Research in Earth Sciences in Norway

Bibliometric analysis

Evaluation
Division for Science

The Research Council of Norway

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Nordic Institute for Studies in
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Evaluation of Earth Sciences – Publication and Citation Analysis

National Indicators and International Comparisons

Institutional Analyses

Dag W. Aksnes & Antje Klitkou

May 2011

Preface

This report presents a bibliometric analysis of research in earth sciences 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) and senior researcher Dr. Antje Klitkou 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 earth sciences in Norway. Both the institution/department level and the research group level are analysed. In addition the report contains a macro analysis of Norwegian earth science 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 earth sciences 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 Frida, which is a joint system for registration of scientific publications applied by several Norwegian higher education institutions, including the universities in Oslo, Bergen, Trondheim and Tromsø.

2.2 Included departments and researchers

The analysis covers the following departments and units:

Universities and university colleges

- Norwegian University of Life Sciences
    - Department of Mathematical Sciences and Technology
    - Department of Plant and Environmental Sciences
- Norwegian University of Science and Technology
    - Department of Geology and Mineral Resources Engineering
    - Department of Petroleum Technology and Applied Geophysics
- Sogn og Fjordane University College
- University Centre in Svalbard
    - Arctic Geology Department
    - Arctic Geophysics Department
- University of Bergen (including Uni Research)
    - Center for Integrated Petroleum Research
    - Department of Earth Science
    - Geophysical Institute
    - Uni Bjerknes Centre
- University of Oslo
    - Department of Geosciences
    - Natural History Museum
- University of Stavanger
    - Petroleum Engineering Department
- University of Tromsø
    - Department of Geology

Research institutes (institute sector)

- CICERO - Center for International Climate and Environmental Research

- Geological Survey of Norway
- Institute of Marine Research
- Nansen Environmental and Remote Sensing Center
- NORSAR
- Norwegian Institute for Air Research
- Norwegian Meteorological Institute
- Norwegian Polar Institute
- Norwegian Water Resources and Energy Directorate (NVE Research Group)
- SINTEF Petroleum Research

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

The analysis of the departments and units is limited to the personnel selected for the evaluation. In other words, we do not present analyses of the total publication output of the departments. Personnel in the following categories are included: Tenured academic employees (professor I, associate professor), post doc fellows and researchers. Also professor IIs (and associate professor IIs) are included in the evaluation (persons with 20 % appointments). However, these are not included in the publication analysis. The same holds for researchers with 20 % appointments. The reason is that their research for the most part is financed and carried out elsewhere.[1] Their research papers co-authored with tenured staff would appear on the publication lists of the latter anyway.

2.3 Methods

The analysis covers the five year period 2005-2009. The general chapter on Norwegian geosciences (chapter 3), also includes some publication indicators for the entire 2000-2009 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

[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.

publications will be included. The basic justification underlying this methodology is that the evaluation has its focus on the institution and research group level, and is not an evaluation of individual persons.

We have used this list of institutions and persons as a basis for publication searches in the Frida and Thomson Reuters databases. The Frida database has a complete coverage of the scientific output at the four traditional universities. However, only publications published in journals indexed in the Thomson Reuters database are included in the analysis. In geosciences, the database covers the large majority of the journals where the original research results are published.

As a first step, we identified all publications where the departments and institutes were listed as an author address in either of the two databases. Second, based on the retrieved publications of each unit we searched for the publications authored by the staff encompassed by the evaluation. We have only included full-papers (regular articles) and review articles in the analyses (not short contributions like letters, editorials, corrections, book-reviews, meeting abstracts, etc.).

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 2010 edition of NCR, with data covering 1981-2009 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 geosciences. 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

[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.

"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 are counted only once (but when fractionalised publication counts have been calculated, each person is credited their publication share).

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

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 2005, citations are counted over a 5-year period, while for the articles published in 2007, citations are counted over a 3-year period (or more precisely a 2-3 year period: the year of publication, 2008 and 2009). It is generally not advisable to use citation windows of only one or two years. Nevertheless, we have also included the recently published articles in the citation analysis. It is "expected" that the articles then are uncited or very poorly cited. It is worth noting that in the citation indicators the oldest publications will have relatively more weight than the recent publications. This is due to the fact that the 2005 publications, for example, will have assembled citations over a longer time period than articles published in 2008. Nevertheless, our method has some advantages compared to the alternatives. In particular, it reduces the problem of the poor reliability of citations as indicators when very short time periods are considered. It is, however, important to notice that the citation indicators presented here hardly reflect the citation rate of the more recent publications. The method adopted here is commonly applied in similar bibliometric performance analyses (see for example Moed & Velde, 1993; van Raan, 1996).

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

[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.

which the particular papers have been published. An indicator based on the journal as a reference standard is the Relative citation index – journal (also called the Relative Citation Rate). Here the citation count of each paper is matched to the mean citation rate per publication of the particular journals (Schubert & Braun, 1986). This means that the journals are considered as the fundamental unit of assessment. If two papers published in the same journal receive a different number of citations, it is assumed that this reflects differences in their inherent impact (Schubert & Braun, 1993). Below the indicators are further described.

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 2009). For example, for a review article published in a particular journal in 2005 we identified the average citation rates (2005–2009) to all the review articles published by this journal in 2005. 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 *Journal of Glaciology* in 2005. This article has been cited 9 times. The articles published in *Journal of Glaciology* were in contrast cited 6.81 times on average this year. The Relative citation index – journal is: (9/6.81)*100 = 132. The world-average citation rate for the subfield which this journal is assigned to is 8.25 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: (9/8.25)*100 = 109. 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. 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. In the standard product the impact factor is calculated as the mean number of citations in a given year, to journal items published during the preceding two years. However, this time period used as basis for the calculation of impact factor is often considered to be too short. In this analysis we have therefore used a three-year period instead.

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.

Another analysis is based on the classification system applied in The Norwegian Association of Higher Education Institutions (UHR)'s bibliometric funding model for performance based budgeting of research institutions. Some years ago Norway implemented a bibliometric model for performance based budgeting of research institutions. The funding of the higher education institutions is now partially based on the measurement of their scientific and scholarly publishing (cf. Sivertsen, 2006). In this system journals are divided into two levels. The highest level (level 2) is given extra weight and includes only the leading and most selective international journals (accounts for about 20 % of the world's publications), see Appendix for an overview. The national councils in each discipline participate annually in determining and revising the highest level under the guidance of the Norwegian Association of Higher Education Institutions.

3 Norwegian geosciences in an international context

This chapter presents various bibliometric indicators on the performance of Norwegian research within geosciences. The chapter is based on *all* publications within geosciences, 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 Geosciences is a separate field category and where there also are categories for particular subfields within Geosciences. In the analysis we have both analysed Geosciences as a collective discipline and subfields. The category for Geosciences 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 Geosciences: Water resources. The latter subfield, however, has been included in some of the analyses.

3.1 Scientific publishing

In 2009 Norwegian scientists published 770 articles in journals classified within the field Geosciences. During the five year period 2005–2009, approximately 3000 articles have been published. The four traditional universities in Norway (in Oslo, Bergen, Trondheim and Tromsø) together account for almost half (46 %) of the Norwegian scientific journal publishing within Geosciences. This can be seen from Table 3.1, where the article production during the period 2005–09 has been distributed according to institutions/sectors. The basis for this analysis is the information available in the address field of the articles. The Institute sector (private and public research institutes) is also a major contributor to the research output and accounts for 36 % of the national production. It should be noted that the incidence of journal publishing in this sector is generally lower than for the universities due to the particular research profile of these units (e.g. contract research published as reports). The industry accounts for 11 % of the Norwegian scientific journal production in Geosciences. Similar to the Institute sector, only a very limited part of the research carried out by the industry is generally published. This is due to the commercial interests related to the research results which mean that the results cannot be published/made public.

While the University of Oslo by far is the largest university in Norway, this does not hold for Geosciences. Here, the University of Bergen is the largest contributor with a proportion of 17 % of the national total, followed by the University of Oslo with 15 %. In the Institute sector, Geological Survey of Norway is the largest contributor with 6 % of the national total.

Table 3.1 The Norwegian profile of scientific publishing in Geosciences. Proportion of the article production 2005-2009 by institutions*/sectors.

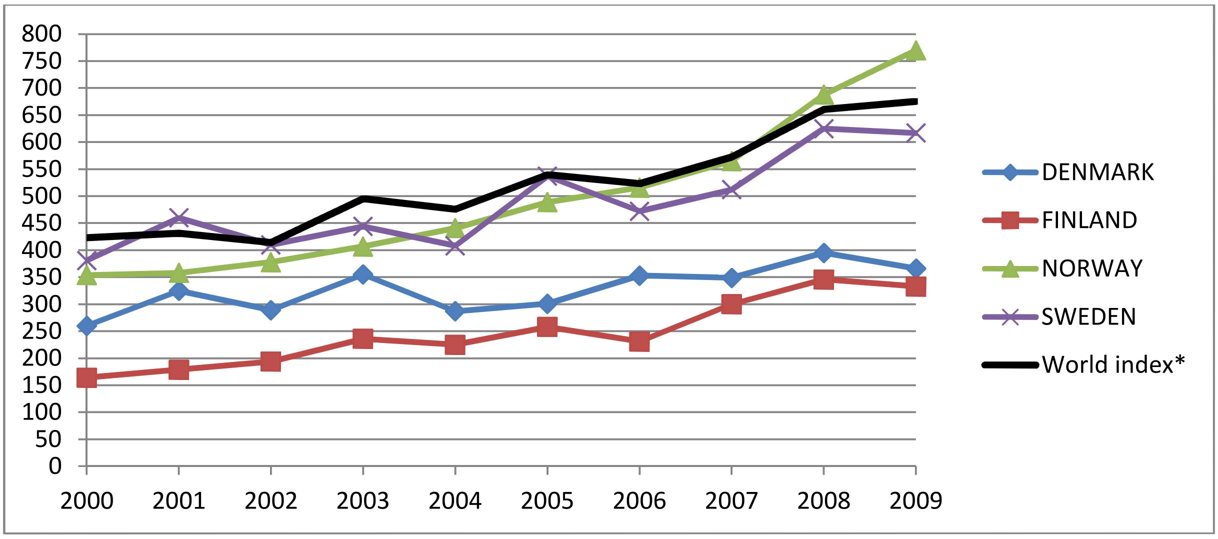
	Number of articles	Proprotion
University of Bergen**	1,036	17 %
University of Oslo	930	15 %
Norwegian University of Science and Technology	510	8 %
University of Tromsø	343	6 %
University Centre in Svalbard	146	2 %
Norwegian University of Life Sciences	110	2 %
University of Stavanger	76	1 %
Other Higher Education institutions	96	2 %
Geological Survey of Norway	382	6 %
Institute of Marine Research	252	4 %
Norwegian Institute for Air Research	214	3 %
SINTEF	192	3 %
Norwegian Polar Institute	178	3 %
Norwegian Meteorological Institute	152	2 %
Norwegian Geotechnical Institute	129	2 %
Nansen Environmental and Remote Sensing Center	102	2 %
Norwegian Institute for Water research	71	1 %
Institute sector - other institutes	616	10 %
Industry	671	11 %

*) Only institutions/institutes with more than 70 publications within Geosciences during the time period are shown separately in the table.
**) Including Uni Research.

In Figure 3.1 we have shown the development in the annual production of articles in Geosciences for Norway and three other Nordic countries for the period 2000–2009. Among these countries, Norway is the largest nation in terms of publication output followed by Sweden. In 2009 the two latter countries produced 770 and 620 articles, respectively. The Norwegian number of publications in Geosciences in 2009 is more than twice as large as the Danish and Finnish. Norway is a much large contributor within Geosciences than in most other scientific disciplines. When considering the total national research output (all fields), Sweden has more than twice as many publications as Norway, and also Denmark and Finland have higher scientific output than Norway. This particular scientific specialisation profile of Norway with strong emphasis on Geosciences has its roots in historical traditions.

In terms of productivity there is a notable positive trend the recent years. This holds for all the Nordic countries, but Norway has a particular strong increase. While less than 400 articles were published annually by Norwegian researchers in the years 2000–2002, the production increased during the following years and reached 770 in 2009.

Figure 3.1 Scientific publishing in Geosciences 2000-2009 in four Nordic countries.



*) The "world index" is a reference line, calculated as the world production of articles in Geosciences divided by 50.

In Table 3.2 we have shown the increase in the number of papers from the year 2000 to the year 2009 for the same set of countries. As can be seen, the number of papers published by Norwegian researchers in Geosciences in 2009 is 118 % higher than the one in 2000. Thus, this shows that the volume of research in Geosciences as measured by publications is significantly higher now than in the previous period. The corresponding figures for Sweden, Denmark and Finland are 62 %, 41 %, and 103 %, respectively. Norway has therefore the highest relative increase of these countries.

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 86 % from 2000 to 2009. In other words, there has been a strong increase in the national publication output, but not as strong as in the one for Geosciences.[4] In a national context the relative position of Geosciences among the other disciplines has been strengthened during the period. 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 Geosciences (59 %) and overall (53 %).[5]

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[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

Table 3.2 Increase in the scientific publishing during the period 2000–2009 in four Nordic countries and the World, Geosciences and all fields.

		Norway	Sweden	Denmark	Finland	World
Geosciences	Increase, per cent	118 %	62 %	41 %	103 %	59 %
	Increase, number of articles	416	236	106	169	12,590
All fields (national totals)	Increase, per cent	86 %	30 %	41 %	32 %	53 %
	Increase, number of articles	4,276	4,468	3,232	2,413	413,880

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.

