERIQUE	3
	FOUNDATIONS OF COMPUTATIONAL MATHEMATICS	3
	JOURNAL OF DIFFERENTIAL EQUATIONS	3
	MATHEMATICS OF COMPUTATION	3
B5	GEOPHYSICS	8
	JOURNAL OF ENGINEERING MECHANICS-ASCE	8
	JOURNAL OF ANIMAL ECOLOGY	7
	JOURNAL OF OFFSHORE MECHANICS AND ARCTIC ENGINEERING-TRANSACTIONS OF THE ASME	6
	APPLIED OCEAN RESEARCH	5
	COMPUTATIONAL STATISTICS & DATA ANALYSIS	5
	PROBABILISTIC ENGINEERING MECHANICS	5
	AMERICAN NATURALIST	4
	EVOLUTION	4
	JOURNAL OF STATISTICAL PLANNING AND INFERENCE	4
	INTERNATIONAL JOURNAL OF NON-LINEAR MECHANICS	3
	JOURNAL OF APPLIED MECHANICS-TRANSACTIONS OF THE ASME	3
	JOURNAL OF SOUND AND VIBRATION	3
	SCANDINAVIAN JOURNAL OF STATISTICS	3
	STRUCTURAL SAFETY	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 groups based on the journal articles (indexed in NCR) published in the period 2006–2009. Overall, the department obtains a field normalized citation index of 127. In other words, the articles are cited 27 % above the world average, moreover 8 % above the corresponding Norwegian average. The B1 research group performs extremely well in terms of citation rates, with a field normalized citation index of

532. Also the publications of the B3 group are quite highly cited with a field normalized citation index of 158. On the other hand, the three groups B2, B4 and B5 have corresponding index values in the range if 57-83, in other words, clearly below the world average.

Table 4.2.3 Citation and journal indicators, 2006–2009 publications indexed in NCR *. Norwegian University of Science and Technology.

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]
TOTAL Dep of Mathematical Sciences	271	1138	85	127	119	108	107
B1	44	332	85	434	453	289	96
B2	23	29	6	76	88	61	86
B3	69	275	27	161	147	139	109
B4	11	12	4	57	78	45	73
B5	124	490	30	83	76	73	110

*) 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.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all journal articles where the department is listed as an author address is 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. In both periods, the publications have been cited somewhat higher than the corresponding field normalised world average and close to the Norwegian average.

Table 4.2.4 Citation and journal indicators, 2001–2009 publications indexed in NCR. Norwegian University of Science and Technology.

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]
2001-2005*	272	2729	84	113	88	97	128
2006-2009**	334	1321	85	123	116	104	106

*) 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.

4.3 University of Agder (UiA)

At the University of Agder, two research groups at the Department of Mathematical Sciences are included in the evaluation: Mathematics and Mathematics/Mathematics education. Table 4.3.1 shows various publication indicators for the research groups. The number of publications per number of man year (full-time equivalents FTE) is with 1.2 and 1.1, respectively, below the average for all units covered by this evaluation (1.9).

Table 4.3.1 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
TOTAL - Dep of Mathematical Sciences	10	44	50	38	1.1
Mathematics	5	20	24	19	1.2
Mathematics/Mathematics Education	5	24	26	19	1.1

Table 4.3.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006-2010.

Table 4.3.2 The most frequently used journals*, number of publications 2006–2010 by unit. UiA.

UNIT	Journal	Numb. of articles
TOTAL - Dep of Mathematical Sciences	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT	5
	IEEE TRANSACTIONS ON MAGNETICS	4
	HISTORIA MATHEMATICA	4
	INTEGRAL TRANSFORMS AND SPECIAL FUNCTIONS	4
Mathematics	NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT	5
	INTEGRAL TRANSFORMS AND SPECIAL FUNCTIONS	4
	IEEE TRANSACTIONS ON MAGNETICS	4
Mathematics/Mathematics Education	HISTORIA MATHEMATICA	4

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

Table 4.3.3 contains a citation and journal profile of the groups based on the journal articles (indexed in NCR) published in the period 2006–2009. Of the two groups the Mathematics group obtains significantly higher scores than the Mathematics/Mathematics Education group, although it should be considered that the number of articles underlying this analysis is quite limited. Both groups publish in journals that are relatively little cited (i.e. have low impact factor), which is reflected by a journal profile of approximately 60.

