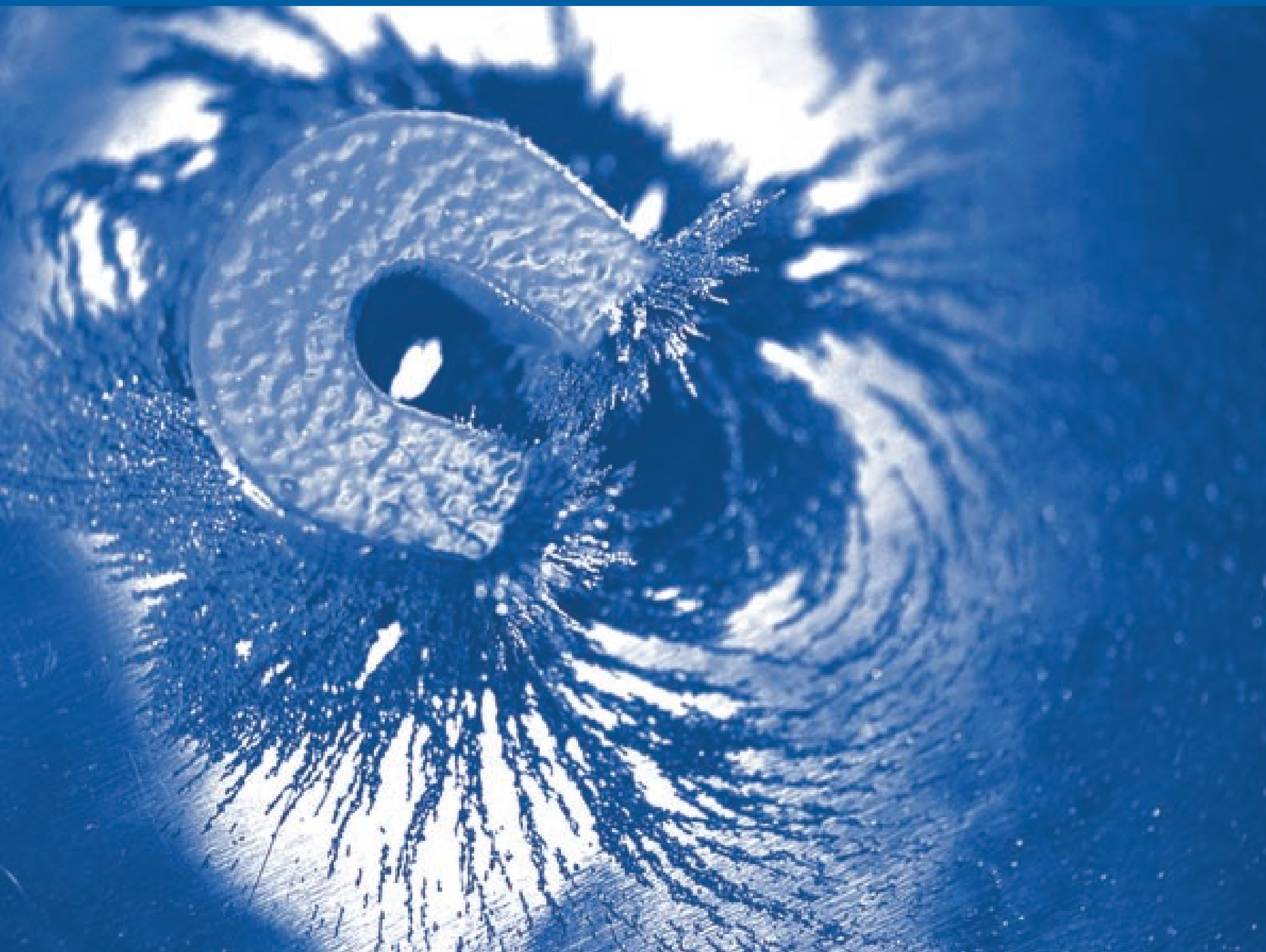
The Research Council of Norway

Basic Physics Research in Norway

– Bibliometric analysis

Evaluation
Division for Science



Evaluation of Physics Research in Norway

Bibliometric analysis

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Preface

This report presents a bibliometric analysis of Physics research in Norway 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 at the Norwegian Institute for Studies in Innovation, Research and Education (NIFU STEP).

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Summary

Compared to the situation when the previous evaluation of Physics research in Norway was carried out (1999-2000), important improvements can be identified. There has been a significant increase in the volume of the research measured in terms of number of publications. Moreover, the scientists tend to publish more of their papers in leading and prestigious journals in the field. The publications also obtain higher citation rates, which can be taken as an indication of increased scientific impact and international visibility.

In a global context Norway is a very small country science-wise. In Physics, the Norwegian publication output represented 0.3 % of the world production of scientific publications. In comparison Norway has an overall publication share of 0.6 % (national total, all fields). This means that Norway contributes much less to the global scientific output in Physics than it does in other fields. Despite the fact that a strong increase in the Norwegian publication output has taken place during the last decade, the relative position of Physics among other disciplines in Norway has not been strengthened. In fact, the general increase in the publication output of Norway has been even as strong as for Physics.

The analysis also shows that the citation rate of the publications has increased. The citation index in the recent years is significantly higher than it was 10 years ago. The Norwegian publications from the four year period 2004-2007 have been cited 47% per cent above the world average. In terms of citation rate, Norway ranks as number 8 among 17 Western countries analysed. Nevertheless, there are differences between the various Physics subfields. Some fields (Mechanics and Fluids & Plasma Physics) obtain citation rates below the world average.

There is extensive international research collaboration. In fact, 77% of the publications co-authored by Norwegian physicists also had co-authors from other countries in 2008. The USA is the most important collaborative partner nation.

The University of Oslo is by far the largest contributor to Norwegian Physics research, followed by the University of Bergen and the Norwegian University of Science and Technology. Together the three universities account for more than 80% of the national publication output in Physics.

The report also presents analyses of individual departments and research groups. We find large differences in terms of performance on the bibliometric indicators. Some departments and groups obtain very good scores while other appears as weak units with low productivity of publications and poor journal and citation records.

1 Introduction

This report presents the results of a bibliometric study of the institutions included in the evaluation of Physics research in Norway. Both the institution/department level and the research group level are analysed. In addition the report contains a macro analysis of Norwegian Physics research in 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 Physics research in an international context. Next follow 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 three 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 joint system for registration of scientific publications applied by several Norwegian higher education institutions, including the universities in Oslo, Bergen, Trondheim and Tromsø. Finally, we have used submitted publication lists and CVs as source of publication data for units that do not apply the Frida registration system (independent research institutes, the University of Stavanger (UiS), Norwegian University of Life Sciences (UMB), the University Centre in Svalbard (UNIS)).

2.2 Categories of scientific publications included

The purpose of the report is to analyse *scientific* publishing. This means that we have limited the study to the following publication types: articles in international peer-reviewed journals, books and articles in books published by publishing houses. 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.). Publications not covered by the above categories are not included (for example material such as popular science articles, reports, feature articles, book reviews are outside the scope of the categories given above). We have also excluded articles in conference proceedings, due to the fact that it is often difficult to determine whether a conference contribution has been published or not and whether it had been published as an abstract or a full paper. The articles in conference proceedings are also often published as journal papers later, although this is not always the case, particularly in technology oriented fields. In Physics, journals represent the channel were the principal and large majority of the original research results are published. In fact, almost all the publications included in the study are articles in international journals.

2.3 Included departments and researchers

The analysis covers the following departments and units:

- University of Oslo (UiO) – Dep. of Physics
- University of Oslo (UiO) – Dep. of Theoretical Astrophysics
- Norwegian University of Science and Technology (NTNU) – Dep. of Physics
- University of Bergen (UiB) – Dep. of Physics and Technology

- University of Tromsø (UiT) – Dep. of Physics and Technology
- The University of Stavanger (UiS) – Dep. of Mathematics and Natural Sciences (selected research groups)
- Norwegian University of Life Sciences (UMB) – Dep. of Mathematical Sciences and Technology (selected research groups)
- The University Centre in Svalbard (UNIS) – Dep. of Arctic Geophysics
- Institute for Energy Technology (IFE) – Physics Department
- SINTEF Materials and Chemistry – Material Physics group
- Norwegian Defence Research Establishment (FFI) (selected research groups)

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

2.4 Methods

The analysis covers the five year period 2004-2008. Separate analyses are provided for the tenured (i.e. professor and associate professors) and the non-tenured personnel (i.e. post. docs and researchers). From the Research Council of Norway we obtained information on the name of the persons encompassed by the evaluation. We have used this list of persons as a basis for publication searches in the Frida database. The database has a complete coverage of the scientific output at the four traditional universities.[2] However, it appears that in the introduction/test year of the database (2004), the coverage was not as good as for the following years. We have therefore added missing publications from this year (by comparing the Frida record lists with the publication lists on the submitted CVs). For the departments and units that do not apply the Frida system, we have used the submitted CVs and publication lists as source of data for the analysis.