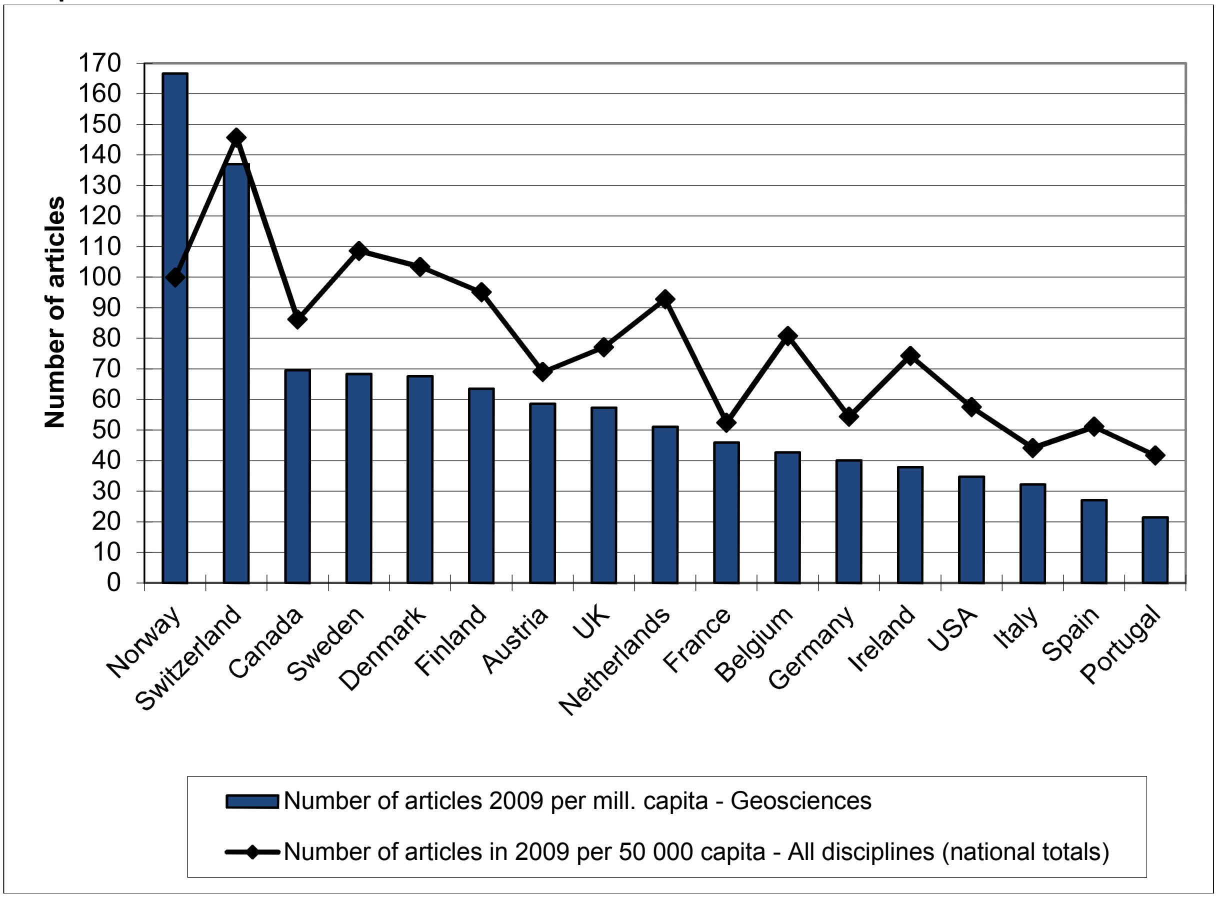
In a global context Norway is a very small country science-wise. In Geosciences, the Norwegian publication output amounts to 1.5 % of the world production of scientific publications (measured as the sum of all countries' publication output). In comparison, Norway has an overall publication share of 0.6 % (national total, all fields). This means that Norway contributes much more to the global scientific output in Geosciences 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 167 articles in Geosciences in 2009. In Figure 3.2 we have shown the corresponding publication output for a selection of other countries (blue bars). Here Norway ranks as number one, and has a much relative higher publication output than most other countries. Following Norway, we find Switzerland with 137 articles per million capita.

In Figure 3.2 we have also shown the production (per 50,000 capita) for all disciplines (national totals) (black line). This can be used as an indication of whether Geosciences has a higher or lower relative position in the science system of the countries than the average. For example, for Norway, Geosciences clearly ranks far above the national average, while the opposite is the case for the Netherlands.

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).

Figure 3.2 Scientific publishing per capita in 2009 in selected countries, Geosciences and all disciplines.



In order to provide further insight into the profile of Norwegian Geosciences we have analysed the distribution of the articles at subfield levels. This is based on the classification system of Thomson Reuters where the journals have been assigned to different categories according to their content (journal-based research field delineation). There is a separate category for journals covering multidisciplinary (geosciences) 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.

Category descriptions – Geosciences and related disciplines

Energy & Fuels: Covers journals on the development, production, use, application, conversion, and management of nonrenewable (combustible) fuels (such as wood, coal, petroleum, and gas) and renewable energy sources (solar, wind, biomass, geothermal, hydroelectric). Note: Journals dealing with nuclear energy and nuclear technology are not included.

Engineering, Geological: Includes multidisciplinary journals that encompass the knowledge and experience drawn from both the geosciences and various engineering disciplines (primarily civil engineering). Journals in this category cover geotechnical engineering, geotechnics, geotechnology, soil dynamics, earthquake engineering, geotextiles and geomembranes, engineering geology, and rock mechanics.

Engineering, Petroleum: Covers journals that report on a combination of engineering concepts, methods, and techniques on drilling and extracting hydrocarbons and other fluids from the earth (e.g., chemical flooding, thermal flooding, miscible displacement techniques, and horizontal drilling) and on the refining process. Relevant topics in this category include drilling engineering, production engineering, reservoir engineering, and formation evaluation, which infers reservoir properties through indirect measurements.

Geochemistry & Geophysics: Journals in this category may focus on either Geochemistry or Geophysics or both. Geochemistry covers journals that deal with the chemical composition and chemical changes in the Earth or other planets or asteroids. Topics include research on related chemical and geological properties of substances, applied geochemistry, organic geochemistry, and biogeochemistry. Geophysics covers journals on the application of the methods and techniques of physics to the study of the structure of the Earth and the processes affecting it. Topics addressed include seismology, tectonics, tectonophysics, geomagnetism, radioactivity, and rock mechanics

Geography, Physical: Covers journals dealing with the differentiation of areas of the Earth's surface as shown in the character, arrangement, and interrelations over the world of such elements as climate, elevation, soil, vegetation, population, land use, industries, or states, as well as the unit areas formed by the complex of these individual elements. Journals which focus on economic, human, and urban topics are not covered in this category.

Geology: Covers journals that deal with the physical history of the Earth, the rock of which it is composed, and the physical changes (not the physics) that the Earth has undergone or is undergoing. Journals in this category cover sedimentology, stratigraphy, hydrogeology, ore geology, structural geology, regional geology, and petrology. These journals are somewhat narrow in scope and are not given to the interdisciplinary study of the Earth Sciences.

Geosciences, Multidisciplinary: Covers journals having a general or interdisciplinary approach to the study of the Earth and other planets. Relevant topics include geology, geochemistry/geophysics, hydrology, paleontology, oceanography, meteorology, mineralogy, geography, and energy and fuels. Journals having a primary focus on geology, or geochemistry & geophysics are placed in their own categories.

Meteorology & Atmospheric Sciences: Covers those journals that deal with the atmosphere and its phenomena, especially weather and weather forecasting. Journals in this category are concerned with the atmosphere's temperature, density, winds, clouds, precipitation and other characteristics, as well as the structure and evolution of the atmosphere in terms of external influences and the basic laws of physics. This category also includes journals dealing with climatology.

Mineralogy: Includes journals that deal with the science of minerals, their crystallography, physical and chemical properties, classification, and the ways of distinguishing them.

Mining & Mineral Processing: Includes journals on locating and evaluating mineral deposits; designing and constructing mines; developing mining equipment; supervising mining operations and safety; and extracting, cleaning, sizing, and dressing mined material. Relevant topics in this category include exploration and mining geology, rock mechanics, geophysics, and mining science and technology.

Oceanography: Covers journals concerning the scientific study and exploration of the oceans and seas in all their aspects, including the delimitation of their extent and depth, the physics and chemistry of their waters, and the exploration of their journals.

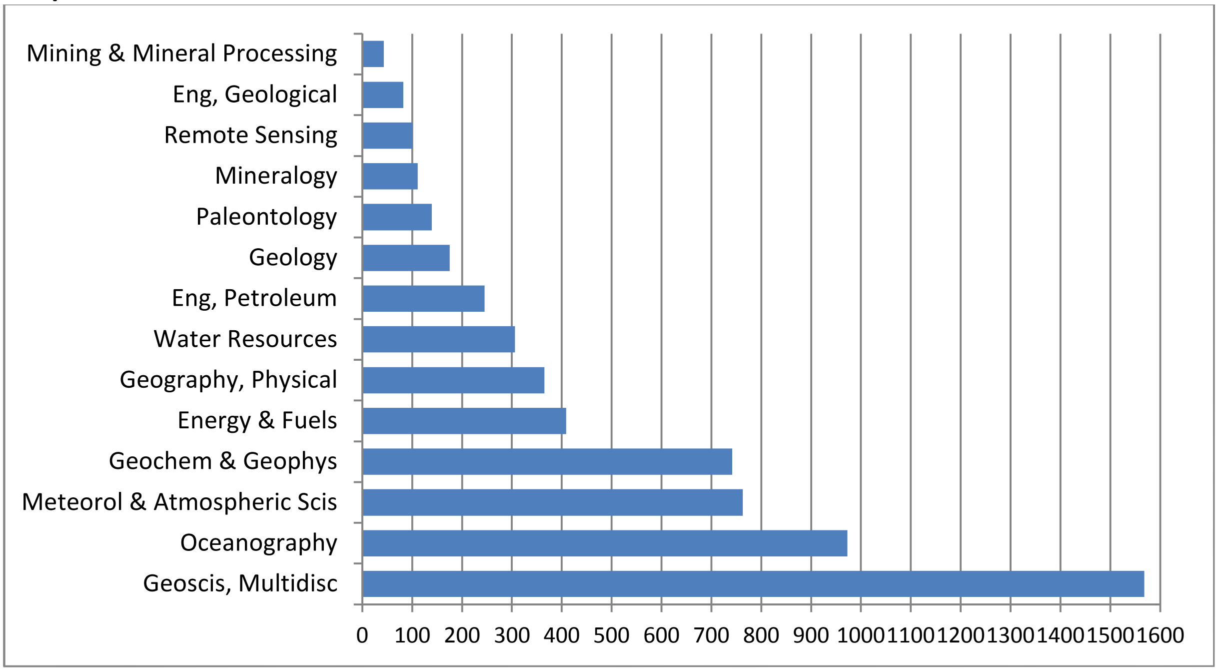
Paleontology: Includes journals that focus on the study of life and physical conditions, such as climate and geography, of past geological periods as recorded by fossil remains.

Remote Sensing: Includes journals on the technique of remote observation and of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiation from space. This category also covers journals on the applications of remote sensing in environmental, atmospheric, meteorological, geographic, and geoscientific observations. Journals on geographic information systems that deal in large part with remote sensing are also included

Water Resources: Covers journals concerning a number of water-related topics. These include desalination, ground water monitoring and remediation, hydrology, irrigation and drainage science and

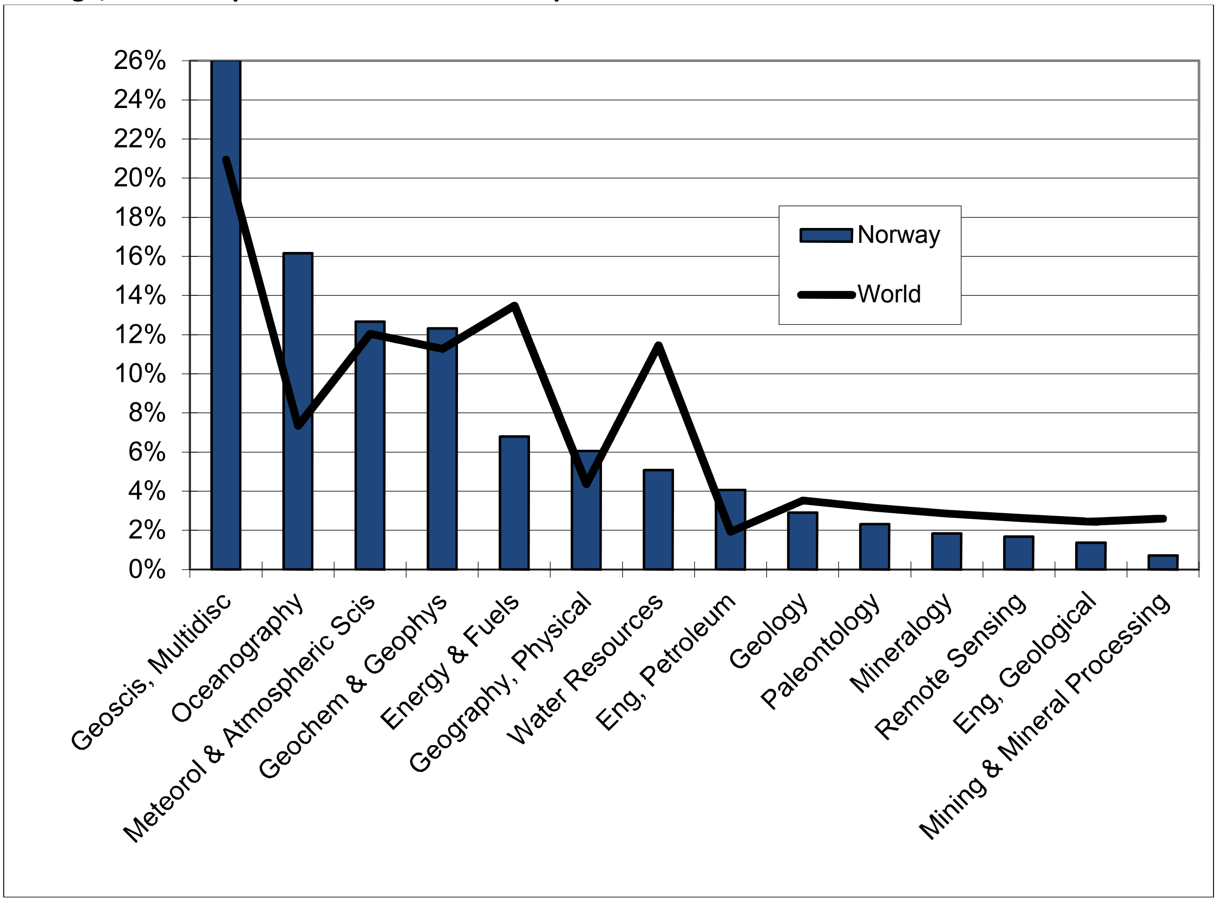
Figure 3.3 shows the distribution of articles for the 5-year period 2005–2009. We note that Geosciences, Multidisciplinary by far is the largest category, and more than 1,550 articles have been published within this field by Norwegian researchers during the period. This category consists of a large number of journals covering more than one subfield within Geosciences (e.g. *International Journal of Earth Sciences).* However, many of the journals included in this category are also included in other categories. We have therefore put less attention to this category in the analysis below. Next follows Oceanography with almost 1000 articles, Meteorology & Atmospheric Sciences and Geochemistry & Geophysics both with approximately 750 articles.