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

Unit	Number of articles	Number of citations	Max cited article	Citation index – field	Citation index – journal	Citation index – Norway	Journal profile
TOTAL	30	100	21	126	204	112	62
Mathematics	16	89	21	170	280	149	61
Mathematics/ Mathematics Education	14	11	3	40	64	37	63

*) 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 Bergen (UiB)

One department at the University of Bergen has been included in the evaluation: Department of Mathematics. Table 4.4.1 shows various publication indicators for the department and its research groups. In the period 2006-2010, almost 250 journal articles have been published by the personnel encompassed by the evaluation, in addition to approximately 40 other scientific publications. Overall the department has a productivity of 2.1 publications per full time equivalent (FTE), which is somewhat higher than the average for all units covered by this evaluation (1.9). However, the productivity varies considerably between the groups. The Reservoir Mechanics (RM) has a productivity of 2.9 publications on the one hand, while the Topology group has a productivity of 1.0 on the other.

Table 4.4.1 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 Mathematics	33	136	286	248	2.1
Algebra/Algebraic Geometry (AG)	4	18	21	20	1.2
Analysis (A)	3	15	27	23	1.8
Applied and Computational Mathematics (AC)	9	40	104	84	2.6
Number Theory (NT)	2	7	15	11	2.1
Reservoir Mechanics (RM)	5	15	43	37	2.9
Statistics (S)	6	26	62	60	2.4
Topology (T)	4	16	16	15	1.0

Table 4.4.2 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 on this list.

Table 4.4.2 The most frequently used journals*, number of publications 2006–2010 by unit. UiB.

Unit	Journal	Numb. of articles
TOTAL - Department of Mathematics	OCEAN DYNAMICS	9
	ADVANCES IN WATER RESOURCES	8
	COMPUTATIONAL GEOSCIENCES	8
	OCEAN MODELLING	5
	WATER RESOURCES RESEARCH	5
	ADVANCES IN MATHEMATICS	4
	INTERNATIONAL JOURNAL OF NUMERICAL ANALYSIS AND MODELING	4
	MATHEMATICS AND COMPUTERS IN SIMULATION	4
	ANNALS OF STATISTICS	3
	BRITISH JOURNAL OF CANCER	3
	CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES	3
	COMPLEX ANALYSIS AND OPERATOR THEORY	3
	CONTINENTAL SHELF RESEARCH	3
	ECONOMETRIC THEORY	3
	INTERNATIONAL JOURNAL OF COMPUTER VISION	3
Analysis (A)	COMPLEX ANALYSIS AND OPERATOR THEORY	3
Applied and Computational Mathematics (AC)	OCEAN DYNAMICS	9
	OCEAN MODELLING	5
	INTERNATIONAL JOURNAL OF NUMERICAL ANALYSIS AND MODELING	4
	MATHEMATICS AND COMPUTERS IN SIMULATION	4
	CONTINENTAL SHELF RESEARCH	3
	INTERNATIONAL JOURNAL OF COMPUTER VISION	3
Reservoir Mechanics (RM)	ADVANCES IN WATER RESOURCES	8
	COMPUTATIONAL GEOSCIENCES	7
	WATER RESOURCES RESEARCH	5
Statistics (S)	ANNALS OF STATISTICS	3
	BRITISH JOURNAL OF CANCER	3
	CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES	3
	ECONOMETRIC THEORY	3
Topology (T)	ADVANCES IN MATHEMATICS	4

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

Table 4.4.3 contains a citation and journal profile of the groups based on the journal articles (indexed in NCR) published in the period 2006–2009. However, for two of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). Overall, the department obtains a field normalised citation index of 104. In other words, the articles are cited 4 % more than the corresponding world-average. Compared to the corresponding Norwegian average the citation index is 84. The Reservoir Mechanics (RM) has the highest field normalized citation index (154). Other groups perform less well in terms of citation rates, notably Algebra/Algebraic Geometry (AG), Analysis (A), and Statistics (S) with field normalised citation indexes in the range of 69-84.

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

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]
TOTAL - Department of Mathematics	184	700	27	104	96	83	108
Algebra/Algebraic Geometry (AG)	12	14	5	69	84	44	83
Analysis (A)	19	29	6	80	75	65	107
Applied and Computational Mathematics (AC)	65	279	24	123	123	102	101
Number Theory (NT)	7	2	2	-	-	-	-
Reservoir Mechanics (RM)	28	151	27	154	134	127	115
Statistics (S)	45	216	21	82	72	65	114
Topology (T)	9	12	5	-	-	-	-

*) 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.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all journal articles where the department is listed as an author address is 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. The analysis shows that 2001-2005 publications were more cited, relatively, compared to the 2006-2009 publications.