[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.

[2] All Frida-items in the publication categories covered (cf. above) were included in the study. We discovered some cases were the data appeared deficient and where we were not able to verify the records. These items were excluded from the analysis.

As secondary data sources we applied ISI-databases which NIFU STEP has purchased from Thomson Reuters. 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 2009 edition of NCR, with data covering 1981-2008 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 Physics. This database was also applied for the purpose of creating reference standards.

A small fraction of the articles were not published in ISI-indexed journals. These articles are therefore not included in some of the analyses (analyses of citation rates and collaboration).

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 that 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.[3] It should be noted that some of the "groups" represent more informal structures whereas other "groups" correspond to formal subdivisions within the departments. 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 multiply 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 multiply reported items in the analysis of departments and groups (but not in the analysis of individuals), i.e. only unique publications were left.

2.4.1 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

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

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 for the tenured personnel, measured as “number of fractional publications per man-year”. 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.

2.4.2 Citation indicators

It is the individual articles and their citation counts that represent the basis for the citation indicators. Citation counts are only available (at least in a systematic way) for the ISI-indexed articles. 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 2004, citations are counted over a 5-year period, while for the articles published in 2006, citations are counted over a 3-year period (or more precisely a 2-3 year period: the year of publication, 2007 and 2008). 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 2004 publications, for example, will have assembled citations over a longer time period than articles published in 2007. 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 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.

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 2007). For example, for a review article published in a particular journal in 2005 we identified the average citation rates (2005–2007) to all the review articles published by this journal in 2005. ISI 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.

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 ISI'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 subsequenlty 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.

The following example can illustrate the principle for calculating relative citation indexes: A scientist has published a regular journal article in *Acta Chrystallographica E* in 2005. This article has been cited 3 times. The articles published in *Acta Chrystallographica E* were in contrast cited 1.74 times on average this year. The Relative citation index – journal is: (3/1.74)*100 = 172. The world-average citation rate for the subfield which this journal is assigned to is 3.7 for articles published this year. In other words, the article obtains a lower score compared to the field average. The Relative citation index – field is: (3/3.7)*100 = 81. 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*:

<u>Citation index: > 150:</u> Very high citation level

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

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

<u>Citation index: 50-80:</u> Low citation level**.**

<u>Citation index: < 50:</u> 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 (for example due to limited coverage of the publication literature). 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.

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.

Another analysis is based on the classification system applied in 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 Physics in an international context

This chapter presents various bibliometric indicators on the performance of Norwegian Physics research. The analysis is mainly based on the database National Science Indicators (cf. Method section), where Physics is a separate field category and where there also are categories for particular subfields within Physics. In the analysis we have both analysed Physics as a collective discipline and subfields. The category for Physics in the database includes the core subfields within the disciplines but some subfields relevant or partly relevant for Physics research are classified outside the category for Physics, for example astronomy. The latter areas, however, have been included in some of the analyses. An overview of the content and classification of Physics applied in the report is given in Table 3.1. Definitions of the various categories can be found in the textbox below.

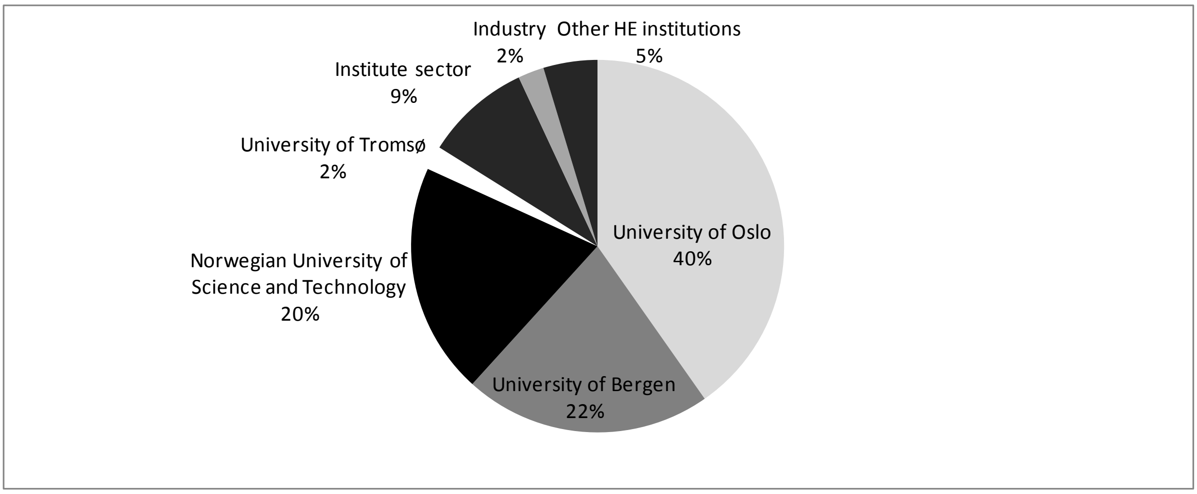
Table 3.1 Overview of the classification of Physics in the analysis

CATEGORY: Physics	CATEGORY: Physics and related subfields
Physics	Acoustics
	Atomic, Molecular & Chemical Physics
	Applied Physics
	Condensed Matter Physics
	Fluids & Plasma Physics
	Imaging Science & Photographic Technology
	Mathematical Physics
	Nuclear Physics
	Optics
	Particles & Fields
Related subfields - not included in Physics category	Astronomy & Astrophysics
	Biophysics
	Electrical & Electronic Enginering
	Material Science & Engineering
	Mechanics
	Nanoscience & Nanotechnology
	Nuclear Science & Technology
	Remote Sensing
	Thermodynamics

3.1 Scientific publishing

In 2008 Norwegian scientists published 430 articles in journals classified within the field Physics. During the five year period 2004-2008, approximately 1900 articles have been published. The numbers include only publication in the Physics category and publications in related subfields (e.g. Astronomy & Astrophysics) are not counted (cf. Table 3.1). The universities account for the large majority of the scientific journal publishing within Physics. This can be seen from Figure 3.1, where the article production during the period 2004-08 has been distributed according to institutions/sectors. The basis for this analysis is the information available in the address field of the articles.

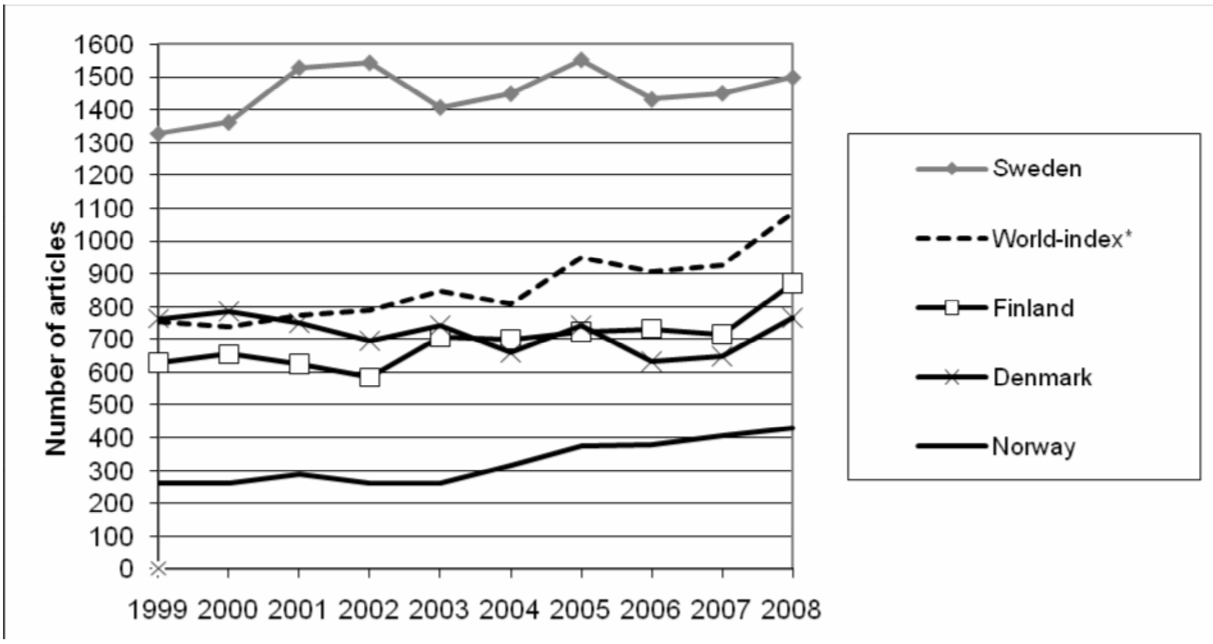
Figure 3.1 The Norwegian profile of scientific publishing in Physics. Proportion of the article production 2004-2008 by institutions/sectors



The University of Oslo is by far the largest contributor (40%) followed by the University of Bergen (22%) and the Norwegian University of Science and Technology in Trondheim (20%). The University of Tromsø is a small contributor with a proportion of only 2%. The Institute sector (private and public research institutes) accounts for 9% of the production. It should be noted, however, 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 2% of the Norwegian scientific journal production in Physics. In a similar way, 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.