Figure 3.3 Scientific publishing in Geoscience subfields, Norway, total number of articles for the period 2005–2009.



The particular distribution of articles by subfields can be considered as the specialisation profile of Norwegian Geosciences. 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 much higher proportion of articles in Oceanography than the world average (respectively 16 and 7 %). In relative terms, the Norwegian proportion in Engineering, Petroleum (4 %) is significantly higher than the world average (2 %). In fact, Norway contributes to 3.1 % of the world production within this field and is the seventh largest country. In Oceanography, Norway contributes to 2.7 % of the world production. On the other hand, Norway has lower proportions in Energy & Fuels and Water Resources than the world average (7 vs. 13 % and 5 vs. 11 %). 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 Geosciences.

Figure 3.4 Relative distributions of articles on Geoscience subfields, Norway and the world average, based on publication counts for the period 2005–2009.



The Norwegian contributions in the field of Geosciences are distributed on a large number of different journals (415 during the period 2005–2009). 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 Geosciences and related fields for the period 2005–2009. The 43 most frequently used journals shown in the table account for 50 % of the Norwegian publication output in Geosciences.

On top of the list we find the *ICES Journal of Marine Sciences* which also covers research outside geosciences with 156 articles, followed by *Geophysical Research Letters* (114) and *Annales Geophysicae* (111). 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 Geosciences.

Table 3.3 The most frequently used journals for the period 2005–2009, number of articles from Norway, Geosciences.

	2005	2006	2007	2008	2009	Total	Journal citation rate (impact factor)*
ICES JOURNAL OF MARINE SCIENCE	23	40	24	29	40	156	3.6
GEOPHYSICAL RESEARCH LETTERS	32	19	16	21	26	114	6.0
ANNALES GEOPHYSICAE	28	17	16	23	27	111	3.5
JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	12	22	31	23	19	107	7.5
ATMOSPHERIC CHEMISTRY AND PHYSICS	15	19	24	18	29	105	10.4
GEOPHYSICS	10	22	24	25	20	101	2.6
DEEP-SEA RESEARCH PART II-TOPIC STUD OCEANOGRA	5	14	3	23	39	84	5.2
MARINE AND PETROLEUM GEOLOGY	28	17	2	9	21	77	3.8
NORWEGIAN JOURNAL OF GEOLOGY	15	16	22	12	5	70	1.8
EARTH AND PLANETARY SCIENCE LETTERS	9	11	10	18	18	66	8.0
QUATERNARY SCIENCE REVIEWS	14	11	8	15	12	60	9.6
GEOPHYSICAL JOURNAL INTERNATIONAL	7	7	18	12	12	56	4.6
ATMOSPHERIC ENVIRONMENT	6	8	11	14	16	55	6.2
ENERGY & FUELS	4	9	13	10	15	51	4.3
JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS	6	14	7	11	11	49	4.5
MARINE GEOLOGY	19	6	9	7	7	48	5.5
PETROLEUM GEOSCIENCE	15	11	5	14	3	48	2.5
ENERGY POLICY	3	9	13	9	11	45	4.1
TECTONOPHYSICS	5	9	5	7	19	45	3.0
HOLOCENE	8	5	9	7	13	42	5.3
COLD REGIONS SCIENCE AND TECHNOLOGY	5	4	11	16	5	41	2.6
POLAR RESEARCH	6	4	9	12	9	40	2.4
JOURNAL OF PETROLEUM SCIENCE AND ENGINEERING	5	10	7	3	14	39	1.8
AAPG BULLETIN	7	4	8	10	8	37	2.3
WATER SCIENCE AND TECHNOLOGY	15	10	1	3	7	36	2.4
BOREAS	5	11	5	7	7	35	4.7
JOURNAL OF MARINE SYSTEMS	5	6	7	8	9	35	5.0
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY		2	12	4	16	34	8.1
LIMNOLOGY AND OCEANOGRAPHY	4	7	9	5	9	34	7.4
PROGRESS IN OCEANOGRAPHY		6	10	7	9	32	7.5
JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH	3	6	8	6	8	31	5.5
JOURNAL OF HYDROLOGY	3	8	7	4	9	31	4.4
JOURNAL OF STRUCTURAL GEOLOGY	11		2	8	10	31	3.2
GEOCHEMISTRY GEOPHYSICS GEOSYSTEMS	4	7	2	10	7	30	4.4
GEOLOGY	4	2	11	9	4	30	8.5
JOURNAL OF GLACIOLOGY	3	4	4	8	10	29	3.7
JOURNAL OF THE GEOLOGICAL SOCIETY	3	6	6	6	8	29	6.2
TELLUS SERIES A-DYNAMIC METEORO AND OCEANOG	1	7	1	15	5	29	4.5
REMOTE SENSING OF ENVIRONMENT	5	4	7	3	8	27	7.0
GEOCHIMICA ET COSMOCHIMICA ACTA	4	5	5	3	9	26	7.9
PALAEOGEOGR PALAEOCLIMATOL PALAEOECOLOGY	7	2	4	7	6	26	5.1
ANNALS OF GLACIOLOGY	6	19				25	-
ARCTIC ANTARCTIC AND ALPINE RESEARCH	11	3	1	3	7	25	2.6

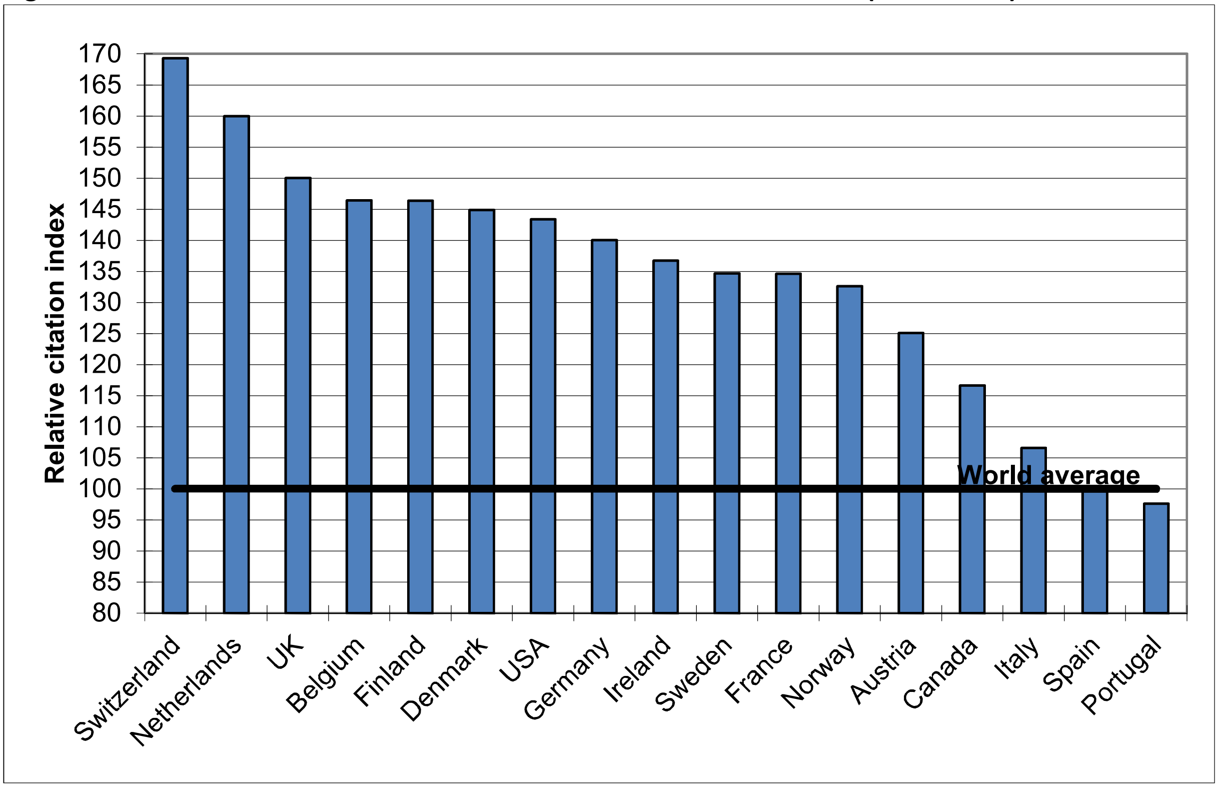
*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the “standard” journal impact factor is calculated in a different way).

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 Geosciences for a selection of countries, based on the citations to the publications from the four year period 2005–2008. The publications from Switzerland and the Netherlands are most highly cited, approximately 70 and 60 % above world average. Norway ranks as number 12 among the 17 countries shown in this figure, with a citation index of 133. In other words, the performance of Norwegian geoscience in terms of citations is somewhat below that of the leading countries. Still, the Norwegian citation index is significantly above world average, although this average does not constitute a very ambitious reference standard as it includes publications from countries with less developed science systems (for example China, which is the second largest producer of publications in the world with a citation index of 80 in Geosciences). The Norwegian index in Geosciences is also higher than the Norwegian total (all disciplines) for this period, which is approximately 125.

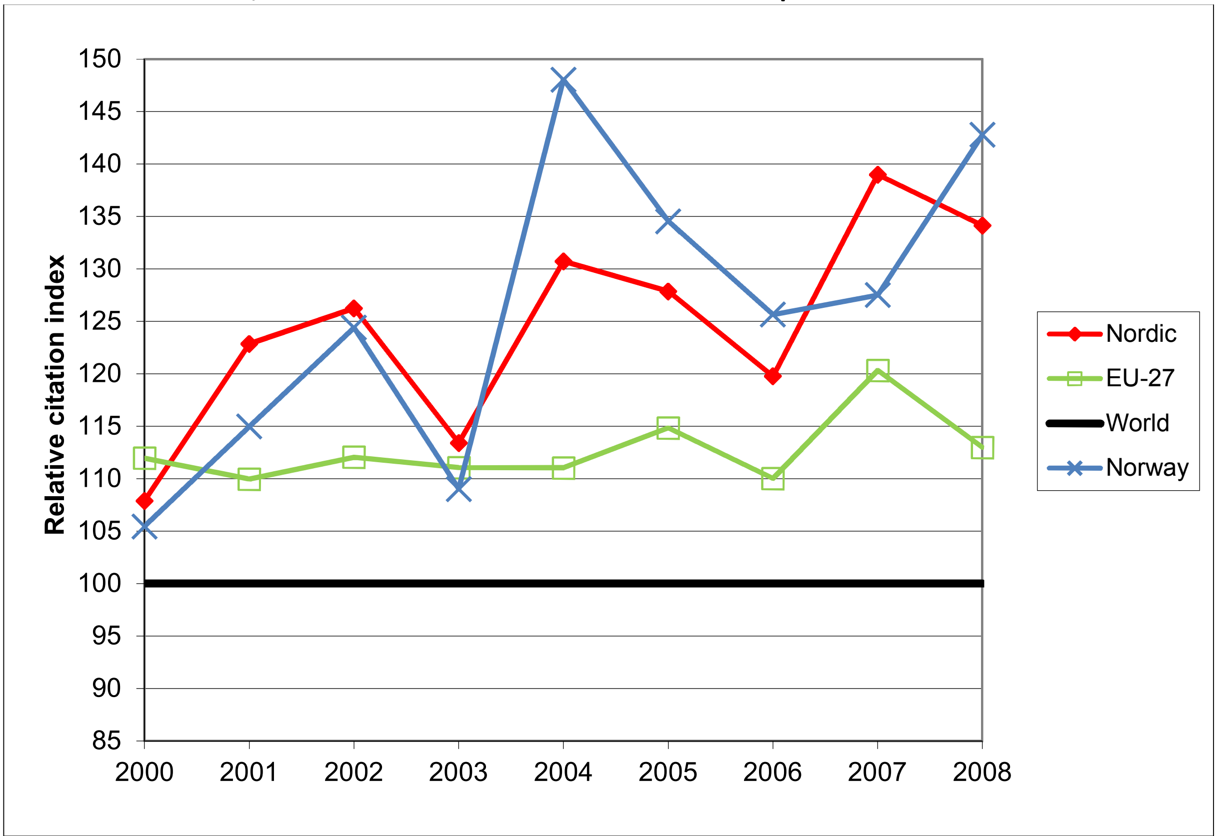
Figure 3.5 Relative citation index in Geosciences for selected countries (2005–2008).*



*) Based on the publications from the period 2005-2008 and accumulated citations to these publications through 2009.