Table 4.4.4 Citation and journal indicators, 2001–2009 publications indexed in NCR. UiB.

	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
2001-2005*	180	2179	62	138	121	111	114
2006-2009**	237	831	27	99	93	81	106

*) 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 Oslo (UiO)

One department at the University of Oslo is included in the evaluation: Department of Mathematics. Table 4.5.1 shows various publication indicators for the department and its research groups. In terms of publication output, the department is the largest of the departments that have been included in the evaluation. In the period 2006-2010, more than 400 journal articles have been published, in addition to approximately 100 other scientific publications. Overall the department has a productivity of 1.9 publications per full time equivalent (FTE), which is equal to the average for all units covered by this evaluation (1.9). However, the productivity varies considerably between the groups and is particularly high at the Partial Differential Equations group (4.3).

Table 4.5.1 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 Mathematics	62	259	498	403	1.9
Algebra and algebraic geometry	7	26	20	17	0.8
Computational mathematics	7	35	78	56	2.3
Fluid Mechanics	7	24	45	35	1.9
Geometry and topology	5	22	30	26	1.4
Logic	1	5	6	3	1.2
Operator algebras	4	20	16	13	0.8
Partial Differential Equations	8	29	126	113	4.3
Several Complex Variables	3	10	14	14	1.4
Solid mechanics	2	10	22	13	2.2
Statistics and biostatistics	7	35	59	52	1.7
Stochastic analysis, finance, insurance and risk	11	45	84	63	1.9

Table 4.5.2 a and b give the most frequently used journals for the department and the 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 4.5.2a The most frequently used journals*, number of publications 2006–2010 by department. UiO.

Department	Journal	Numb. of articles
TOTAL - Department of Mathematics	MATHEMATICS OF COMPUTATION	12
	BIT NUMERICAL MATHEMATICS	8
	SCANDINAVIAN JOURNAL OF STATISTICS	8
	JOURNAL OF FLUID MECHANICS	7
	MATHEMATICA SCANDINAVICA	7
	SIAM JOURNAL ON NUMERICAL ANALYSIS	7
	COMPUTER AIDED GEOMETRIC DESIGN	6
	JOURNAL OF DIFFERENTIAL EQUATIONS	6
	JOURNAL OF ENGINEERING MATHEMATICS	6
	JOURNAL OF HYPERBOLIC DIFFERENTIAL EQUATIONS	6
	NETWORKS AND HETEROGENEOUS MEDIA	6
	NUMERISCHE MATHEMATIK	6
	COMPUTER GRAPHICS FORUM	5
	JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS	5
	LINEAR ALGEBRA AND ITS APPLICATIONS	5
	STOCHASTIC ANALYSIS AND APPLICATIONS	5
	ADVANCES IN COMPUTATIONAL MATHEMATICS	4
	BULLETIN OF THE LONDON MATHEMATICAL SOCIETY	4
	COMPUTATIONAL GEOSCIENCES	4
	ENGINEERING STRUCTURES	4
	INTERNATIONAL JOURNAL OF MATHEMATICS	4
	JOURNAL OF COMPUTATIONAL PHYSICS	4
	JOURNAL OF FUNCTIONAL ANALYSIS	4
	STOCHASTICS-AN INTERNATIONAL JOURNAL OF PROBABILITY AND STOCHASTIC PROCESSES	4
	ADVANCES IN MATHEMATICS	3
	ANNALS OF STATISTICS	3
	COMMUNICATIONS IN PARTIAL DIFFERENTIAL EQUATIONS	3
	COMPTES RENDUS MATHEMATIQUE	3
	COMPUTER METHODS IN APPLIED MECHANICS AND ENGINEERING	3
	ENERGY ECONOMICS	3
	IMA JOURNAL OF NUMERICAL ANALYSIS	3
	INFINITE DIMENSIONAL ANALYSIS QUANTUM PROBABILITY AND RELATED TOPICS	3
	INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN FLUIDS	3
	INTERNATIONAL JOURNAL OF THEORETICAL AND APPLIED FINANCE	3
	LIFETIME DATA ANALYSIS	3
	MATHEMATICAL MODELS & METHODS IN APPLIED SCIENCES	3
	MATHEMATISCHE ANNALEN	3
	PHYSICS OF FLUIDS	3

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

Table 4.5.2b The most frequently used journals*, number of publications 2006–2010 by group. UiO.