In figure 3.2 we have shown the development in the annual production of articles in Physics for Norway and three other Nordic countries for the period 1999-2008. Among countries shown in the figure, Sweden is by far the largest nation in terms of publication output while Denmark and Finland make almost equal contributions. In 2008 the two latter countries produced 770 and 870 articles, respectively. Norway is a small research nation in Physics compared to our neighbouring countries. The Norwegian number of publications in Physics in 2008 is approximately one half of the Danish and Finnish and only one fourth of the Swedish. However, in terms of productivity there is a notable positive trend the recent years. While less than 300 articles were published annually by Norwegian researchers in the years 1999-2003, the production increased during period 2004-2008 and reached 430 in 2008.

Figure 3.2 Scientific publishing in Physics 1999-2008 in four Nordic countries



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

In Table 3.2 we have shown the increase in the number of papers from the year 1999 to the year 2008 for the same set of countries. This corresponds to the last year of the previous evaluation of Physics in Norway and the last year of the present evaluation. As can be seen, the number of papers published by Norwegian researchers in Physics in 2008 is 63% higher than the one in 1999. Thus, this shows that the volume of research in Physics as measured by publications is significantly higher now than in the previous period. The corresponding figures for Sweden, Denmark and Finland are 13%, 0%, and 39%, respectively. Norway has therefore by far 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 74% from 1999 to 2008. In other words, this growth is even higher than the one for Physics.[4] In a national context the relative position of Physics among the other disciplines has not been strengthened during the period. As another reference parameter, Table 3.2 and Figure 3.2 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 Physics (44%) and overall (49%).[5]

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

[5] The figures are for the universe represented by the Thomson Reuters' database. We do not have independent measures to assess the "real" global development. It is clear that the global science system is expanding from year to year. More money is being spent on research activities, which involves an increasing number of persons. This is also reflected in the publication counts. In addition, the coverage of the database in terms of the number of journals indexed has grown during the period. Particularly from 2007 to 2008 the

Table 3.2 Increase in the scientific publishing during the period 1999-2008 in four Nordic countries and the World, Physics and all fields

		Norway	Sweden	Denmark	Finland	World
Physics	Increase, per cent	63%	13%	0%	39%	44%
	Increase, number of articles	165	171	3	243	33169
All fields (national totals)	Increase, per cent	74%	24%	39%	34%	49%
	Increase, number of articles	3738	3685	3038	2472	380375

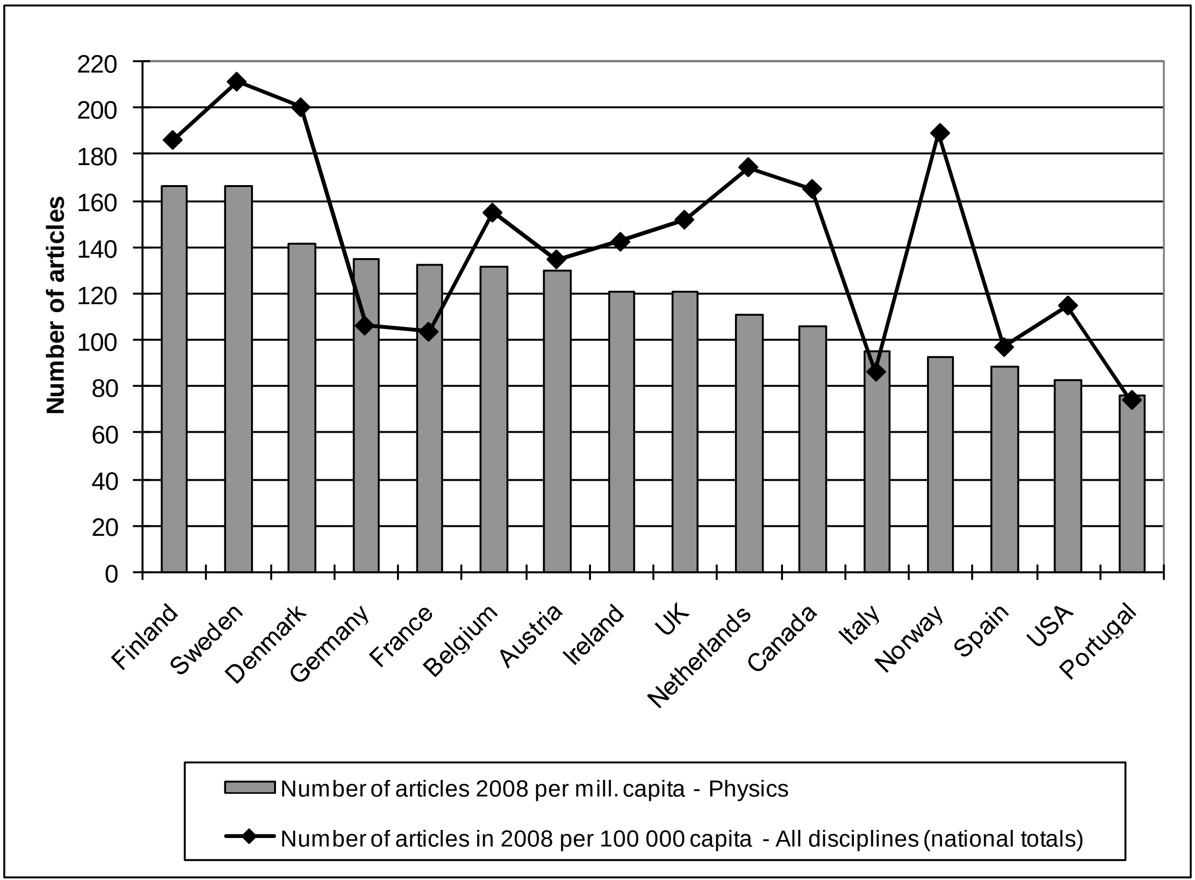
As described in Chapter 2 many publications are multi-authored, and are the results of collaborative efforts involving researchers from more than one country. In the figure we have used the "whole" counting method, i.e. a country is credited an article if it has at least one author address from the respective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

In a global context Norway is a very small country science-wise. In Physics, the Norwegian publication output represented 0.3 % 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 less to the global scientific output in Physics than it does in other fields. In order to reach the national average, the number of articles in Physics would have to be increased by approximately 100%.

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 93 articles in Physics in 2008. In Figure 3.3 we have shown the corresponding publication output for a selection of other countries (grey bars). Here Finland and Sweden have the highest relative number of articles with publication counts of 166. However, Switzerland has an even higher number, 318 (not shown in the figure for visibility reasons). Norway ranks as number 13 among the 16 nations shown in this figure. In other words, Norway has a relative publication output in Physics which is among the lowest found in these Western countries.

number of journals indexed increased significantly. Whether this increase in the database coverage correlates with the increase in the total scientific literature globally, is hard to assess. But at least part of the increase can be seen as a database artifact (cf. Aksnes & Hessen 2009).

Figure 3.3 Scientific publishing per capita in 2008 in selected countries,* Physics and all disciplines



*) Switzerland has a publication output in Physics of 318 articles per mill capita but been omitted from the figure of visibility reasons.

In Figure 3.3 we have also shown the production (per 100,000 capita) for all disciplines (national totals) (black line). This can be used as an indication of whether Physics has a higher or lower relative position in the science system of the countries than the average. For example, for Norway, Physics clearly ranks far below the national average, while the opposite is the case for the Germany and France.

In order to provide further insight into the profile of Norwegian Physics 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 (physics) 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 – Physics and related subdisciplines

Acoustics: Covers resources on the study of the generation, control, transmission, reception, and effects of sounds. Relevant subjects include linear and nonlinear acoustics; atmospheric sound; underwater sound; the effects of mechanical vibrations; architectural acoustics; audio engineering; audiology; and ultrasound applications.

Applied Physics: Covers those resources dealing with the applications of condensed matter, optics, vacuum science, lasers, electronics, cryogenics, magnets and magnetism, acoustical Physics, and mechanics. This category also may include resources on Physics applications to other sciences, engineering, and industry.

Astronomy & Astrophysics: Covers resources that focus on the science of the celestial bodies and their magnitudes, motions, and constitution. Topics include the properties of celestial bodies such as luminosity, size, mass, density, temperature, and chemical composition, as well as their origin and evolution. This category includes some resources on planetary science that focus on astrophysical aspects of planets. Space science is also included in this category.

Atomic, Molecular & Chemical Physics: Includes resources concerned with the Physics of atoms and molecules. Topics covered in this category include the structure of atoms and molecules, atomic and molecular interactions with radiation, magnetic resonances and relaxation, Mossbauer effect, and atomic and molecular collision processes and interactions.