We have also analysed how the citation rate of the Norwegian publications within Geosciences has developed over the period 2000–2008. The results are shown in Figure 3.6. Also the respective averages for the Nordic countries, the EU-27 and the world (=100) have been included in this figure. As can be seen, there are significant variations in the Norwegian citation index when measured on annual basis. [6] However, there is a positive trend.

Figure 3.6 Relative citation index* in Geosciences for Norway compared with the average for the Nordic countries, the EU-27 countries and the world for the period 2000–2008.

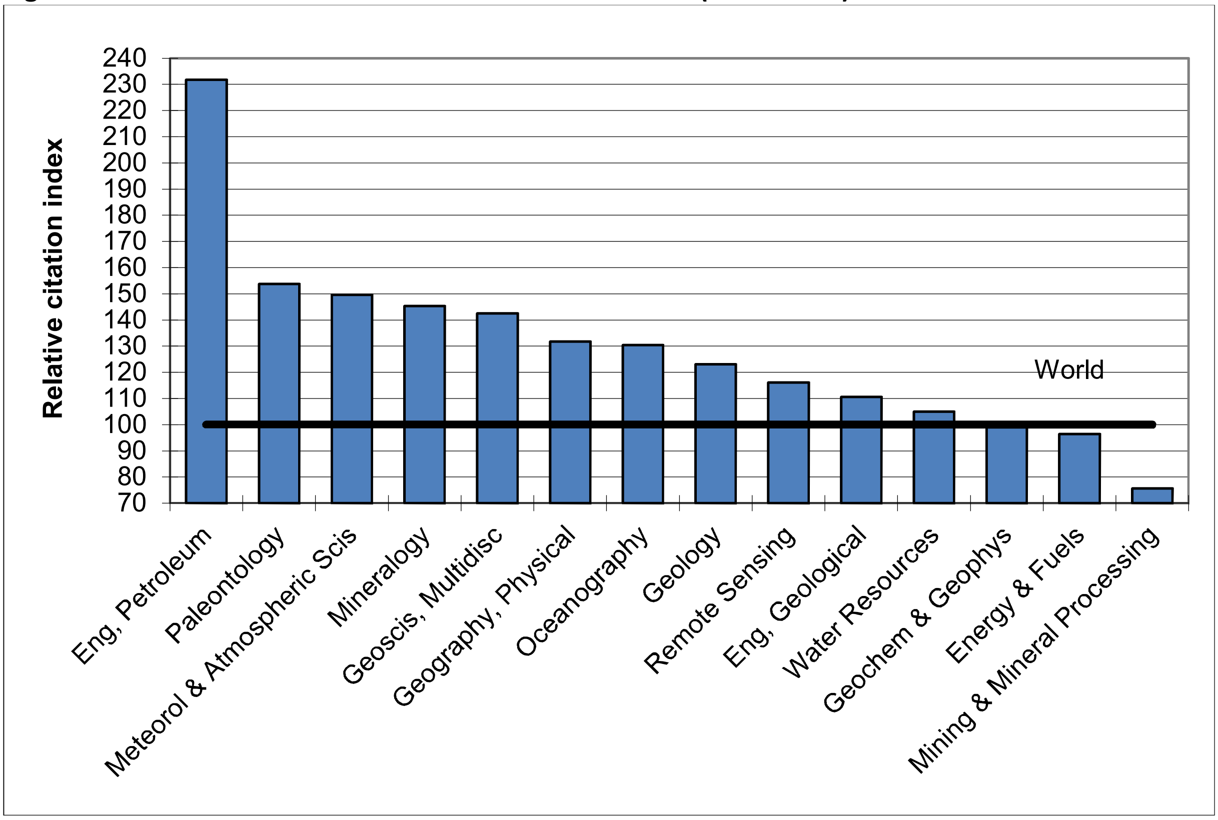


*) Based on annual publication windows and accumulated citations to these publications.

The overall citation index for Geosciences 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 Geosciences for the 2005–2008 publications. Norway performs very well in several of the subfields, notably Engineering, Petroleum where the publications are cited more than 130 % above the world average (citation index 232). Then follow Paleontology and Meteorology & Atmospheric Sciences with citation indexes of 154 and 150, respectively. Lowest citation rate is found for Geochemistry & Geophysics (99), Energy & Fuels (96) and Mining & Mineral Processing (76). Thus, in these fields the citation indexes do not even reach the world-average.

[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.

Figure 3.7 Relative citation index in Geoscience subfields (2005–2008).*



*) Based on the publications from the period 2005–2008 and accumulated citations to these publications through 2009.

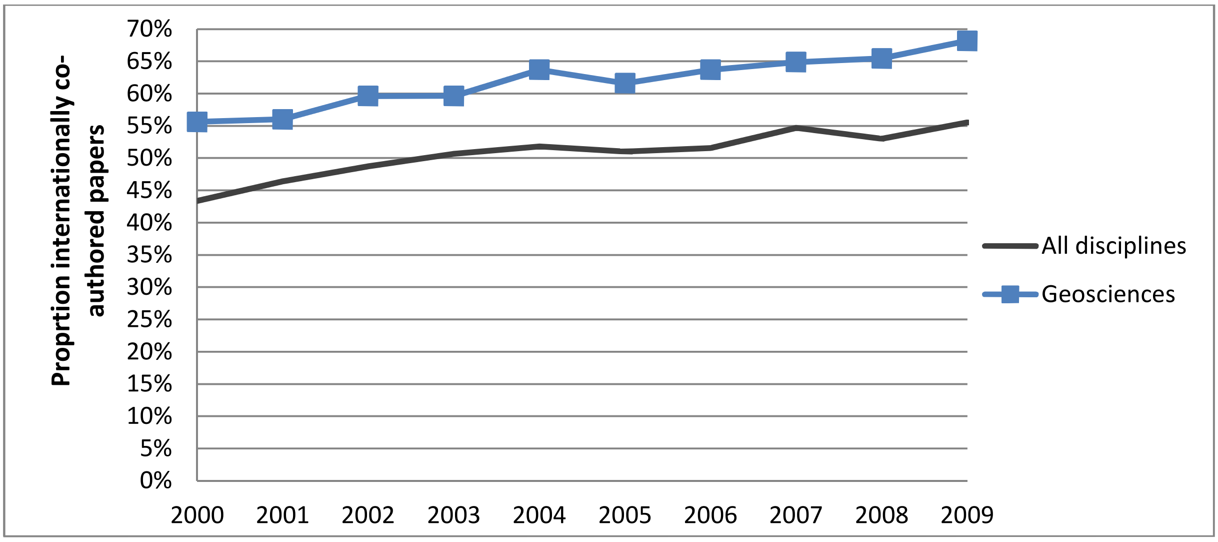
3.3 Collaboration indicators

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 Geosciences and for all disciplines (national total). In Geosciences, 68 % of the articles had co-authors from other countries in 2009. In other words, two out of three publications were internationally co-authored. This is significantly higher than the national average (53 %). Thus, the extent of international collaboration is very large in Geosciences.

The proportion of international collaboration in Geosciences has increased from 56 % to 68 % during the 10 year period. The national total has also increased during the period from 43 % in 1998 to 56 % in 2009.

Figure 3.8 The proportion of international co-authorship, 2000–2009, Norway.



Which countries are the most important collaboration partners for Norway in Geosciences? 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 2000 to 2009.

The USA is the most important collaboration partner. In fact, almost one third of the "Norwegian" articles within Geosciences also had co-authors from this nation. Next follows UK – 26 % of the "Norwegian" articles were co-authored with British scientists – and Germany (19 %).

Table 3.4 Collaboration by country* 2000–2009. Number and proportion of the Norwegian article production in Geosciences with co-authors from the respective countries.

Country	Num. articles	Proportion	Country	Num. articles	Proportion
USA	1385	29 %	Japan	217	5 %
UK	1257	26 %	Australia	217	5 %
Germany	931	19 %	China	175	4 %
France	590	12 %	Spain	168	3 %
Sweden	562	12 %	Austria	156	3 %
Denmark	424	9 %	Poland	114	2 %
Canada	413	9 %	Belgium	105	2 %
Netherlands	374	8 %	Iceland	98	2 %
Russia	350	7 %	South Africa	98	2 %
Finland	269	6 %	Wales	94	2 %
Italy	266	6 %	Greece	80	2 %
Switzerland	255	5 %	Ireland	75	2 %

*) Only countries with more than 75 collaborative articles are shown in the table.

3.4 The units selected for the evaluation

The next chapters analyse the publication output of the units selected for the evaluation. In total, 507 persons are encompassed by this analysis (Professor IIs are not included, cf. Method section). In total these persons have contributed to 2050 (unique) publications during the period 2005–2009. Of these publications, 91 % are classified within the Geosciences category.

The units selected for the evaluation are the core environments for geoscience research in Norway. Nevertheless, there is also some geoscience research being carried out in Norway that has not been included. In fact, we find that 54 % of the articles that have been published by Norwegian scientists in the period and which are classified within the Geoscience category cannot be attributed to persons included in the evaluation. There are three explanations for this: the articles have been published by persons who work or have worked at the selected units, but who are not included in the publication analysis (e.g. retired personnel, PhD students, etc.), the articles have been published by the included persons before they were engaged by their current employer, and the articles have been published by persons at other units.

4 Institutional analyses

4.1 Norwegian University of Life Sciences

Two research groups at the Norwegian University of Life Sciences are included in the evaluation: The Research Group Geosciences at the Department of Mathematical Sciences and Technology and the Geology Group at the Department of Plant and Environmental Sciences. 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 Geosciences has published 0.5 fractionalised publications per full time equivalent (FTE) which is close to the average for all units covered by this evaluation (0.45). The Geology Group has a very low scientific productivity (0.1 per FTE).

Table 4.1.1 Number of publications, 2005–2009, Norwegian University of Life Sciences.

Unit	Number of man years (FTE)	Publications - whole counts	Publications - fractional counts	Number of publications (fractional counts) per number of FTE
Research Group Geosciences*	17.5	14	8.2	0.5
Geology Group**	16.0	8	1.9	0.1

*) Department of Mathematical Sciences and Technology. **) Department of Plant and Environmental Sciences.

Table 4.1.2 shows the average citation rate of the journals the groups have published in. Both groups publish in journals with lower than average citation rate, which is 5.4 for all units encompassed by the evaluation.

Table 4.1.2 Journal profile by groups/sections, 2005–2009 publications. Norwegian University of Life Sciences.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
Research Group Geosciences**	14	3.0
Geology Group***	8	4.1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
) Department of Mathematical Sciences and Technology. *) Department of Plant and Environmental Sciences.

Table 4.1.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005–2009. Therefore, there is only one journal on this list.

Table 4.1.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. Norwegian University of Life Sciences.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Geology Group****	BOREAS	5	4.7	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.
****) Department of Plant and Environmental Sciences.

Table 4.1.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. However, due to the small number of articles we have not calculated relative citation indexes for the groups (cf. Method section).

Table 4.1.4 Citation and journal indicators, 2005–2008 publications*. 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]
Research Group Geosciences[5]	9	6	2	-	-	-	-
Geology Group[6]	4	28	11	-	-	-	-

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100. 5) Department of Mathematical Sciences and Technology. 6) Department of Plant and Environmental Sciences.

4.2 Norwegian University of Science and Technology

At the Norwegian University of Science and Technology (NTNU) there are research groups at two departments that are included in the evaluation: Department of Geology and Mineral Resources Engineering and Department of Petroleum Technology and Applied Geophysics. Table 4.2.1 shows various publication indicators for the research groups. The Applied Geophysics group at the Department of Petroleum Technology and Applied Geophysics has a very high productivity: 1.4 fractionalised publications per full time equivalent (FTE), significantly above the average for all unites covered by this evaluation (0.45). At the Department of Geology and Mineral Resources Engineering. the Engineering geology & rock mechanics group has productivity close to the national average. The Geology group and the Mineral production & HSE group have published very few papers, and have scientific productivity significantly below the national average.

Table 4.2.1 Number of publications, 2005–2009, Norwegian University of Science and Technology.

Unit	Number of man years (FTE)	Publications - whole counts	Publications - fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL*	92.9	39	18.1	0.2
Engineering geology & rock mechanics	23.6	24	9.1	0.4
Geology	32.0	6	3.0	0.1
Mineral production & HSE	37.3	9	6.1	0.2
Applied Geophysics**	24.1	61	33.7	1.4

*) Department of Geology and Mineral Resources Engineering. **) Department of Petroleum Technology and Applied Geophysics.

Table 4.2.2 shows the average citation rate of the journals the groups have published in. All groups tend to publish in journals with low impact factors and significantly below the national average for the units encompassed by the evaluation which is 5.4 (with the exception of the geology group with very few papers included). A part of the explanation may be that technology journals generally have lower citation rate than the basic science journals.

Table 4.2.2 Journal profile by groups/sections, 2005–2009 publications. Norwegian University of Science and Technology.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL**	39	2.3
Engineering geology & rock mechanics	24	1.7
Geology	6	5.0
Mineral production & HSE	9	1.9
Applied Geophysics***	61	2.5

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

) Department of Geology and Mineral Resources Engineering. *) Department of Petroleum Technology and Applied Geophysics.

Table 4.2.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005–2009. As can be seen, the Applied Geophysics group has a very large number of articles in the journal *Geophysics*.

Table 4.2.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. Norwegian University of Science and Technology.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Engineering geology & rock mechanics	TUNNELLING AND UNDERGROUND SPACE TECHNOLOGY	6	1.2	1
	Bulletin of Engineering Geology and the Environment	4	0.7	2
	INTERNATIONAL JOURNAL OF ROCK MECHANICS AND MINING SCIENCES	4	1.7	1
Mineral production & HSE	MINERALS ENGINEERING	4	1.9	2
Applied Geophysics	GEOPHYSICS	37	2.6	2
	Journal of Geophysics and Engineering	9	1.5	1
	GEOPHYSICAL JOURNAL INTERNATIONAL	5	4.6	2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.