Group	Journal	Numb. of articles
Computational mathematics	COMPUTER AIDED GEOMETRIC DESIGN	6
	COMPUTER GRAPHICS FORUM	5
	ADVANCES IN COMPUTATIONAL MATHEMATICS	4
	LINEAR ALGEBRA AND ITS APPLICATIONS	4
	BIT NUMERICAL MATHEMATICS	3
	JOURNAL OF COMPUTATIONAL AND APPLIED MATHEMATICS	3
	MATHEMATICS OF COMPUTATION	3
Fluid Mechanics	JOURNAL OF FLUID MECHANICS	7
	PHYSICS OF FLUIDS	3
Geometry and topology	MATHEMATICA SCANDINAVICA	3
Partial Differential Equations	MATHEMATICS OF COMPUTATION	9
	JOURNAL OF DIFFERENTIAL EQUATIONS	6
	JOURNAL OF HYPERBOLIC DIFFERENTIAL EQUATIONS	6
	NETWORKS AND HETEROGENEOUS MEDIA	6
	SIAM JOURNAL ON NUMERICAL ANALYSIS	6
	BIT NUMERICAL MATHEMATICS	5
	NUMERISCHE MATHEMATIK	5
	JOURNAL OF ENGINEERING MATHEMATICS	4
	COMMUNICATIONS IN PARTIAL DIFFERENTIAL EQUATIONS	3
	COMPUTATIONAL GEOSCIENCES	3
	JOURNAL OF COMPUTATIONAL PHYSICS	3
	MATHEMATICAL MODELS & METHODS IN APPLIED SCIENCES	3
Solid mechanics	ENGINEERING STRUCTURES	4
Statistics and biostatistics	SCANDINAVIAN JOURNAL OF STATISTICS	5
	ANNALS OF STATISTICS	3
	LIFETIME DATA ANALYSIS	3
Stochastic analysis, finance, insurance and risk	STOCHASTIC ANALYSIS AND APPLICATIONS	5
	STOCHASTICS-AN INTERNATIONAL JOURNAL OF PROBABILITY AND STOCHASTIC PROCESSES	4
	ENERGY ECONOMICS	3
	INFINITE DIMENSIONAL ANALYSIS QUANTUM PROBABILITY AND RELATED TOPICS	3
	INTERNATIONAL JOURNAL OF THEORETICAL AND APPLIED FINANCE	3
	SCANDINAVIAN JOURNAL OF STATISTICS	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. However, for two of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). Overall, the department obtains a field normalized citation index of 122. In other words, the articles are cited 22 % above the world average, moreover 4 % above the corresponding Norwegian average. The Partial Differential Equations research group and the Fluid Mechanics group perform very well in terms of citation rates, with a field normalized citation index of 198 and 158, respectively. On the other hand, the publications of the groups Algebra and algebraic geometry, Stochastic analysis, finance, insurance and risk, and Solid mechanics are little cited with field normalized citation indexes of 22, 51 and 65, respectively.

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

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]
TOTAL	293	1065	42	122	104	104	117
Algebra and algebraic geometry	14	6	3	22	25	15	89
Computational mathematics	49	153	21	136	109	113	124
Fluid Mechanics	28	176	40	158	164	141	97
Geometry and topology	13	28	6	115	90	67	128
Logic	3	4	3	-	-	-	-
Operator algebras	10	14	6	76	66	69	116
Partial Differential Equations	81	400	42	198	164	171	121
Several Complex Variables	8	13	7	-	-	-	-
Solid mechanics	10	16	6	65	75	63	86
Statistics and biostatistics	43	243	40	103	75	88	138
Stochastic analysis, finance, insurance and risk	36	54	7	51	52	47	96

*) 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.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all journal articles where the department is listed as an author address is 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. The analysis shows that 2001-2005 publications were slightly more cited, relatively, compared to the 2006-2009 publications.

Table 4.5.4 Citation and journal indicators, 2001–2009 publications indexed in NCR. UiO.

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]
2001-2005*	334	4099	238	138	117	112	118
2006-2009**	507	2563	72	126	105	107	120

*) 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.