Biophysics: Covers resources that focus on the transfer and effects of physical forces and energy-light, sound, electricity, magnetism, heat, cold, pressure, mechanical forces, and radiation-within and on cells, tissues, and whole organisms.

Condensed Matter Physics: Covers resources that deal with the study of the structure and the thermal, mechanical, electrical, magnetic, and optical properties of condensed matter. Topics covered in this category include superconductivity, surfaces, interfaces, thin films, dielectrics, ferroelectrics, and semiconductors. This category also includes resources from the former category of Solid State Physics as well as resources on condensed fluids.

Electrical & Electronic Engineering: Covers resources that deal with the applications of electricity, generally those involving current flows through conductors, as in motors and generators. This category also includes resources that cover the conduction of electricity through gases or a vacuum as well as through semiconducting and superconducting materials. Other relevant topics in this category include image and signal processing, electromagnetics, electronic components and materials, microwave technology, and microelectronics.

Fluids & Plasma Physics: Covers resources on the kinetic and transport theory of fluids, the physical properties of gases, and the Physics of plasmas and electric discharges. This category may include resources on nuclear fusion.

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

Material Science & Engineering: Is concerned with admixtures of matter or the basic matter from which products are made. The category covers ceramics, paper and wood products, polymers, textiles, composites, coatings & films, and biomaterials. Other areas covered in this category include Materials Chemistry, the application of chemistry to materials design and testing; Condensed Matter/Solid State Physics, the branch of Physics concerned with the structure and properties of condensed matter (superconductors, semiconductors, ferroelectrics, and dielectrics); and Physical Chemistry/Chemical Physics, the application of the concepts and laws of Physics to chemical phenomena.

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

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

Category descriptions – Physics and related subdisciplines

Nanoscience & Nanotechnology: Includes resources that focus on basic and applied research at the micro and nano level across a variety of disciplines including chemistry, biology, bioengineering, Physics, electronics, clinical and medical science, chemical engineering and materials science.

Nuclear Physics: Includes resources on the study of nuclear structure, decay, radioactivity, reactions, and scattering. Resources in this category focus on low-energy Physics. High-energy Physics is covered in the PARTICLES & FIELDS category.

Nuclear Science & Technology: Covers resources on nuclear energy (fission and fusion processes), nuclear energy and fuel, nuclear power, and nuclear electric power generation. This category also includes resources on nuclear engineering (the branch of technology that applies the nuclear fission process to power generation), nuclear safety, radiation effects, and radioactive waste management. Note: Resources on nuclear Physics (low-energy Physics) appear in the category NUCLEAR Physics.

Optics: Covers resources that deal with the genesis and propagation of light, the changes that it undergoes and produces, and other phenomena closely associated with it. Resources in this category cover subject areas such as lasers and laser technology, infrared Physics and technology, microwave technology, quantum optics, lightwave technology, fiber optics, opto-electronics, and photonics. Resources on photometry and luminescence are also included in this category.

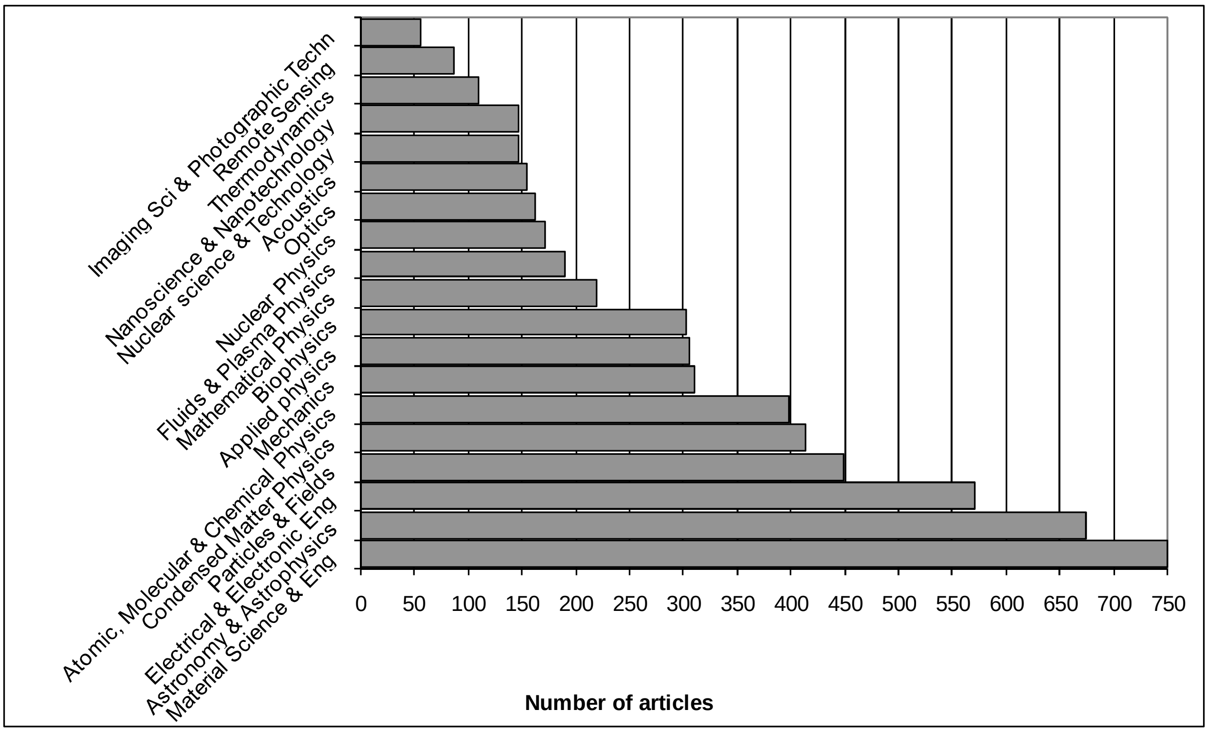
Particles & Fields: Includes resources on the study of the structure and properties of elementary particles and resonances and their interactions. Resources in this category focus on high-energy Physics. Low-energy Physics is covered in the NUCLEAR Physics category

Remote sensing: Includes resources 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 resources on the applications of remote sensing in environmental, atmospheric, meteorological, geographic, and geoscientific observations. Resources on geographic information systems that deal in large part with remote sensing are also included.

Thermodynamics: Includes resources that focus on the areas of Physics examining the transformations of matter and energy in physical and chemical processes, particularly those processes that involve the transfer of heat and changes in temperature. Relevant topics in this category include cooling and heating systems, cryogenics, refrigeration, combustion, energy conversion, and thermal stresses.

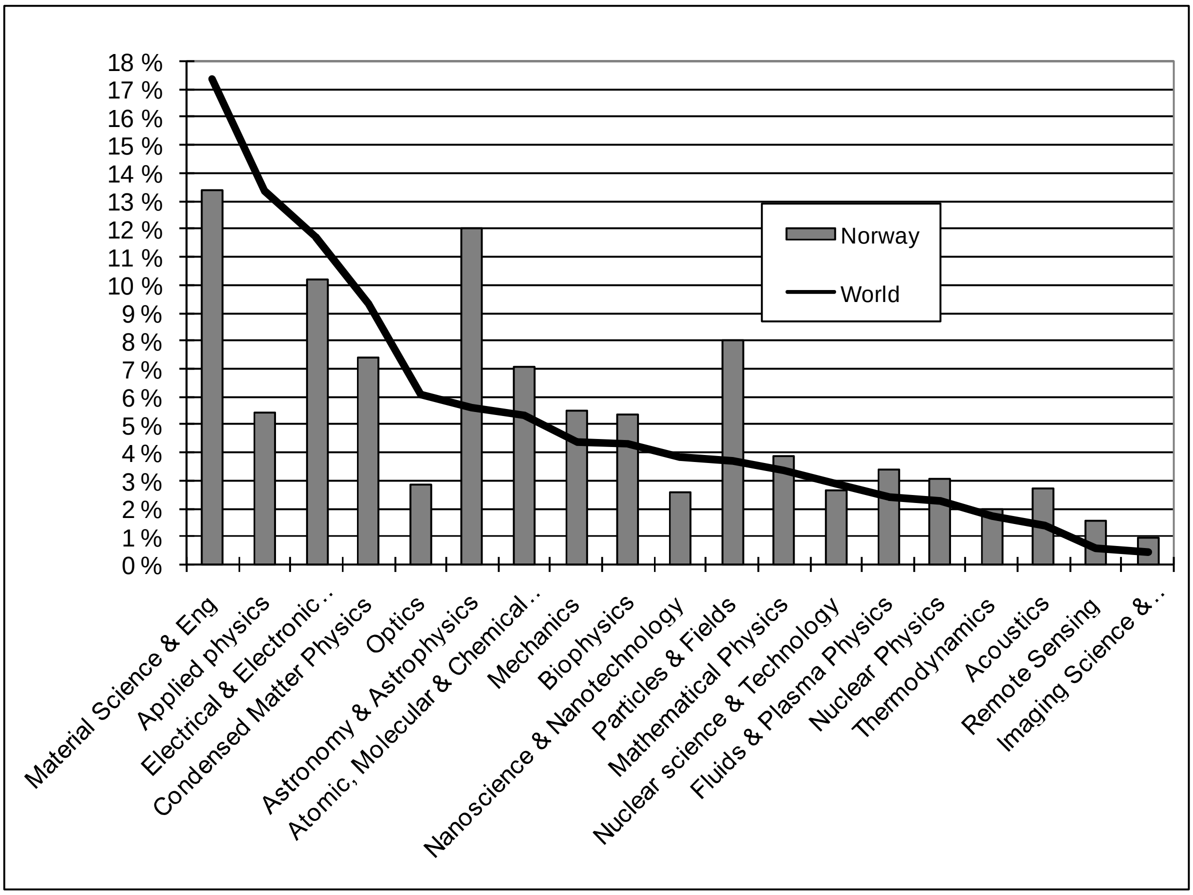
Figure 3.4 shows the distribution of articles for the 5-year period 2004-2008. Here, we have also included disciplines and subdisciplines outside the Physics category but relevant for the evaluation of Physics. We note that Material Science and Engineering is the largest category and 750 articles have been published within this field by Norwegian researchers during the period. Next follows Astronomy & Astrophysics with 675 articles. This category also includes space physics.