***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.2.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. However, for two of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). All the other groups have a rather poor performance measured in terms of citations. Their publications are little cited compared to corresponding world and Norwegian averages. Moreover, the groups tend to publish in journal with low impact factors.

Table 4.2.4 Citation and journal indicators, 2005–2008 publications*. 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[5]	29	76	16	80	124	66	64
Engineering geology & rock mechanics	19	33	8	63	106	54	60
Geology	3	19	16	-	-	-	-
Mineral production & HSE	7	24	15	-	-	-	-
Applied Geophysics[6]	49	113	12	46	79	48	58

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100. 5) Department of Geology and Mineral Resources Engineering. 6) Department of Petroleum Technology and Applied Geophysics.

4.3 Sogn og Fjordane University College

At the Sogn og Fjordane University College, one research group is included in the evaluation: Geology and geohazards. This group consists of very few staff members, and has only published 8 articles during the period 2005–2009. A bibliometric analysis is not very meaningful for such a small number of publications. However, some indicators are given in the tables below.

Table 4.3.1 shows various publication indicators for the research group. The number of publications per number of FTE is with 0.2 far below the average for all unites covered by this evaluation (0.45).

Table 4.3.1 Number of publications, 2005–2009, Sogn og Fjordane University College.

Unit	Number of man years (FTE)	Publications - whole counts	Publications - fractional counts	Number of publications (fractional counts) per number of FTE
Geology and geohazards	15.9	8	3.8	0.2

Table 4.3.2 Journal profile by groups/sections, 2005–2009 publications. Sogn og Fjordane University College.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
Geology and geohazards	8	4.2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.3.3 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. However, we have not calculated relative citation indexes due to the small number of articles (cf. Method section).

Table 4.3.3 Citation and journal indicators, 2005–2008 publications*. Sogn og Fjordane University College.

Unit	Number of articles	Number of citations	Max cited article	Citation index – field	Citation index – journal	Citation index – Norway	Journal profile
Geology and geohazards	8	26	9	-	-	-	-

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.

4.4 University Centre in Svalbard

There are two departments at the University Centre in Svalbard (UNIS) that have been included in the evaluation: Arctic Geology Department and Arctic Geophysics Department. At UNIS there are many affiliated researchers with 20 % positions, and these are not included in the present analysis (cf. Method section).

Table 4.4.1 shows various publication indicators for the research groups. The Cryosphere Research Group at the Arctic Geology department has a high productivity: 1.1 fractionalised publications per full time equivalent (FTE), significantly above the average for all units covered by this evaluation (0.45). At the Arctic Geophysics department the Air-Chryosphere-Sea Interaction Observation and Modelling Group has a productivity close to the national average. The other groups have published very few papers, and have scientific productivity significantly below the national average.

Table 4.4.1 Number of publications, 2005–2009, University Centre in Svalbard.

Unit	Number of man years (FTE)	Publications - whole counts	Publications - fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL Arctic Geology department	20.6	37	12.6	0.6
Cryosphere Research Group	10.5	30	11.1	1.1
Quaternary and Marine Geology Research Group	4.4	4	0.6	0.1
Sedimentary Bedrock Research Group	5.7	4	0.9	0.2
Air-Chryosphere-Sea Interaction Observation and Modelling Group*	22.1	20	9.2	0.4

*) Arctic Geophysics department

We have calculated the average citation rate (impact factor) for the journals the staff have published their articles in (weighted average). The results are given in Table 4.4.2. The average journal citation rate of the journals is between 4.4 and 5.4 which is close to the national average for the units encompassed by the evaluation (5.4).

Table 4.4.2 Journal profile by groups/sections, 2005–2009 publications. University Centre in Svalbard.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL Arctic Geology department	37	4.9
Cryosphere Research Group	30	4.9
Quaternary and Marine Geology Research Group	4	5.4
Sedimentary Bedrock Research Group	4	4.6
Air-Chryosphere-Sea Interaction Observation and Modelling Group**	20	4.4

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Arctic Geophysics department.

Table 4.4.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005-2009. Therefore, for two of the groups there are no journals on this list. Almost all the journals on the list are classified at the highest level (level 2) as the leading and most selective international journals in UHR's bibliometric funding model.

Table 4.4.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. University Centre in Svalbard.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Cryosphere Research Group	JOURNAL OF GLACIOLOGY	6	3.7	2
	PERMAFROST AND PERIGLACIAL PROCESSES	6	5.0	2
	QUATERNARY SCIENCE REVIEWS	4	9.6	2
Air-Chryosphere-Sea Interaction Observation and Modelling Group	JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS	4	4.5	2
	COLD REGIONS SCIENCE AND TECHNOLOGY	3	2.6	2
	CONTINENTAL SHELF RESEARCH	3	4.6	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.4.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. However, for two of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). The Cryosphere Research Group has a field normalized citation index of 111. In other words, the articles are cited 11 % above the world average. The citation rate is slightly lower than the Norwegian average (88). The Air-Chryosphere-Sea Interaction

Observation and Modelling Group has a citation index-field of 193, which is significantly above the world average. However, the number of articles included in the analysis is rather low.

Table 4.4.4 Citation and journal indicators, 2005–2008 publications*. University Centre in Svalbard.

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 Arctic Geology department	26	91	13	115	102	90	113
Cryosphere Research Group	21	78	13	111	98	88	112
Quaternary and Marine Geology Research Group	3	8	4	-	-	-	-
Sedimentary Bedrock Research Group	2	5	5	-	-	-	-
Air–Chryosphere–Sea Interaction Observation and Modelling Group[5]	16	140	38	193	181	149	107

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100. 5) Arctic Geophysics department.

4.5 University of Bergen (including Uni Research)

There are two departments at the University of Bergen included in the evaluation: Department of Earth Science and Geophysical Institute. In addition there are two centres that formally are part of Uni Research: Centre for Integrated Petroleum Research and Uni Bjerknes Centre. These centres have very close links to University of Bergen, and the two included departments in particular. They are therefore included in the present chapter.

Table 4.5.1 shows various publication indicators for the departments and their research groups. In terms of publication output, the Department of Earth Science is the third largest of the departments that have been included in the evaluation. Many of the research groups have a scientific productivity which is close to the average for all units covered by the evaluation (0.45 fractionalised publications per number of full time equivalents (FTE)). The highest productivity is found for the Quaternary Geology and Palaeoclimate (QGP) group at the Department of Earth Science and the Climate Dynamics (CLIMATE) group at the Geophysical Institute.

Table 4.5.1 Number of publications, 2005–2009, University of Bergen & Uni Research.

Unit	Number of man years (FTE)	Publications – whole counts	Publica–tions – fractional counts	Numb of publications (fractional counts) per number of FTE
TOTAL Department of Earth Science	215.2	296	93.4	0.4
Geobiology research group (GB)	32.1	47	13.6	0.4
Geodynamics Group (GdG)	59.5	53	17.9	0.3
Marine Geology and Geophysics (MGG)	52.3	97	22.6	0.4
Petroleum Geosciences Group (PGG)	37.5	35	16.9	0.5
Quaternary Geology and Palaeoclimate (QGP)	33.3	74	22.5	0.7
TOTAL Geophysical Institute	90.8	118	39.6	0.4
Meteorology (METEO)	17.0	17	6.6	0.4
Climate Dynamics (CLIMATE)	14.1	32	9.8	0.7
Small Scale Oceanography (ScOcean)	22.9	29	11.7	0.5
Large Scale Oceanography (LaScO)	21.5	22	6.6	0.3
Chemical Oceanography (ChemOcean)	15.3	24	5.0	0.3
TOTAL Uni Bjerknes Centre	90.8	132	33.1	0.4
Palaeoclimate processes & past climate sensitivity	23.9	44	10.3	0.4
Climate variability and dynamics	36.7	52	12.5	0.3
Carbon biogeochemistry and marine ecosystems	20.0	36	7.6	0.4
Global and regional climate projections	10.3	8	2.7	0.3
Geoscience (CIPR)	17.3	23	5.3	0.3

Table 4.5.2 shows the average citation rate of the journals the groups have published in. All the research groups at the Uni Bjerknes Centre tend to publish in journals with high impact factors, significantly above the national average for the units encompassed by the evaluation (5.4). Particularly the Carbon biogeochemistry and marine ecosystems group stands out in this respect, with an average of 11.2 The Petroleum Geosciences Group (PGG) at the Department of Earth science and the Geosciene group at CIPR have the lowest average values (3.0 and 2.9, respectively). A part of the explanation may be that technology journals generally have lower citation rate than the basic science journals. The other groups have average values close to or above the national average.

Table 4.5.2 Journal profile by groups/sections, 2005–2009 publications. University of Bergen &Uni Research.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL Department of Earth Science	296	5.6
Geobiology research group (GB)	47	7.0
Geodynamics Group (GdG)	53	4.4
Marine Geology and Geophysics (MGG)	97	6.0
Petroleum Geosciences Group (PGG)	35	3.0
Quaternary Geology and Palaeoclimate (QGP)	74	6.2
TOTAL Geophysical Institute	118	5.5
Meteorology (METEO)	17	4.5
Climate Dynamics (CLIMATE)	32	4.9
Small Scale Oceanography (ScOcean)	29	4.5
Large Scale Oceanography (LaScO)	22	5.3
Chemical Oceanography (ChemOcean)	24	8.1
TOTAL Uni Bjerknes Centre	132	9.5
Palaeoclimate processes & past climate sensitivity	44	7.7
Climate variability and dynamics	52	9.5
Carbon biogeochemistry and marine ecosystems	36	11.2
Global and regional climate projections	8	7.2
Geoscience (CIPR)	23	2.9

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the “standard” journal impact factor is calculated in a different way).

Table 4.5.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005-2009.

Table 4.5.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. University of Bergen & Uni Research.**

Unit	Journal	Numb. of publ	Journal citation* rate, impact factor	Level**
Geobiology research group (GB)	GEOCHEMISTRY GEOPHYSICS GEOSYSTE	4	4.4	2
	JOURNAL OF THE GEOLOGICAL SOCIETY	4	6.2	1
	CHEMICAL GEOLOGY	3	6.7	1
	JOURN ANALYTICAL ATOMIC SPECTROMET	3	7.0	2
	LITHOS	3	8.1	2
Geodynamics Group (GdG)	GEOPHYSICAL JOURNAL INTERNATIONAL	8	4.6	2
	Ameri Assoc of Petroleum Geologists Bull	6	2.3	2
	PRECAMBRIAN RESEARCH	4	6.2	1
	TECTONOPHYSICS	4	3.0	1
Marine Geology and Geophysics (MGG)	MARINE GEOLOGY	16	5.5	1
	MARINE AND PETROLEUM GEOLOGY	15	3.8	1
	MARINE GEOPHYSICAL RESEARCHES	10	1.5	1
Petroleum Geosciences Group (PGG)	BASIN RESEARCH	6	3.8	1
	JOURNAL OF SEISMIC EXPLORATION	4	0.4	1
	PETROLEUM GEOSCIENCE	3	2.5	1
Quaternary Geology & Palaeoclimate	HOLOCENE	14	5.3	2
	QUATERNARY SCIENCE REVIEWS	14	9.6	2
	BOREAS	7	4.7	1
Meteorology (METEO)	METEOROLOGISCHE ZEITSCHRIFT	3	2.4	1
	METEOROLOGY & ATMOSPHERIC PHYSICS	3	1.8	1
	TELLUS SERIES A–DYNAMIC MET & OCEAN	3	4.5	1
Climate Dynamics (CLIMATE)	CLIMATE DYNAMICS	5	6.4	1
	GEOPHYSICAL RESEARCH LETTERS	5	6.0	1
	TELLUS SERIES A–DYNAMIC MET & OCEAN	5	4.5	1
Small Scale Oceanography	JOUR GEOPHYSICAL RESEARCH–OCEANS	7	4.5	2
	JOURNAL OF MARINE SYSTEMS	4	5.0	1
Large Scale Oceanography	GEOPHYSICAL RESEARCH LETTERS	6	6.0	1
	JOUR GEOPHYSICAL RESEARCH–OCEANS	3	4.5	2
Chemical Oceanography (ChemOcean)	Biogeosciences	4	8.0	1
	GLOBAL BIOGEOCHEMICAL CYCLES	4	8.1	1
	DEEP–SEA RESEARCH PART II–OCEANOGR	3	5.2	1
Palaeoclimate processes and past climate sensitivity	QUATERNARY SCIENCE REVIEWS	9	9.6	2
	GEOCHEMISTRY GEOPHYSICS GEOSYST	4	4.4	2
	EARTH AND PLANETARY SCIENCE LETTERS	3	8.0	2
	PALEOCEANOGRAPHY	3	6.6	1
	Quaternary Geochronology	3	5.4	1
Climate variability and dynamics	HOLOCENE	7	5.3	2
	GEOPHYSICAL RESEARCH LETTERS	6	6.0	1
	JOUR GEOPHYSICAL RESEARCH–OCEANS	5	4.5	2
	QUATERNARY SCIENCE REVIEWS	5	9.6	2
Carbon biogeochemistry and marine ecosystems	Biogeosciences	10	8.0	1
	PROGRESS IN OCEANOGRAPHY	5	7.5	1
	DEEP–SEA RESEARCH PART II–OCEANOGR	3	5.2	1
	GEOPHYSICAL RESEARCH LETTERS	3	6.0	1

Geoscience	PETROLEUM GEOSCIENCE	8	2.5	1
(CIPR)	Ameri Assoc of Petroleum Geologists Bulletin	5	2.3	2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Finally, we have analysed the citation rate of the journal publications. The results are given in Table 4.5.4. Generally, University of Bergen and Uni Research perform very well in terms of citation rates. The publications from Department of Earth Science and Uni Bjerknes Centre are cited almost 100 % more than the field normalised world average (citation index 194). The two units rank as number five in terms of citation rates of the departments and institutes included in the evaluation. Also the citation index for Center for Integrated Petroleum Research is very high (179), although the indicator is based on a rather small number of publications. The publications from the Geophysical Institute are less cited than those of the other departments and the field normalised citation index is 109. All the four units tend to publish in journals that are more cited than average, particularly the Uni Bjerknes Centre publishes in journals with very high impact factors. As a consequence, the citation index – journal is significantly lower than the field normalised citation index.