4.6 University of Stavanger (UiS)

At the University of Stavanger, the evaluation encompasses the Section Mathematics at the Department of Mathematics and Natural Science. Table 4.6.1 shows various publication indicators for the section and its research groups. Overall the department has a productivity of 1.7 publications per full time equivalent (FTE), which is slightly below the average for all units covered by this evaluation (1.9). However, there are large differences between the groups, and the Statistics group has a very high productivity with 4.3 publications per full time equivalent (FTE).

Table 4.6.1 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
TOTAL - Department of Mathematics and Natural Science, Section of Mathematics	10	43	72	66	1.7
Analysis	4	20	14	11	0.7
Applied	4	14	19	19	1.4
Statistics	2	9	39	36	4.3

Table 4.6.2 gives the most frequently used journals – limited to journals with at least three publications during the period 2006-2010.

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

Unit	Journal	Numb. of articles
TOTAL - Department of Mathematics and Natural Science, Section of Mathematics	CLASSICAL AND QUANTUM GRAVITY	12
	RESUSCITATION	6
	COMPTES RENDUS MATHEMATIQUE	3
	CIRCULATION	3
	INTERNATIONAL JOURNAL OF CARDIOLOGY	3
Analysis	COMPTES RENDUS MATHEMATIQUE	3
Applied	CLASSICAL AND QUANTUM GRAVITY	12
Statistics	RESUSCITATION	6
	CIRCULATION	3
	INTERNATIONAL JOURNAL OF CARDIOLOGY	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 4.6.3. Overall the publications are cited 7 % more than the field normalized world average (citation index 107), but less than the corresponding Norwegian average (index: 84). For one of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). The other two groups have almost equal field normalised citation indexes: 105 and 106.

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

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]
TOTAL Section of Mathematics	51	275	44	107	120	84	89
Analysis	8	22	5	-	-	-	-
Applied	13	62	14	105	138	92	76
Statistics	30	191	44	106	114	82	93

*) 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 University of Tromsø (UiT)

At the University of Tromsø, the Department of mathematics and statistics is included in the evaluation. In the period 2006-2010, almost 80 scientific publications have been published of the personnel encompassed by the evaluation. Overall the department has a productivity of 1.1 publications per full time equivalent (FTE), which is clearly below the average for all units covered by this evaluation (1.9).

Table 4.7.1 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
TOTAL - Department of mathematics and statistics	18	74	82	70	1.1
Applied math	4	17	23	19	1.4
Pure math	8	37	37	33	1.0
Statistics	6	20	28	23	1.4

Table 4.7.2 gives the most frequently used journals for the department and the research groups – limited to journals with at least three publications during the period 2006–2010. Therefore, for one the groups there are no journals on this list.

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

Unit	Journal	Numb. of articles
TOTAL - Dep TOTAL - Department of mathematics and statistics artment of mathematics and statistics	ACTA APPLICANDAE MATHEMATICAE	6
	LOBACHEVSKI JOURNAL OF MATHEMATICS	4
	COMPUTATIONAL STATISTICS & DATA ANALYSIS	4
	JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	3
	NONLINEAR PROCESSES IN GEOPHYSICS	3
Pure math	ACTA APPLICANDAE MATHEMATICAE	6
	LOBACHEVSKI JOURNAL OF MATHEMATICS	4
Statistics	COMPUTATIONAL STATISTICS & DATA ANALYSIS	4
	JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	3

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

Table 4.7.3 contains a citation and journal profile of the groups based on the journal articles (indexed in NCR) published in the period 2006–2009. Overall, the department obtains a field normalized citation index of 51. In other words, the articles are cited significantly below the world average. At group level, the Pure mathematics group obtains the highest citation index, but also the publications of this group are cited below the corresponding field normalized and Norwegian averages.

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

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]
TOTAL - Dep of mathematics and statistics	42	90	11	51	53	40	95
Applied math	13	28	11	43	44	34	98
Pure math	16	37	6	71	94	55	76
Statistics	17	31	6	41	39	33	105

*) 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.

While the tables above only include the persons encompassed by the evaluation, we have made an additional analysis where all journal articles where the department is listed as an author address is 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. In both periods, the department's publications are rather little cited.

Table 4.7.4 Citation and journal indicators, 2006–2009 publications indexed in NCR. UiT.