Figure 3.4 Scientific publishing in Physics and related fields, Norway, total number of articles for the period 2004-2008



The particular distribution of articles by subfields can be considered as the specialisation profile of Norwegian Physics. 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 3.5. As can be seen, Norway has a much higher proportion of articles in Astronomy & Astrophysics (including space physics) than the world average (respectively 12 and 6%). Also for the Physics subfield Particles & Fields the Norwegian proportion (8%) is significantly higher than the world average (4%). On the other hand, Norway has lower proportions in Applied Physics and Optics than the world average (5 vs. 13% and 3 vs. 6%). 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 satisfactory. Thus, the analysis is primarily interesting for providing insight into the particular characteristics of Norwegian Physics.

Figure 3.5 Relative distributions of articles on Physics and related subfields, Norway and the world average, based on publication counts for the period 2004-2008.



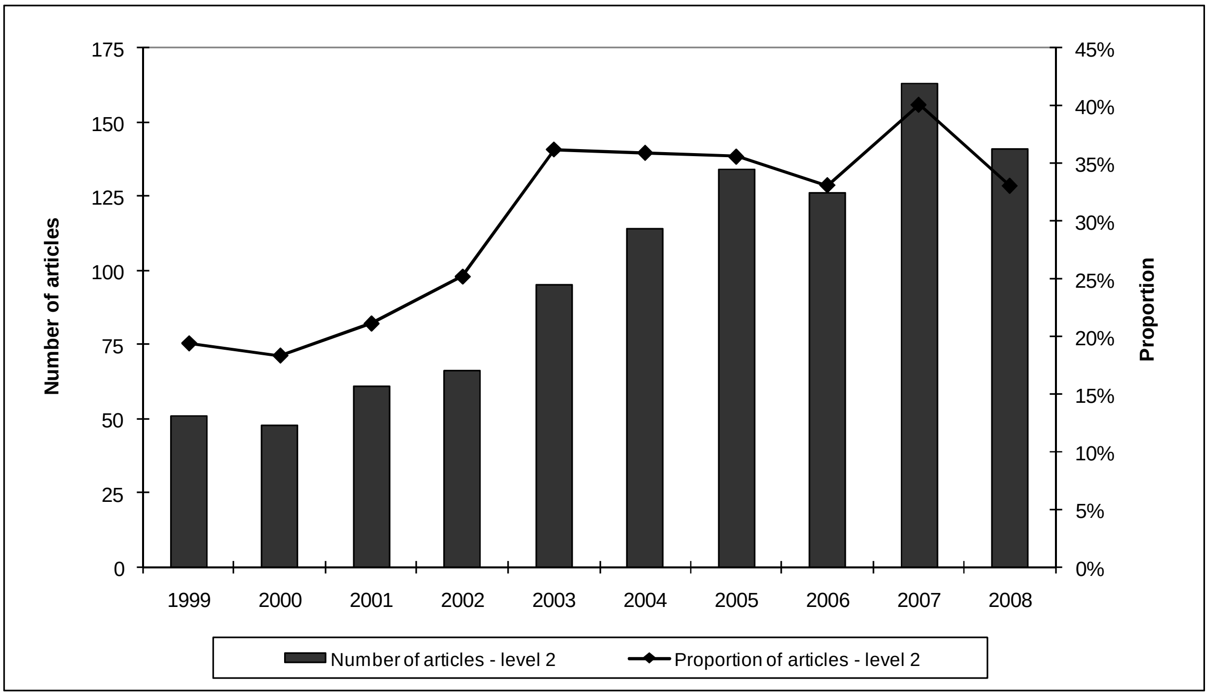
The Norwegian contributions in the field of Physics are distributed on a large number of different journals. However, the frequency distribution is very skewed and a limited number of journals account for a substantial amount of the publication output. Table 3.3 gives the annual publication counts for the most frequently used journals in Physics and related fields for the period 1999-2008. On the top of the list we find the *Physical Review Letters* with 320 articles, followed by *Physical Review D* (283) and *Physical Review B* (263). These are also among the largest Physics journals generally and in total more than 100,000 articles have been published in the three journals during the 10 year period. The table shows how the Norwegian contribution in the various journals has developed during the time period. From the list of journals one also gets an impression of the overall research profile of Norwegian Physics research.

Table 3.3 The most frequently used journals for the period 1999-2008, number of articles Norway, Physics and related subfields

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
PHYSICAL REVIEW LETTERS	14	10	18	22	32	46	53	37	48	40	320
PHYSICAL REVIEW D	6	6	7	16	12	27	50	58	37	64	283
PHYSICAL REVIEW B	14	19	22	18	16	23	28	35	42	51	268
JOURNAL OF CHEMICAL PHYSICS	15	12	11	10	21	22	16	17	15	27	166
PHYSICAL REVIEW E	9	10	12	22	9	11	18	14	15	25	145
JOURNAL OF PHYSICAL CHEMISTRY A	10	11	6	13	8	8	18	20	16	26	136
JOURNAL OF ALLOYS & COMPOUNDS	8	9	6	12	18	12	17	20	14	11	127
PHYSICS LETTERS B	35	28	18	5	9	5	4	8	7	6	125
ASTROPHYSICAL JOURNAL	10	9	5	8	12	15	20	15	18	9	121
EUROPEAN PHYSICAL JOURNAL C	14	17	9	3	11	19	10	12	11	9	115
PHYSICAL REVIEW C	7	19	8	9	5	10	15	18	7	15	113
ASTRONOMY & ASTROPHYSICS	3	1	12	7	16	14	17	15	17	9	111
JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	7	11	12	7	15	9	1	7	8	17	94
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECT A	5	6	4	9	9	7	13	12	9	7	81
PHYSICAL CHEMISTRY CHEMICAL PHYSICS	4	9	7	9	6	8	6	9	8	13	79
PHYSICA SCRIPTA	9	11	7	2	3	5	2	7	17	1	64
JOURNAL OF APPLIED PHYSICS	3	3	2	6	10	6	4	11	11	7	63
PHYSICAL REVIEW A	6	4	3	6	3	3	7	10	9	9	60
MATERIALS SCIENCE & ENG A-STRUC MAT PROP MICROSTR AND PROC	2	4	5	4	1	4	7	17	4	11	59
APPLIED PHYSICS LETTERS	1		1	1	9	9	9	6	9	10	55
JOURNAL OF PHYSICS G-NUCLEAR AND PARTICLE PHSICS	6		4	6	1	3	11	9	4	6	50
NUCLEAR PHYSICS A	6	5	13	6	7	2	8	1	1	1	50
METALLURGICAL & MATERIALS TRANSACTIONS A-PHYS METALLURGY & MATERIALS SCI	6	5	11	2	2	8	3	6	2	4	49
PHYSICS OF FLUIDS		3	1	3	9	4	8	8	6	6	48
JOURNAL OF FLUID MECHANICS	3	5	4	3	4	6	8	5	3	5	46
APPLIED OPTICS	6	10	6	4	4	3	3	4	3	2	45
JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA	2	5	2	1	4	8	5	2	8	7	44
SOLID STATE IONICS	5	2	8		5	1	6	9	5	3	44
CHEMICAL PHYSICS LETTERS	6	2	3	3	6	7	3	7	4	2	43
PHYSICA A-STATISTICAL MECHANICS AND ITS APPLICATIONS	4	1	3	10	6	5	5	4	3	1	42
MICROPOROUS AND MESOPOROUS MATERIALS	12	9	3	1	1	1	6	3	3	2	41
INTER JOURN OF REMOTE SENSING	8	3	2	3	4	3	6		5	5	39
AUTOMATICA	3	2	3	3	4	2	3	3	3	12	38
IEEE TRANSACTIONS ON ULTRASONICS FERROELECTRICS AND FREQUENCY CONTROL	4		6	5		1	1	6	7	7	37
MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY	3	4	4	2	3	2	3	9	3	4	37
JOURNAL OF COMPUTATIONAL PHYS	3	1	1	3	1	4	9	2	4	8	36
SURFACE SCIENCE	7	3	5	4		1	3	3	4	5	35
REMOTE SENSING OF ENVIRONMENT	1	2	2	4	2	3	5	4	7	3	33
ENERGY		1	2	1		9	5	1	11	2	32
SOLAR PHYSICS	6	5	4	2	3	3	4	1	1	3	32
THIN SOLID FILMS		1		1	1	4	4	5	13	3	32
JOURN OF THE AMER CERAMIC SOCI	3	3	3		1	4	3	2	7	2	28
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY	2	1	1	2	3			2	12	4	27
JOURNAL OF PHYSICS B-ATOMIC MOLECULAR AND OPTICAL PHYSICS	5	3	2	7	2	4		1		3	27
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION B	1	3	1	3	6	1		3	7	2	27
ACTA MATERIALIA	1	2	4	3	2	3	3	2	5	1	26
ENGINEERING FRACTURE MECHANICS	2	2	2	1	1	2	1	4	2	9	26
EUROPHYSICS LETTERS	1	3	2	2	2	4	6	5	1		26