At group level all research groups at Department of Earth Science and Uni Bjerknes Centre perform very well in terms of citation rates. At the Geopysical Institute, the publications of the Meteorology group and Climate Dynamics groups, in particular, are little cited.

Table 4.5.4 Citation and journal indicators, 2005–2008 publications*. University of Bergen & Uni Research.

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]
Department of Earth Science – TOTAL	228	2099	103	194	122	154	160
Geobiology research group (GB)	32	295	29	213	125	177	170
Geodynamics Group (GdG)	41	235	74	136	109	117	125
Marine Geology and Geophysics (MGG)	76	907	103	231	131	183	177
Petroleum Geosciences Group (PGG)	24	175	24	158	105	123	150
Quaternary Geology and Palaeoclimate (QGP)	62	493	37	168	111	126	152
Geophysical Institute – TOTAL	79	445	50	109	99	79	110
Meteorology (METEO)	12	39	8	53	56	39	95
Climate Dynamics (CLIMATE)	20	54	10	74	67	52	110
Small Scale Oceanography (ScOcean)	21	121	23	122	132	91	93
Large Scale Oceanography (LaScO)	16	168	50	167	140	122	120
Chemical Oceanography (ChemOcean)	12	99	24	129	100	93	128
Uni Bjerknes Centre – TOTAL	99	880	45	194	87	144	224
Palaeoclimate processes and past climate sensitivity	34	262	36	177	84	137	210
Climate variability and dynamics	43	397	41	188	85	140	220
Carbon biogeochemistry and marine ecosystems	24	224	45	195	87	145	223
Global and regional climate projections	4	12	8	–	–	–	–
Geoscience (CIPR)	19	91	9	179	163	122	110

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.

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

4.6 University of Oslo

At the University of Oslo, the evaluation encompasses the Department of Geosciences. In addition two research groups at the Natural History Museum are included.

Table 4.6.1 shows various publication indicators for the departments and their research groups. In terms of man power and publication output, the Department of Geosciences is the largest of the departments that have been included in the evaluation. Moreover, the productivity is generally good, measured in terms of fractionised publications per full-time equivalents (FTE). With the exception of the Mineralogy group at the Museum, all the research groups have a scientific productivity which is above the average for all units covered by the evaluation (which is 0.45 fractionalised publications per number of FTE). The productivity is particularly high for the Tectonics, Petrology and Geochemistry (TPG) group at the Department of Geosciences.

Table 4.6.1 Number of publications, 2005–2009, University of Oslo.

Unit	Number of man years (FTE)	Publica–tions – whole counts	Publica–tions – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL Department of Geosciences	255.3	481	162.8	0.6
Cryosphere Research Group (NatGeo/Cryos)	28.0	57	18.3	0.7
Environmental Geology and Hydrology (MGH)	39.4	85	22.7	0.6
Meteorology and Oceanography (MetOs)	36.3	102	26.0	0.7
Petroleum Geology and Geophysics (PEGG)	73.7	96	35.5	0.5
Physics of Geological Processes (PGP)	62.9	109	44.4	0.7
Tectonics, Petrology and Geochemistry (TPG)	15.0	48	16.0	1.1
TOTAL Natural History Museum	52.2	75	27.4	0.5
Mineralogy	27.0	30	9.0	0.3
Paleontology / Stratigraphy	25.2	45	18.4	0.7

Table 4.6.2 shows the average citation rate of the journals the groups have published in. Overall, both the Department of Geosciences and the Natural History Museum have published in journals with citation rates somewhat below the national average for the units encompassed by the evaluation, which is 5.4. At group level, the average varies from 3.3 for the Paleontology / Stratigraphy group at the Museum to 6.7 for the Meteorology and Oceanography (MetOs) group at the Department of Geosciences.

Table 4.6.2 Journal profile by groups/sections, 2005–2009 publications. University of Oslo.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL Department of Geosciences	481	4.9
Cryosphere Research Group (NatGeo/Cryos)	57	3.6
Environmental Geology and Hydrology (MGH)	85	3.8
Meteorology and Oceanography (MetOs)	102	6.7
Petroleum Geology and Geophysics (PEGG)	96	3.9
Physics of Geological Processes (PGP)	109	5.6
Tectonics, Petrology and Geochemistry (TPG)	48	5.2
TOTAL Natural History Museum	75	3.5
Mineralogy	30	3.9
Paleontology / Stratigraphy	45	3.3

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the “standard” journal impact factor is calculated in a different way).

Table 4.6.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005-2009.

Table 4.6.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. University of Oslo.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Cryosphere Research Group (NatGeo/Cryos)	PERMAFROST AND PERIGLACIAL PROCESSES	11	5.0	2
	ANNALS OF GLACIOLOGY	5	0.0	1
	JOURNAL OF GEOPHYSICAL RESEARCH–EARTH SURFACE	5	5.4	2
Environmental Geology and Hydrology (MGH)	JOURNAL OF HYDROLOGY	16	4.4	2
	THEORETICAL AND APPLIED CLIMATOLOGY	8	2.4	1
	HYDROLOGICAL PROCESSES	6	3.5	1
Meteorology and Oceanography (MetOs)	ATMOSPHERIC CHEMISTRY AND PHYSICS	28	10.4	1
	JOURNAL OF GEOPHYSICAL RESEARCH–ATMOSPHERES	14	7.5	2
	ATMOSPHERIC ENVIRONMENT	7	6.2	1
Petroleum Geology and Geophysics (PEGG)	TECTONOPHYSICS	12	3.0	1
	GEOPHYSICAL JOURNAL INTERNATIONAL	11	4.6	2
	American Association of Petroleum Geologists BULLETIN	6	2.3	2
	MARINE AND PETROLEUM GEOLOGY	6	3.8	1
	NORWEGIAN JOURNAL OF GEOLOGY	6	1.8	1
Physics of Geological Processes (PGP)	EARTH AND PLANETARY SCIENCE LETTERS	20	8.0	2
	JOURNAL OF THE GEOLOGICAL SOCIETY	5	6.2	1
	NORWEGIAN JOURNAL OF GEOLOGY	5	1.8	1
Tectonics, Petrology and Geochemistry (TPG)	PRECAMBRIAN RESEARCH	6	6.2	1
	JOURNAL OF THE GEOLOGICAL SOCIETY	5	6.2	1
	EARTH AND PLANETARY SCIENCE LETTERS	4	8.0	2
	LITHOS	4	8.1	2
Mineralogy	CANADIAN MINERALOGIST	3	2.7	1
	EUROPEAN JOURNAL OF MINERALOGY	3	2.4	1
	GEOCHIMICA ET COSMOCHIMICA ACTA	3	7.9	2
	MINERALOGY AND PETROLOGY	3	1.9	1
Paleontology / Stratigraphy	ACTA PALAEONTOLOGICA POLONICA	6	3.1	1
	NORWEGIAN JOURNAL OF GEOLOGY	5	1.8	1
	LETHAIA	3	3.5	1
	MARINE MICROPALEONTOLOGY	3	4.5	2
	MICROPALEONTOLOGY	3	1.5	1
	POLAR RESEARCH	3	2.4	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Finally, we have analysed the citation rate of the journal publications. The results are given in Table 4.6.4. The Department of Geosciences performs well in terms of citation rates. The publications are cited 57 % more than the field normalized world average (citation index 157) and 21 % more than the corresponding Norwegian average. The Natural History Museum performs less well and obtains a citation index– field of 81, and a citation index – Norway of 66. In other words, the publications are cited below the world average and considerably below the Norwegian average.

At group level the publications of the Meteorology and Oceanography group are very highly cited (citation index – field 250), but also the Physics of Geological Processes (PGP), Tectonics, Petrology and Geochemistry (TPG) and Environmental Geology and Hydrology (MGH) groups performs well in terms of citation rates with citation indexes – field ranging from 132 to 152. At the opposite end we find that Paleontology/Stratigraphy group at the Museum with a citation index field significantly below average.

Table 4.6.4 Citation and journal indicators, 2005–2008 publications*. University of Oslo.

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]
Department of Geosciences – TOTAL	336	2382	103	157	123	121	128
Cryosphere Research Group (NatGeo/Cryos)	51	186	19	102	105	78	97
Environmental Geology and Hydrology (MGH)	53	344	26	132	116	99	114
Meteorology and Oceanography (MetOs)	70	1016	103	250	162	172	154
Petroleum Geology and Geophysics (PEGG)	69	266	17	101	93	84	109
Physics of Geological Processes (PGP)	67	411	34	142	103	118	138
Tectonics, Petrology and Geochemistry (TPG)	37	224	38	152	117	128	130
Natural History Museum– TOTAL	59	211	15	81	93	66	88
Mineralogy	22	97	12	102	105	94	97
Paleontology / Stratigraphy	37	114	15	69	85	52	82

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.

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

4.7 University of Stavanger

At the University of Stavanger, one research group at the Petroleum Engineering Department is included in the evaluation: Petroleum Geosciences group. The group was basically established at the end of 2008, beginning of 2009 (3-4 people then, 5 full time faculty 2011). Before that time, there was basically one full time faculty in geosciences in the department. Thus, the group consists of few staff members, and was recently established. Considering this fact, a bibliometric analysis cannot provide much information on the performance of the group and only 9 articles have been published during the period. However, some numbers are given in the tables below.

Table 4.7.1 Journal profile by groups/sections, 2005–2009 publications. University of Stavanger, Petroleum Engineering Department.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
Petroleum Geosciences group	9	3.3

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the “standard” journal impact factor is calculated in a different way).

Table 4.7.2 Citation and journal indicators, 2005–2008 publications*. University of Stavanger, Petroleum Engineering Department.

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]
Petroleum Geosciences group	3	4	2	–	–	–	–

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.

4.8 University of Tromsø

At the University of Tromsø one department is included in the evaluation: Department of Geology, consisting of three research groups.

Table 4.8.1 shows various publication indicators for the department and its research groups. The by far largest research group both in terms of manpower and number of publications is the Polar Marine Geology & Geophysics (PMGG) group. This group has a scientific productivity of 0.5 fractionalised publications per full time equivalent (FTE), which is close to the average for all unites covered by this evaluation (0.45). The other groups have published very few papers, and have scientific productivity significantly below the national average.

Table 4.8.1 Number of publications, 2005–2009, University of Tromsø, Department of Geology.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL Department of Geology	84.9	94	31.2	0.4
Coastal and Terrestrial Geology (CTG)	10.0	2	0.7	0.1
Crustal Dynamics (CD)	22.2	9	2.9	0.1
Polar Marine Geology & Geophysics (PMGG)	52.8	83	27.6	0.5

Table 4.8.2 shows the average citation rate of the journals the groups have published in. For the department as a whole, the average journal citation rate of the journals is 5.8, which is close to the national average for the units encompassed by the evaluation (5.4).

Table 4.8.2 Journal profile by groups/sections, 2005–2009 publications. University of Tromsø, Department of Geology.

	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL Department of Geology	94	5.8
Coastal and Terrestrial Geology (CTG)	2	4.9
Crustal Dynamics (CD)	9	4.7
Polar Marine Geology & Geophysics (PMGG)	83	6.0

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.8.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005-2009. Therefore, there are no journals on this list for two of the research groups.

Table 4.8.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. University of Tromsø, Department of Geology.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Crustal Dynamics (CD)	NORWEGIAN JOURNAL OF GEOLOGY	3	1.8	1
Polar Marine Geology & Geophysics (PMGG)	MARINE AND PETROLEUM GEOLOGY	16	3.8	1
	QUATERNARY SCIENCE REVIEWS	11	9.6	2
	MARINE GEOLOGY	10	5.5	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.8.4 contains a citation and journal profile of the department and its groups based on the articles published in the period 2005–2008. 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 performs very well in terms of citation rates – largely due to the Polar Marine Geology & Geophysics (PMGG) group. The publications of the department have been cited almost 100 % above the field normalized world average (citation index – field 199). The department ranks as number three in terms of citation rates of the departments and institutes included in the evaluation. The citation index of the Polar Marine Geology & Geophysics (PMGG) group is even higher (Citation index – field 217). The department tends to publish in journals that are more cited than average, i.e. have high impact factors. As a consequence, the citation index – journal is significantly lower than the field normalised citation index.

Table 4.8.4 Citation and journal indicators, 2005–2008 publications*. University of Tromsø, Department of Geology.

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	79	770	74	199	134	143	149
Coastal and Terrestrial Geology (CTG)	1	8	8	–	–	–	–
Crustal Dynamics (CD)	8	45	19	–	–	–	–
Polar Marine Geology & Geophysics (PMGG)	70	717	74	217	138	153	157

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.9 CICERO – Center for International Climate and Environmental Research

There are two research groups included in the evaluation from CICERO – Center for International Climate and Environmental Research.

Table 4.9.1 shows various publication indicators for the research groups. The research activity in terms of manpower and publication output is strongly dominated by the Climate system group. This group has a scientific productivity of 1.1 which is significantly above the average for all units covered by this evaluation (0.45).

Table 4.9.1 Number of publications, 2005–2009, CICERO.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL CICERO	16.4	57	14.9	0.9
Group 1: The climate system	14.4	56	14.4	1.0
Group 3: Adaptation to climate change	2.0	1	0.5	0.3

Table 4.9.2 shows the average citation rate of the journals the groups have published in. The Climate system group tends to publish in journals with high impact factors. The average citation rate of the journals is 7.5, which is above the national average for the units encompassed by the evaluation (5.5).