	Number of articles	Number of citations	Max cited article	Citation index – field[1]	Citation index – journal[2]	Citation index – Norway[3]	Journal profile[4]
2001-2005*	34	212	27	63	62	55	101
2006-2009**	46	100	11	49	54	39	92

*) 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.

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.[7]

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.

[7] 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).[8]

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

[8] 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[9]

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.

[9] 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 Mathematics

Acta Mathematica	Journal of Applied Probability
Acta Numerica	Journal of combinatorial theory. Series A
Advances in Applied Probability	Journal of combinatorial theory. Series B (Print)
Advances in Mathematics	Journal of Computational And Graphical Statistics
Algorithmica	Journal of Cryptology
American Journal of Mathematics	Journal of Differential Equations
Annales de l'Institut Fourier	Journal of differential geometry
Annales de l'Institut Henri Poincare. Analyse non linéar	Journal of Fluid Mechanics
Annales Scientifiques de l'Ecole Normale Supérieure	Journal of Fourier Analysis and Applications
Annals of Mathematics	Journal of Functional Analysis
Annals of Probability	Journal of Geometric Analysis
Annals of Pure and Applied Logic	Journal of Mathematical Behavior
Annals of Statistics	Journal of Mathematical Imaging and Vision
Annual Review of Fluid Mechanics	Journal of Mathematics Teacher Education
Applicable Algebra in Engineering, Communication and Computing	Journal of Number Theory
Applied Mathematics and Optimization	Journal of Symbolic Logic (JSL)
Archive for History of Exact Sciences	Journal of The American Mathematical Society
Archive for Rational Mechanics and Analysis	Journal of the American Statistical Association
Bernoulli	Journal of the European Mathematical Society (Print)
Biometrics	Journal of the London Mathematical Society
Biometrika	Journal of the Royal Statistic Society, Series C: Applied Statistics
Biostatistics	Journal of The Royal Statistical Society Series B-statistical Methodology
Bulletin of Symbolic Logic	Journal of Time Series Analysis
Bulletin of the American Mathematical Society	Journal of Topology
Bulletin of the London Mathematical Society	Mathematical Finance
Combinatorica	Mathematical Models and Methods in Applied Sciences
Commentarii Mathematici Helvetici	Mathematical Research Letters
Communications in analysis and geometry	Mathematical Thinking and Learning
Communications in Mathematical Physics	Mathematics of Computation
Communications in Partial Differential Equations	Mathematics of Operations Research
Communications on Pure and Applied Mathematics	Mathematische Annalen
Compositio Mathematica	Mathematische Zeitschrift
Computational Complexity	Memoirs of the American Mathematical Society
Computer Aided Geometric Design	Methodology and Computing in Applied Probability
Computer Methods in Applied Mechanics and Engineering	Numerische Mathematik
Constructive approximation	Physica D : Non-linear phenomena
Discrete and Continuous Dynamical Systems. Series A	Physics of Fluids
Documenta Mathematica	Probability theory and related fields
Duke mathematical journal	Proceedings of the London Mathematical Society
Educational Studies in Mathematics	Publications mathématiques (Bures-sur-Yvette)
Ergodic Theory and Dynamical Systems	Random structures & algorithms (Print)
Foundations of Computational Mathematics	Scandinavian Journal of Statistics
Geometric and Functional Analysis	SIAM Journal of Control and Optimization
Geometry and Topology	SIAM Journal on Applied Mathematics
Historia Mathematica	SIAM journal on computing (Print)
IMA Journal of Numerical Analysis	SIAM Journal on Mathematical Analysis
Infinite Dimensional Analysis Quantum Probability and Related Topics	SIAM Journal on Matrix Analysis and Applications
International Journal for Numerical Methods in Engineering	SIAM Journal on Numerical Analysis
International Journal of Computers for Mathematical Learning	SIAM Journal on Optimization
International Journal of Mathematics	SIAM Journal on Scientific Computing
International mathematics research notices	SIAM Review
Inventiones Mathematicae	Statistica sinica
Journal d'Analyse Mathematique	Statistical Science
Journal des Mathématiques Pures et Appliquées	Stochastic Processes and their Applications
Journal für die Reine und Angewandte Mathematik	Technometrics
Journal of Algebra	The Annals of Applied Probability
Journal of Algebraic Geometry	Transactions of the American Mathematical Society
Journal of Algorithms	ZDM - Zentralblatt für Didaktik der Mathematik

*) 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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