As described in the Method chapter we have also used the classification system applied in the bibliometric model for performance based budgeting of research institutions. Here, the journals and publishers are classified in two levels and the highest level (level 2) includes only the leading and most selective international journals and publishers. In our analysis we identified the journal production at this highest level. Figure 3.6 shows the results of this analysis. As can be seen, both the number and proportion of articles in these journals have increased markedly during the time period. In 2007 40% of the international journal production appeared in leading journals, although this proportion decreased to 33% in 2008. It can be concluded that the ambitions when selecting journals for publication has increased. Moreover, in order to appear in these journals it can reasonably be assumed that the quality of the research is generally very good. Thus, the analysis suggests that the ambitions and quality has increased in recent years.

Figure 3.6 Number and proportion of articles in leading Physics journals – "level 2"*, Norway 1999-2008



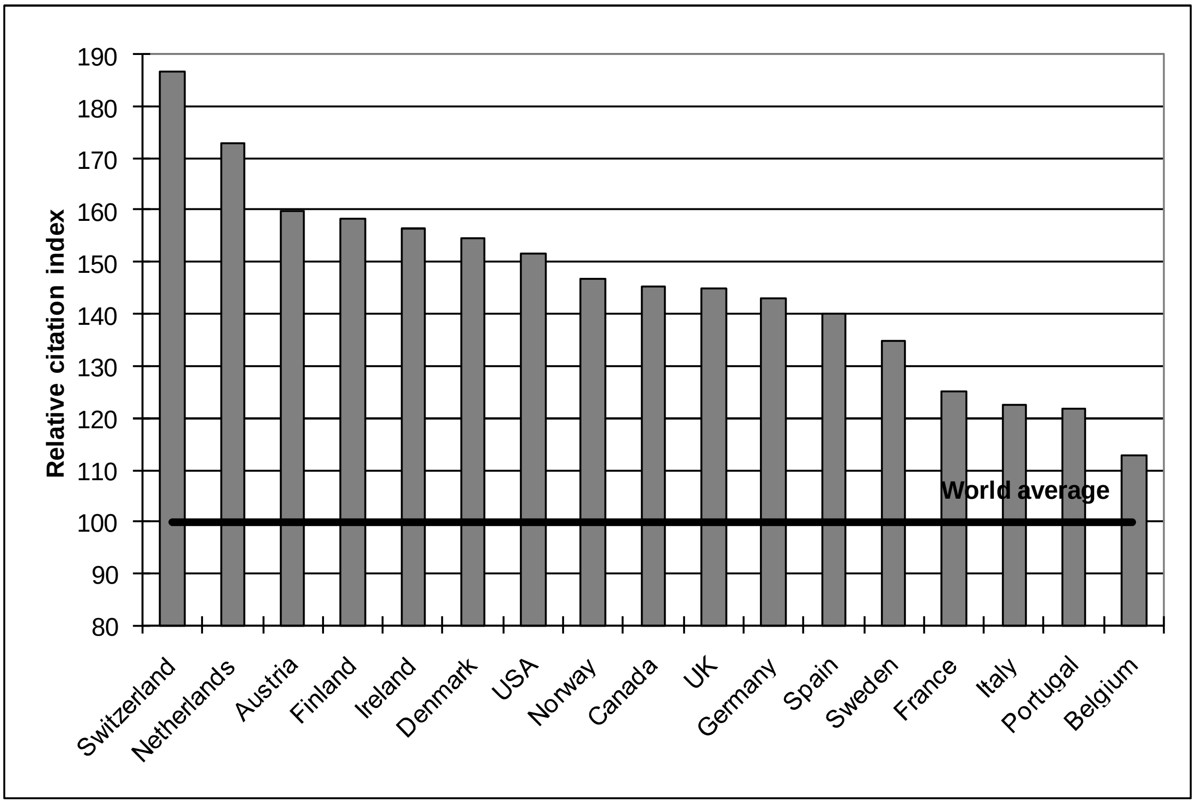
*) Cf. the guidance of the Norwegian Association of Higher Education Institutions.

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 3.7 shows the relative citation index in Physics for a selection of countries, based on the citations to the publications from the four year period 2004-2007. The publications from Switzerland and the Netherlands are most highly cited, approximately 90 and 70 % above world average. Norway ranks as number 8 among the 17 countries shown in this figure with a citation index of 147. In other words, the performance of Norwegian Physics in terms of citations is intermediate compared to these Western countries. Still, the Norwegian citation index is significantly above world average, although this average does not represent 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 82). The Norwegian index in Physics is also significantly higher than the Norwegian total (all disciplines) for this period which is approximately 120.

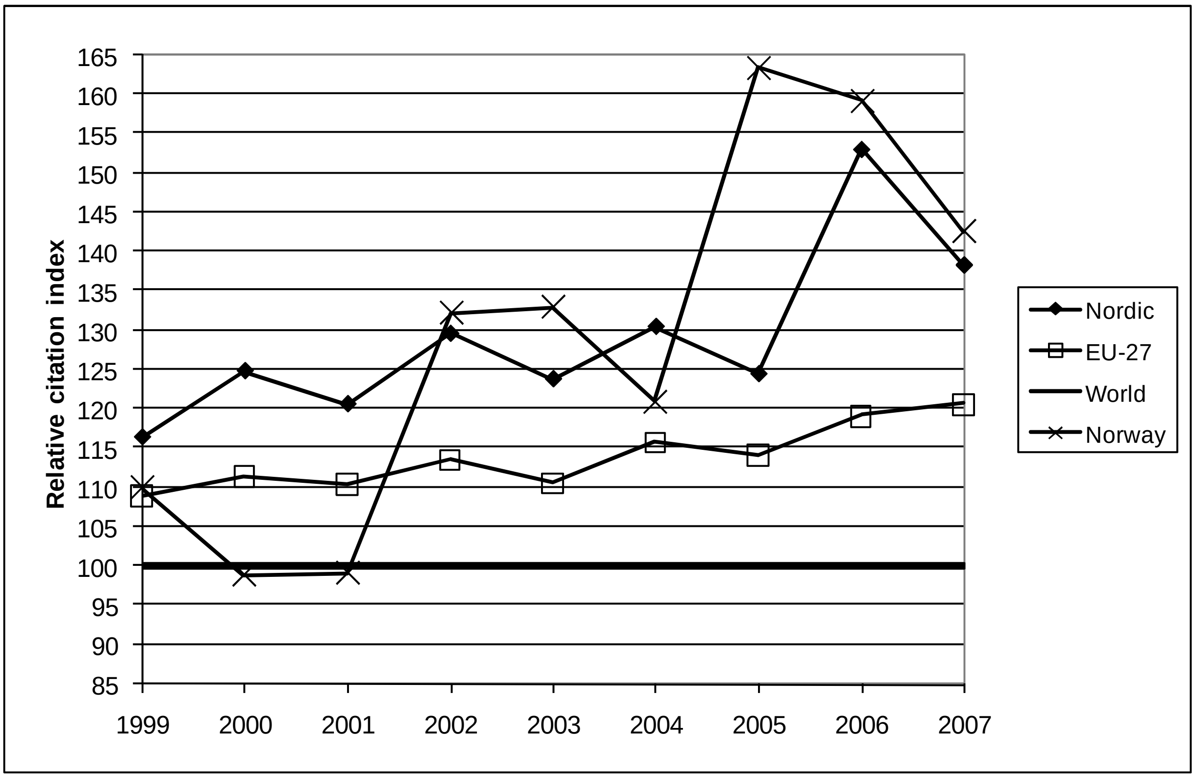
Figure 3.7 Relative citation index in Physics for selected countries (2004-2007)*



*) Based on the publications from the period 2004-2007 and accumulated citations to these publications through 2008.