Table 4.9.2 Journal profile by groups/sections, 2005–2009 publications. CICERO.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL CICERO	57	7.4
Group 1: The climate system	56	7.5
Group 3: Adaptation to climate change	1	1.7

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.9.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005-2009. Therefore, there are no journals on this list for Adaptation to climate change group.

Table 4.9.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. CICERO.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Group 1: The climate system	ATMOSPHERIC CHEMISTRY AND PHYSICS	15	10.4	1
	TELLUS SERIES B–CHEMICAL AND PHYSICAL METEOROLOGY	7	5.8	1
	GEOPHYSICAL RESEARCH LETTERS	5	6.0	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.9.4 contains a citation and journal profile of the institute and its groups based on the articles published in the period 2005–2008.

The climate system group performs very well in terms of citation rates. The publications have been cited almost 200 % above the field normalized world average (citation index – field 298). The group tends to publish in journals that are more cited than average, i.e. have high impact factors. As a consequence, the citation index – journal is lower than the field normalised citation index, but still significantly above average for the journals.

Table 4.9.4 Citation and journal indicators, 2005–2008 publications*. CICERO.

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	32	549	100	295	158	204	186
Group 1: The climate system	31	549	100	298	158	206	188
Group 3: Adaptation to climate change	1	0	–	–	–	–	–

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.10 Geological Survey of Norway

Geological Survey of Norway is the research institute with the highest output of publications. At the Geological Survey of Norway there are seven research groups included in the evaluation.

Table 4.10.1 shows various publication indicators for the research groups. Overall, the scientific productivity at Geological Survey of Norway is good. The number of fractionalised publications per number of full time equivalents (FTE) is 0.6, which is above the average for all units covered by this evaluation (0.45). Particularly, the Geodynamics group and the Geochemistry group have high productivity levels, 1.1 and 0.9 publications, respectively.

Table 4.10.1 Number of publications, 2005–2009, Geological Survey of Norway.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL Geological Survey of Norway	190.3	293	119.3	0.6
Bedrock and crustal processes	39.0	84	27.0	0.7
Continental Shelf Geophysics	26.1	35	15.1	0.6
Geochemistry	16.8	39	14.5	0.9
Geodynamics	21.4	61	23.1	1.1
Geohazards	39.8	50	13.5	0.3
Quaternary Geology and Climate	33.5	58	19.0	0.6
Tectonics and landscape Evolution	13.8	20	6.9	0.5

Table 4.10.2 shows the average citation rate of the journals the groups have published in. Overall, the average journal citation rate of the journals is 5.2, which is close to the national average for the units encompassed by the evaluation (5.4). Particularly, the Geodynamics group stands out with publications in journals with an average citation rate of 8.4.

Table 4.10.2 Journal profile by groups/sections, 2005–2009 publications. Geological Survey of Norway.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTALT Geological Survey of Norway	293	5.2
Bedrock and crustal processes	84	4.5
Continental Shelf Geophysics	35	4.2
Geochemistry	39	4.1
Geodynamics	61	8.4
Geohazards	50	4.9
Quaternary Geology and Climate	58	4.4
Tectonics and landscape Evolution	20	5.0

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.10.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005-2009. Therefore, there are only two journals on this list for the Tectonics and landscape Evolution group, but five journals for the Bedrock and crustal processes group and for the Quaternary Geology group and four journals for Quaternary Geology and Climate group.

Table 4.10.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. Geological Survey of Norway.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Bedrock and crustal processes	PRECAMBRIAN RESEARCH	7	6.2	1
	NORWEGIAN JOURNAL OF GEOLOGY	6	1.8	1
	JOURNAL OF THE GEOLOGICAL SOCIETY	5	6.2	1
	TECTONICS	5	5.3	2
	TERRA NOVA	5	3.4	1
Continental Shelf Geophysics	TECTONOPHYSICS	10	3.0	1
	NORWEGIAN JOURNAL OF GEOLOGY	5	1.8	1
	GEOPHYSICAL PROSPECTING	3	2.0	1
Geochemistry	SCIENCE OF THE TOTAL ENVIRONMENT	11	5.4	2
	APPLIED GEOCHEMISTRY	7	3.7	1
	GEOCHEMISTRY–EXPLORATION ENVIRONMENT ANALYSIS	6	1.0	1
Geodynamics	EARTH AND PLANETARY SCIENCE LETTERS	8	8.0	2
	GEOPHYSICAL JOURNAL INTERNATIONAL	8	4.6	2
	JOURNAL OF THE GEOLOGICAL SOCIETY	5	6.2	1
Geohazards	MARINE GEOLOGY	11	5.5	1
	MARINE AND PETROLEUM GEOLOGY	6	3.8	1
	QUATERNARY SCIENCE REVIEWS	3	9.6	2
Quaternary Geology and Climate	BOREAS	12	4.7	1
	MARINE GEOLOGY	5	5.5	1
	GEOMORPHOLOGY	4	5.7	2
	QUATERNARY SCIENCE REVIEWS	4	9.6	2
Tectonics and landscape Evolution	NORWEGIAN JOURNAL OF GEOLOGY	3	1.8	1
	PRECAMBRIAN RESEARCH	3	6.2	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.10.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. The institute performs very well in terms of citation rates. All groups have a field normalized citation index above 120. In other words, the articles are cited at least 20 % more than the world average. The citation rates are also higher than the Norwegian average. The publications of the Geodynamics Group are particularly highly cited. This group has a citation index-field of 261. Also the Geohazards group and the Geochemistry group perform very well, with citation indexes -field of 204 and 174, respectively.

Table 4.10.4 Citation and journal indicators, 2005–2008 publications*. Geological Survey of Norway.

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	216	1729	74	171	122	140	140
Bedrock and crustal processes	62	417	52	136	95	113	143
Continental Shelf Geophysics	20	136	18	120	117	107	103
Geochemistry	29	270	52	174	181	146	96
Geodynamics	44	480	52	261	128	212	204
Geohazards	39	294	74	204	142	151	143
Quaternary Geology and Climate	41	276	29	142	110	110	129
Tectonics and landscape Evolution	13	106	32	150	108	126	139

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.

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

4.11 Institute of Marine Research

At the Institute of Marine Research there is only one research group included in the evaluation, specialised in oceanography.

Table 4.11.1 shows various publication indicators for this research group. The number of fractionalised publications per number of full time equivalents (FTE) is 0.4 which is close to average for all units covered by this evaluation (0.45).

Table 4.11.1 Number of publications, 2005–2009, Institute of Marine Research.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
Oceanography	77.3	88	32.0	0.4

Table 4.11.2 shows the average citation rate of the journals the group has published in. The average journal citation rate of the journals is 5.0, which is close to the national average for the units encompassed by the evaluation (5.5).

Table 4.11.2 Journal profile by groups/sections, 2005–2009 publications. Institute of Marine Research.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
Oceanography	88	5.3

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.11.3 gives the three most frequently used journals during the period 2005–2009.

Table 4.11.3 The most frequently used journals, number of publications 2005–2009 by groups/sections. Institute of Marine Research.

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Oceanography	DEEP–SEA RESEARCH PART II–TOPICAL STUDIES IN OCEANOGRAPHY	11	5.2	1
	ICES JOURNAL OF MARINE SCIENCE	10	3.6	1
	MARINE ECOLOGY–PROGRESS SERIES	9	5.6	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.

Table 4.11.4 contains a citation and journal profile of the group based on the articles published in the period 2005–2008. The group performs very well in terms of citation rates. Their publications are highly cited compared to corresponding world and Norwegian averages. The group has a field normalized citation index at 191. In other words, the articles are cited 91 % more than the world average. The citation rate is also significantly higher than the corresponding Norwegian average.

Table 4.11.4 Citation and journal indicators, 2005–2008 publications*. Institute of Marine Research.

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]
Oceanography	61	492	38	191	130	146	147

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.12 Nansen Environmental and Remote Sensing Center

At the Nansen Environmental and Remote Sensing Center there are three research groups included in the evaluation.

Table 4.12.1 shows various publication indicators for the three research groups. Overall, the number of fractionalised publications per number of full time equivalents (FTE) is 0.4, which is close to the average for all units covered by this evaluation (0.45). The productivity rate is lowest for the Marine remote sensing group (0.2)

Table 4.12.1 Number of publications, 2005–2009, Nansen Environmental and Remote Sensing Center.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL Nansen Environmental and Remote Sensing Center	129.3	96	48.2	0.4
A. Marine remote sensing	44.8	24	7.3	0.2
B. Ocean and sea ice modelling and data assimilation	24.0	40	14.4	0.6
C. Climate studies and modelling	60.5	62	26.4	0.4

Table 4.12.2 shows the average citation rate of the journals the groups have published in. For the institute as a whole, the average journal citation rate of the journals is 5.4, which is almost identical to the national average for the units encompassed by the evaluation (5.5).

Table 4.12.2 Journal profile by groups/sections, 2005–2009 publications. Nansen Environmental and Remote Sensing Center.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL Nansen Environmental and Remote Sensing Center	96	5.4
A. Marine remote sensing	24	6.0
B. Ocean and sea ice modelling and data assimilation	40	3.8
C. Climate studies and modelling	62	6.3

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.12.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005–2009.

Table 4.12.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. Nansen Environmental and Remote Sensing Center.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
A. Marine remote sensing	GEOPHYSICAL RESEARCH LETTERS	4	6.0	1
	JOURNAL OF GEOPHYSICAL RESEARCH–OCEANS	4	4.5	2
B. Ocean and sea ice modelling and data assimilation	JOURNAL OF GEOPHYSICAL RESEARCH–OCEANS	5	4.5	2
	ADVANCES IN ATMOSPHERIC SCIENCES	4	1.1	1
	GEOPHYSICAL RESEARCH LETTERS	3	6.0	1
	JOURNAL OF MARINE SYSTEMS	3	5.0	1
	OCEANOGRAPHY	3	0.0	1
C. Climate studies and modelling	GEOPHYSICAL RESEARCH LETTERS	7	6.0	1
	ADVANCES IN ATMOSPHERIC SCIENCES	5	1.1	1
	JOURNAL OF CLIMATE	4	7.6	2
	JOURNAL OF GEOPHYSICAL RESEARCH–OCEANS	4	4.5	2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the “standard” journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR’s bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.12.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. Overall, the institute has a field normalized citation index of 115. In other words, the publications are 15 % more cited than the world average. Nevertheless, the publications of the institute are cited below the corresponding Norwegian average.

The Marine remote sensing group has a field normalized citation index of 102, and the Climate studies and modelling group has a field normalized citation index of 129. In other words, the articles are cited 2 % and resp. 29 % above the world average. The citation rate of both groups is lower than the Norwegian average (78 and resp. 94). The Ocean and sea ice modelling and data assimilation group has a rather poor performance measured in terms of citations. Their publications are little cited compared to corresponding world and Norwegian averages.

Table 4.12.4 Citation and journal indicators, 2005–2008 publications*. Nansen Environmental and Remote Sensing Center.

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	72	451	84	115	77	85	149
A. Marine remote sensing	21	111	41	102	56	78	182
B. Ocean and sea ice modelling and data assimilation	23	60	14	55	54	39	102
C. Climate studies and modelling	54	394	84	129	78	94	164

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4.13 NORSAR

At NORSAR there are two research groups included in the evaluation.

Table 4.13.1 shows various publication indicators for the two research groups. Both groups have a productivity level corresponding to 0.4 fractionalised publications per number of full time equivalents (FTE), which is close to the average for all units covered by this evaluation (0.45).

Table 4.13.1 Number of publications, 2005–2009, NORSAR.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL NORSAR	49.9	45	20.3	0.4
Earthquake and the Environment	22.4	27	9.8	0.4
Seismology and nuclear–test–ban treaty monitoring	27.5	20	10.5	0.4

Table 4.13.2 shows the average citation rate of the journals the groups have published in. The average journal citation rate of the journals is 3.2 for the institute as a whole, which is below the national average for the units encompassed by the evaluation (5.5).

Table 4.13.2 Journal profile by groups/sections, 2005–2009 publications. NORSAR.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTALT NORSAR	45	3.2
Earthquake and the Environment	27	2.6
Seismology and nuclear–test–ban treaty monitoring	20	4.3

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.13.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005–2009.

Table 4.13.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. NORSAR.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Earthquake and the Environment	JOURNAL OF EARTHQUAKE ENGINEERING	5	1.2	1
	BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA	4	5.2	2
Seismology and nuclear–test–ban treaty monitoring	GEOPHYSICAL JOURNAL INTERNATIONAL	5	4.6	2
	BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA	4	5.2	2
	PHYSICS OF THE EARTH AND PLANETARY INTERIORS	3	4.7	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.13.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. Both groups have an average performance measured in terms of citations. The citation rate is at the same level as the world and Norwegian averages.

Table 4.13.4 Citation and journal indicators, 2005–2008 publications*. NORSAR.

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	38	200	28	108	118	102	91
Earthquake and the Environment	22	118	21	109	124	98	89
Seismology and nuclear–test–ban treaty monitoring	17	84	28	99	103	104	96

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4. 14 Norwegian Institute for Air Research

At the Norwegian Institute for Air Research there is only one research groups included in the evaluation, specialised in Atmospheric Transport Processes.

Table 4.14.1 shows various publication indicators for this research group. The productivity of the group in terms of number of published papers is good. The number of fractionalised publications per number of full time equivalents (FTE) is 0.7, significantly higher than the average for all units covered by this evaluation (0.45).

Table 4.14.1 Number of publications, 2005–2009, Norwegian Institute for Air Research.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
Atmospheric Transport Processes	34.0	111	24.0	0.7

Table 4.14.2 shows the average citation rate of the journals the group has published in. The average journal citation rate of the journals is 7.7, which is well above the national average for the units encompassed by the evaluation (5.5).

Table 4.14.2 Journal profile by groups/sections, 2005–2009 publications. Norwegian Institute for Air Research.

	Numb. of articles	Avg. journal citation rate (impact factor)*
Atmospheric Transport Processes	111	7.7

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.14.3 gives the three most frequently used journals.

Table 4.14.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. Norwegian Institute for Air Research.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Atmospheric Transport Processes	JOURNAL OF GEOPHYSICAL RESEARCH–ATMOSPHERES	33	7.5	2
	ATMOSPHERIC CHEMISTRY AND PHYSICS	30	10.4	1
	ATMOSPHERIC ENVIRONMENT	7	6.2	1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals.

Table 4.14.4 contains a citation and journal profile of the group based on the articles published in the period 2005–2008. The group performs very well in terms of citation rates. The group has a field normalized citation index of 268. In other words, the publications are cited 168 % more than the world average. The citation rate is also much higher than the Norwegian average. Moreover, the group tends to publish in journals with high impact factors.

Table 4.14.4 Citation and journal indicators, 2005–2008 publications*. Norwegian Institute for Air Research.

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]
Atmospheric Transport Processes	81	1128	110	268	165	185	162

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4. 15 Norwegian Meteorological Institute

At the Norwegian Meteorological Institute there are three research groups included in the evaluation.

Table 4.15.1 shows various publication indicators for the three research groups. The number of fractionalised publications per number of full time equivalents (FTE) is 0.4 for the institute as a whole, which is close to the average for all units covered by this evaluation (0.45).

Table 4.15.1 Number of publications, 2005–2009, Norwegian Meteorological Institute.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL Norwegian Meteorological Institute	109.1	111	43.3	0.4
Group 1: Climate research	42.2	45	21.8	0.5
Group 2: Environmental research	28.0	49	11.2	0.4
Group 3: Atmosphere and ocean modelling	38.9	34	10.3	0.3

Table 4.15.2 shows the average citation rate of the journals the groups have published in. The average journal citation rate of the journals is 6.4 for the institute, which is above the national average for the units encompassed by the evaluation (5.5)

Table 4.15.2 Journal profile by groups/sections, 2005–2009 publications. Norwegian Meteorological Institute.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTALT Norwegian Meteorological Institute	111	6.4
Group 1: Climate research	45	6.6
Group 2: Environmental research	49	6.9
Group 3: Atmosphere and ocean modelling	34	5.1

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.15.3 gives the most frequently used journals during the period 2005–2009.

Table 4.15.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. Norwegian Meteorological Institute.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Group 1: Climate research	TELLUS SERIES A–DYNAMIC METEOROLOGY AND OCEANOGRAPHY	9	4.5	1
	GEOPHYSICAL RESEARCH LETTERS	6	6.0	1
	CLIMATE DYNAMICS	4	6.4	1
Group 2: Environmental research	ATMOSPHERIC CHEMISTRY AND PHYSICS	10	10.4	1
	ATMOSPHERIC ENVIRONMENT	9	6.2	1
	JOURNAL OF GEOPHYSICAL RESEARCH–ATMOSPHERES	8	7.5	2
Group 3: Atmosphere and ocean modelling	TELLUS SERIES A–DYNAMIC METEOROLOGY AND OCEANOGRAPHY	9	4.5	1
	ATMOSPHERIC CHEMISTRY AND PHYSICS	3	10.4	1
	JOURNAL OF MARINE SYSTEMS	3	5.0	1
	JOURNAL OF PHYSICAL OCEANOGRAPHY	3	5.3	2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals.

Table 4.15.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. One group has a very high performance measured in terms of citations: The Environmental research group has a field normalized citation index of 261. This means that the publications are 161 % more cited than the corresponding world-average. The citation rate is in addition much higher than the Norwegian average. Also the Climate research group performs well in terms of citation rates with a citation index-field of 151.

Table 4.15.4 Citation and journal indicators, 2005–2008 publications*. Norwegian Meteorological Institute.

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	80	744	95	182	119	128	153
Group 1: Climate research	36	299	95	151	90	106	168
Group 2: Environmental research	31	393	44	261	179	182	146
Group 3: Atmosphere and ocean modelling	25	99	24	99	84	71	118

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
1) World average field = 100. 2) Journal average = 100. 3) Norwegian average field = 100, 4) Average journal profile = 100.

4. 16 Norwegian Polar Institute

The Norwegian Polar Institute has seven research groups included in the evaluation.

Table 4.16.1 shows various publication indicators for the research groups. The number of fractionalised publications per number of full time equivalents (FTE) for the institute as a whole is 0.3. This is below the average for all units covered by this evaluation (0.45). The Glaciology group has the highest productivity level (0.6). The other research groups have productivity rates close to or below the national average.

Table 4.16.1 Number of publications, 2005–2009, Norwegian Polar Institute.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
TOTAL Norwegian Polar Institute	96.2	116	30.1	0.3
Atmospheric Science	3.1	4	0.7	0.2
Geomapping	14.0	6	1.7	0.1
Glaciology	18.6	53	11.4	0.6
Marine Geology	16.2	24	5.7	0.4
Oceanography	26.8	18	6.0	0.2
Polar climate/statistics	3.0	6	1.5	0.5
Sea ice Physics	14.6	12	3.1	0.2

Table 4.16.2 shows the average citation rate of the journals the groups have published in. For the institute as a whole, the average journal citation rate of the journals is 6.9 which is above the national average for the units encompassed by the evaluation (5.5). Particularly the Marine Geology group tends to publish in journals with high impact factors (11.1).

Table 4.16.2 Journal profile by groups/sections 2005–2009 publications. Norwegian Polar Institute.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTALT Norwegian Polar Institute	116	6.9
Atmospheric Science	4	7.4
Geomapping	6	4.8
Glaciology	53	6.3
Marine Geology	24	11.1
Oceanography	18	5.1
Polar climate/statistics	6	5.7
Sea ice Physics	12	5.2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the “standard” journal impact factor is calculated in a different way).

Table 4.16.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005-2009. Because of the threshold, there are no journals listed for Atmospheric Science, Geomapping, and Polar climate/statistics groups. Almost all the journals on the list are classified at the highest level (level 2) as the leading and most selective international journals in UHR's bibliometric funding model.

Table 4.16.3 The most frequently used journals*, number of publications 2005–2009 by groups/sections. Norwegian Polar Institute.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Glaciology	JOURNAL OF GLACIOLOGY	12	3.7	2
	ANNALS OF GLACIOLOGY	8	0.0	1
	JOURNAL OF GEOPHYSICAL RESEARCH–ATMOSPHERES	8	7.5	2
Marine Geology	PALEOCEANOGRAPHY	8	6.6	1
	MARINE MICROPALEONTOLOGY	4	4.5	2
	QUATERNARY SCIENCE REVIEWS	4	9.6	2
Oceanography	GEOPHYSICAL RESEARCH LETTERS	5	6.0	1
	JOURNAL OF GEOPHYSICAL RESEARCH–OCEANS	4	4.5	2
	JOURNAL OF PHYSICAL OCEANOGRAPHY	3	5.3	2
Sea ice Physics	JOURNAL OF GEOPHYSICAL RESEARCH–ATMOSPHERES	4	7.5	2
	JOURNAL OF GEOPHYSICAL RESEARCH–OCEANS	3	4.5	2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).
**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.
***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.16.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. However, for four of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). The Glaciology group and the Marine Geology group have a high field normalized citation index; especially the performance for the Marine Geology group – 440 – can be highlighted, although the number of papers included in the analysis is rather limited. The articles of this group are cited 340 % above the world average. Moreover, both groups tend to publish in journals with high impact factors.

Table 4.16.4 Citation and journal indicators, 2005–2008 publications*. Norwegian Polar Institute.

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	89	826	119	197	116	140	170
Atmospheric Science	1	7	7	–	–	–	–
Geomapping	5	32	14	–	–	–	–
Glaciology	49	368	119	141	89	99	158
Marine Geology	19	271	103	440	148	303	298
Oceanography	9	140	50	–	–	–	–
Polar climate/statistics	5	5	1	–	–	–	–
Sea ice Physics	5	17	11	–	–	–	–

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.

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

4. 17 Norwegian Water Resources and Energy Directorate

At the Norwegian Water Resources and Energy Directorate there are three research groups included in the evaluation.

Table 4.17.1 shows various publication indicators for the three research groups. The number of fractionalised publications per number of full time equivalents (FTE) for the Directorate is with 0.3 below the average for all units covered by this evaluation (0.45).

Table 4.17.1 Number of publications, 2005–2009, NVE Research Group.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
NVE Research Group	46.0	33	12.8	0.3
HB: Glaciers, ice and snow	25.0	25	8.5	0.3
HM: Hydrological modelling	16.0	9	2.9	0.2
HS: Sediment and erosion	5.0	3	1.3	0.3

Table 4.17.2 shows the average citation rate of the journals the groups have published in. Overall, the average citation rate of the journals is 3.6, which is below the national average for the units encompassed by the evaluation (5.5)

Table 4.17.2 Journal profile by groups/sections, 2005–2009 publications. NVE Research Group.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
TOTAL NVE Research Group	33	3.6
HB: Glaciers, ice and snow	25	3.4
HM: Hydrological modelling	9	5.3
HS: Sediment and erosion	3	3.3

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

Table 4.17.3 gives the most frequently used journals – limited to journals with at least three publications during the period 2005–2009. Because of the threshold, there are no journals listed for two of the groups.

Table 4.17.3 The most frequently used journals*, number of publications, 2005–2009 by groups/sections. NVE Research Group.**

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
HB: Glaciers. ice and snow	ANNALS OF GLACIOLOGY	7	0.0	1
	JOURNAL OF GLACIOLOGY	5	3.7	2

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the "standard" journal impact factor is calculated in a different way).

**) Cf. the two categories of publication channels applied in the UHR's bibliometric funding model.

***) Limited to the three most frequently used journals – with at least three publications during the time period.

Table 4.17.4 contains a citation and journal profile of the groups based on the articles published in the period 2005–2008. However, for two of the groups, we have not calculated relative citation indexes due to the small number of articles (cf. Method section). The Glaciers, ice and snow group has a field normalized citation index of 89. In other words, the articles are cited 11 % below the world average. The citation rate of this group is with 64 significantly lower than the Norwegian average.

Table 4.17.4 Citation and journal indicators, 2005–2008 publications*. NVE Research Group.

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	29	119	18	88	90	64	97
HB: Glaciers, ice and snow	24	106	18	89	95	64	94
HM: Hydrological modelling	7	51	18	–	–	–	–
HS: Sediment and erosion	2	4	4	–	–	–	–

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.

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

4. 18 SINTEF Petroleum Research

At the SINTEF Petroleum Research one research group is included in the evaluation: Formation Physics. This group consists of few staff members, and has only published 12 articles during the period 2005–2009. A bibliometric analysis is not very meaningful for such a small number of publications. However, some indicators are given in the tables below.

Table 4.18.1 shows various publication indicators for the research group. The number of fractionalised publications per number of full time equivalents FTE is with 0.1 far below the average for all units covered by this evaluation (0.45).

Table 4.18.1 Number of publications, 2005–2009, SINTEF Petroleum Research.

Unit	Number of man years (FTE)	Publications – whole counts	Publications – fractional counts	Number of publications (fractional counts) per number of FTE
Formation Physics	59.1	12	8.5	0.1

Table 4.18.2 shows the average citation rate of the journals the group has published in.

Table 4.18.2 Journal profile by groups/sections, 2005–2009 publications. SINTEF Petroleum Research.

Unit	Numb. of articles	Avg. journal citation rate (impact factor)*
Formation Physics	12	2.7

*) The average journal citation rate is here based on the 2007 articles published in the respective journals and their citation rates in the period 2007–2009 (the “standard” journal impact factor is calculated in a different way).

Table 4.18.3 contains a citation and journal profile of the group based on the articles published in the period 2005–2008. However, we have not calculated relative citation indexes due to the small number of articles (cf. Method section).

Table 4.18.3 Citation and journal indicators, 2005–2008 publications*. SINTEF Petroleum Research.

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]
Formation Physics	9	19	7	–	–	–	–

*) Based on the publications from the period 2005–2008 and the accumulated citations to these publications through 2009.
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 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.

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[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.

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

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.

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

List of ”level 2” journals within geosciences and related fields*

American Association of Petroleum Geologists Bulletin
Biogeochemistry
Bulletin of Engineering Geology and the Environment
Bulletin of The American Meteorological Society - (BAMS)
Bulletin of The Seismological Society of America (BSSA)
Cold Regions Science and Technology
Contributions to Mineralogy and Petrology
Earth and Planetary Science Letters
Environmental Science and Technology
Geochemistry Geophysics Geosystems
Geochimica et Cosmochimica Acta
Geological Society of America Bulletin
Geology
Geophysical Journal International
Geophysics
IEEE Transactions on Geoscience and Remote Sensing
Journal of Climate
Journal of Environmental Quality
Journal of Geophysical Research
Journal of Glaciology
Journal of hydrologic engineering
Journal of Hydrology
Journal of Petroleum Science& Engineering
Journal of Petrology
Journal of Physical Oceanography
Journal of Structural Geology
Lithos
Marine Micropaleontology
Mineralium Deposita
Minerals Engineering
Permafrost and Periglacial Processes
Quarterly Journal of the Royal Meteorological Society
Quaternary Research
Quaternary Science Reviews
Remote Sensing of Environment
Reviews of Geophysics
Rock Mechanics and Rock Engineering
Science of the Total Environment
Sedimentology
SPE Journal
SPE Reservoir Evaluation and Engineering
Tectonics
The Holocene
The International Journal of Life Cycle Assessment
Water Research
Water Resources Research
Water Science and Technology
Wind Energy

*) 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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