We have also analysed how the citation rate of the Norwegian Physics publications has developed over the period 1999-2007. The results are shown in Figure 3.8. 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 very a positive trend and the index has improved from the 100-110 in the period 1999-2001 to 140-160 in the period 2005-2007.

Figure 3.8 Relative citation index in Physics for Norway compared with the average for the Nordic countries, the EU-27 and the world for the period 1999-2007

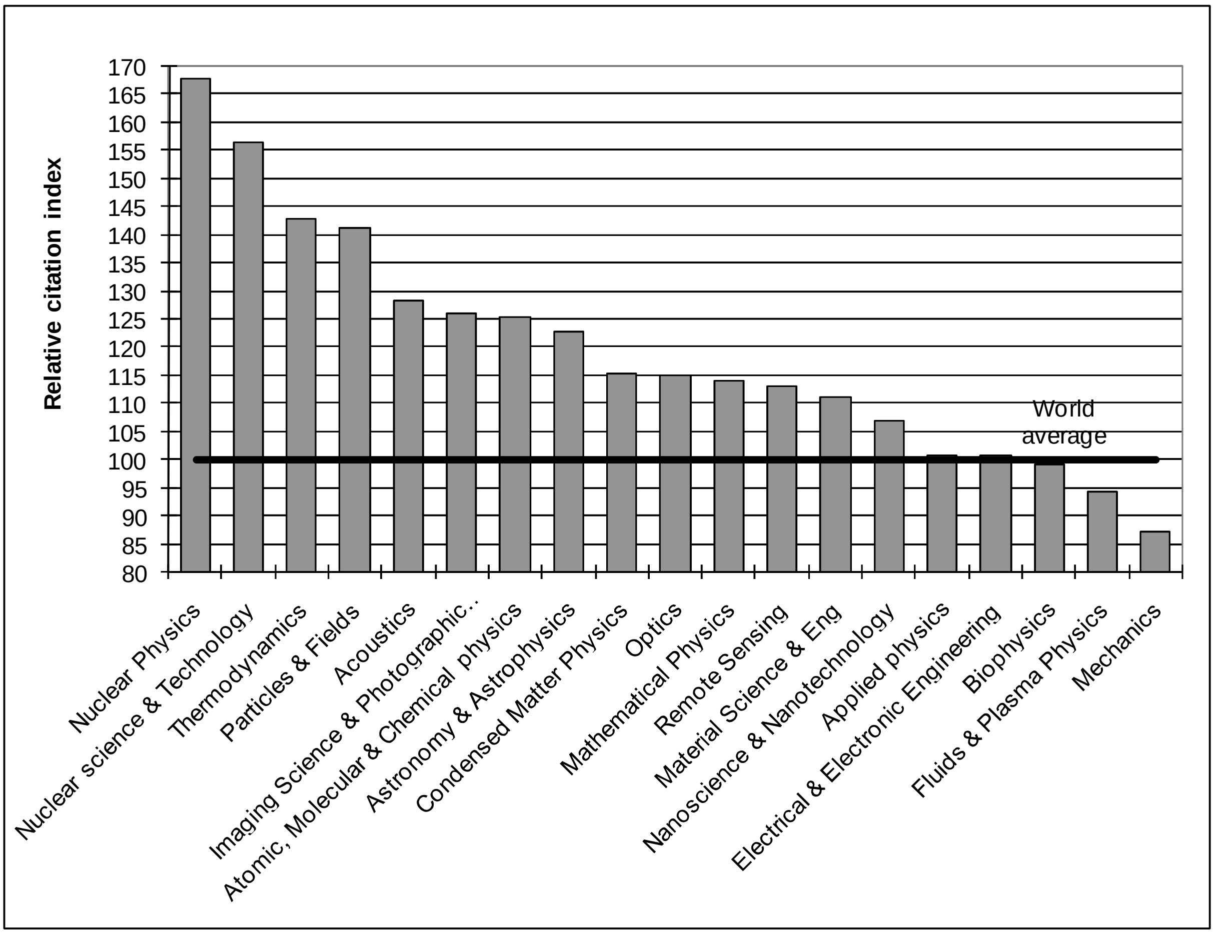


*) Based on annual publication windows and accumulated citations to these publications.

The overall citation index for Physics does however disguise important differences at subfield levels. This can be seen in figure 3.9 where a citation index has been calculated for each of the Physics and related subfields for the 2004-2007 publications. Norway performs very well in several of the subfields, notably Nuclear Physics, Nuclear Science & Technology, Thermodynamics, and Particles & Fields with index values of above 140. In the latter field we find the "CERN-papers" with several hundred authors and the citation rate is strongly influenced by these papers. Lowest citation rate is found for Mechanics (87).

[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 3.9 Relative citation index in Physics and related subfield (2004-2007)*



*) Based on the publications from the period 2004-2007 and accumulated citations to these publications through 2008.

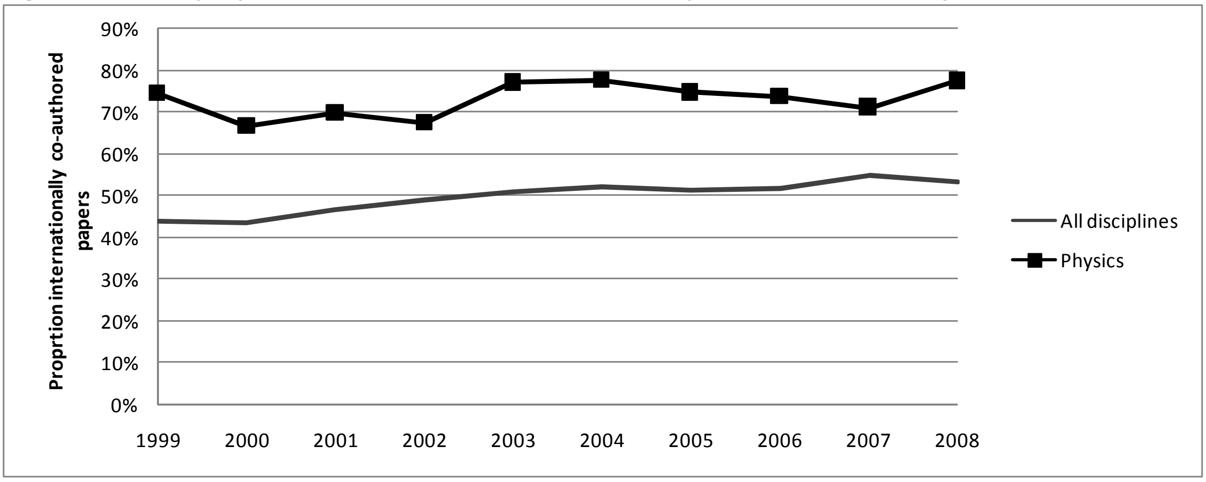
3.3 Collaboration indicators

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 3.10 we have shown the development in the extent of international co-authorship for Norway in Physics and for all disciplines (national total). In Physics 77% of the articles had co-authors from other countries in 2008. This is significantly higher than the national average (53%). Thus, the extent of international collaboration is very large in Physics.

The proportion in Physics has varied between 68 and 78 % in the 10 year period. The national total has increased steadily during the period from 43 % in 1998 to 53 % in 2007.

Figure 3.10 The proportion of international co-authorship, 1999-2008, Norway



Which countries are the most important collaborative partners for Norway in Physics? 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 collaborative partners from 1999 to 2008. A particular issue when dealing with this question is the large scale collaborative articles, most notably the "CERN-papers" that typically have several hundred authors. During the period we find 570 articles that have more than 50 authors (of a total of 3240 papers). These papers influence strongly on the international collaboration patterns. In the table we have therefore also shown the proportions when articles with more than 50 authors have been excluded from the dataset.

Table 3.4 Collaboration by country* 1999-2008. Number and proportion of the Norwegian article production in Physics with co-authors from the respective countries

Country	Num. articles	Proportion**	Country	Num. articles	Proportion**
USA	1053	32% (19%)	Switzerland	310	10% (4%)
Russia	815	25% (10%)	Poland	260	8% (3%)
France	808	25% (9%)	Finland	244	8% (4%)
Germany	759	23% (9%)	Czech Rep.	211	7% (1%)
UK	756	23% (8%)	Greece	190	6% (1%)
Italy	697	21% (6%)	Austria	184	6% (1%)
Netherlands	592	18% (4%)	Brazil	181	6% (1%)
Spain	543	17% (3%)	Belgium	177	5% (1%)
Sweden	426	13% (10%)	Slovenia	176	5% (1%)
Canada	419	13% (2%)	Portugal	174	5% (1%)
China	317	10% (2%)	Slovakia	121	4% (1%)
Denmark	312	10% (8%)	Japan	108	3% (4%)

* =Only countries with more than 100 collaborative articles are shown in the table.
**) The numbers in brackets show the proportions when excluding articles with more than 50 authors.

The USA is the most important collaborative partner. In fact, almost one third of the "Norwegian" articles within Physics also had co-authors from this country. Next follows Russia. 25% of the articles were co-authored with Russian scientists. As can be seen from the figures in brackets, the country shares get significantly lower when excluding articles with more than 50 authors. For some countries the large majority of the collaboration can be attributed these articles. For example, the proportion of co- authored articles with Spanish researchers decrease from 17% to 3% when these papers are excluded.

3.4 The units selected for the evaluation

The next chapters analyse the publication output of the units selected for the evaluation. In total, 292 persons are encompassed by this analysis (Professor IIs are not included cf. Method section). In total these persons have contributed to 2380 (unique) publications during the period 2004-2008, of which 98 per cent are articles in scientific journals. Moreover 95% of the latter items are published in journals indexed by Thomson Reuters (ISI). Approximately, 55% of them are classified within the Physics category, 11% in Chemistry, 8% in Astronomy & Astrophysics (including space physics), 7% in Material sciences, 6% in Geosciences, 6% in Engineering, and 8% in other categories.

The units selected for the evaluation are the core environments for Physics research in Norway. Nevertheless, there is also some Physics research being carried out in Norway that has not been included. In fact, we find that 38% of the articles that have been published by Norwegian scientists in the period and which are classified within the Physics category cannot be attributed persons included in the evaluation. There are two 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.) and the articles have been published by persons at other units.

4 University of Oslo (UiO) - Department of Physics

Department of Physics at the University of Oslo is the largest Physics department in Norway, both in terms of staff and number of publications. Below we present an analysis of this department, based on the publications during the period 2004 to 2008. [7]

4.1 Productivity indicators

The analysis shows that the tenured staff at the Department of Physics published 665 publications in the period 2004-2008. This includes for the large part articles in international journals, but also some scientific publications in the category of books and book chapters.

Table 4.1 Number of publications 2004-2008, Department of Physics, UiO

Unit		Number of persons incl.	Publications - whole counts	Publications - fractional counts	Number of publications - fractional counts per man-year
TOTAL DEPARTMENT*	Tenured personnel	50	665	170.9	0.70
Advanced materials and complex systems		5	130	32.6	1.30
Biophysics and medical physics		4	39	12.0	0.60
Electronics		8	194	42.4	1.06
Experimental particle physics		5	78	1.9	0.08
Nuclear and energy physics		7	109	17.4	0.50
Physics of geological processes		4	32	9.5	0.56
Plasma and space physics		5	83	20.7	0.83
Structural physics		3	36	8.7	0.62
Theoretical physics		7	48	21.7	0.68
Post docs/researchers*		23	185	33.2	–

*) In the department total and in the category for the non-tenured personnel (post docs/researchers) publications with more than 100 authors have not been included, cf. Method section.

Table 4.1 shows various publication indicators for the department and its research groups. When fractionalised for co-authorship contributions, the 665 publications corresponded to 170.9 publications. This corresponds to an average of 0.70 publications (fractional count) per staff member per year. This is close to the national average for the population of staff included in this evaluation (0.73).

There are, however, large differences between the various research groups/subdivisions. The research group, Advanced materials and complex systems has the highest level, 1.30. This is particularly due to two persons with a very high productivity. The Experimental particle physics group, on the other hand, has the lowest productivity level,

[7] The analysis includes retired professors who have been active during the evaluation period. Separate figures for Physics education group are not shown in the tables.

0.08 fractionalised publications per person per year. This is, however, a consequence of the fact that the publication output of this groups mainly consists of CERN-papers. These publications typically have several hundred authors and accordingly the fractionalised credit to each author is close to zero.

There is a significant number of post docs and other researchers affiliated with the department. As can be seen from Table 4.1, this group of persons contributed to 185 publications (33.2 publications when fractionalised for co-authorship) while being affiliated with the department).

4.2 Journal profile

We have analysed how the publication output from the period 2004-2008 is distributed on publication channels. 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 4.2. The average impact factor (journal citation rate) of the journals (5.5) is close to the national average for the units encompassed by the evaluation (5.8). In particular, the groups Physics of geological processes and Nuclear and energy physics, tend to publish their papers in journals with high impact factors (average 7.5-8.6).

Table 4.2 Journal profile, 2004-2008 publications (whole counts). Department of Physics, UiO

Unit		Numb. of persons incl.	Publications - whole counts**	Avg. journal citation rate (impact factor)**
TOTAL DEPARTMENT*	Tenured personnel	50	625	5.5
Advanced materials and complex systems		5	126	6.3
Biophysics and medical physics		4	38	4.3
Electronics		8	179	3.9
Experimental particle physics		5	78	6.5
Nuclear and energy physics		7	106	7.5
Physics of geological processes		4	27	8.6
Plasma and space physics		5	81	4.1
Structural physics		3	34	3.8
Theoretical physics		7	45	6.8
Post docs/researchers*		23	185	160

*) In the department total and in the category for the non-tenured personnel (post docs/researchers) publications with more than 100 authors have not been included, cf. Method section.
**) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (the "standard" journal impact factor is calculated in a different way).

Table 4.3 shows which journals the staff most often published their articles in and the journal citation rates and levels of the respective journals.

Table 4.3 The most frequently used journals, number of publications (whole counts) 2004-2008 by groups/sections, Department of Physics, UiO (tenured personnel)

Group/section	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Advanced materials and complex systems	PHYSICAL REVIEW B	28	6.5	2
	PHYSICAL REVIEW LETTERS	17	13.7	2
	PHYSICAL REVIEW E	14	4.6	1
Biophysics and medical physics	JOURNAL OF PHYSICAL CHEMISTRY A	7	6.0	2
	ACTA CRYSTALLOGRAPHICA SECTION E	6	1.2	1
Electronics	JOURNAL OF APPLIED PHYSICS	24	3.6	2
	APPLIED PHYSICS LETTERS	18	6.3	2
	PHYSICAL REVIEW B	18	6.5	2
Experimental particle physics	EUROPEAN PHYSICAL JOURNAL C	43	5.7	1
	PHYSICS LETTERS B	13	8.4	1
	NUCLEAR INSTRUMENTS & METHODS IN Physics RESEARCH SECTION A	9	1.9	1
Nuclear and energy physics	PHYSICAL REVIEW C	33	6.2	1
	JOURNAL OF PHYSICS G-NUCLEAR AND PARTICLE PHYSICS	16	13.4	1
	PHYSICAL REVIEW LETTERS	13	13.7	2
Physics of geological processes	EARTH AND PLANETARY SCIENCE LETTERS	7	7.6	2
	PHYSICAL REVIEW E	6	4.6	1
Plasma and space physics	ANNALES GEOPHYSICAE	25	2.8	1
	GEOPHYSICAL RESEARCH LETTERS	10	5.0	1
	JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	8	4.9	2
Structural physics	PHYSICAL REVIEW B	4	6.5	2
	JOURNAL OF APPLIED PHYSICS	4	3.6	2
Theoretical physics	PHYSICAL REVIEW D	7	9.8	1
	PHYSICAL REVIEW A	7	5.9	2
	PHYSICAL REVIEW B	7	6.5	2

*) The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (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.

4.3 Citation indicators

Finally, we have analysed the citation rate of the journal publications. The results are given in Table 4.4. Altogether the articles published by the tenured personnel in the period 2004-2008 have received more than 3300 citations. This corresponds to a field citation index of 127. In other words, the articles have been cited 27 % more than the corresponding field average. Compared to the citation average for the journals where the articles have been published the index value is 100, that is, equal to the average. The difference is a consequence of the journal profile of the department where the journals tend to have a higher than average impact factor.

In terms of citation rates the department has an intermediate position among the departments included in the evaluation (average 133). There are, nevertheless, large differences among the various units. The publications from the Physics of geological processes are generally very highly cited compared to the field average (citation index 210). This also holds for the Experimental particle physics group and the Nuclear and energy physics group. For the first group one should however take into account that their publications tend to have extremely large numbers of authors and the UiO contribution is evidently limited. The Biophysics and medical physics group has a rather poor citation record and their publications are cited significantly below average.

Table 4.4 Citation indicators, 2004-2008 publications (whole counts). Department of Physics, UiO

Unit		Number of articles**	Total number of citations	Citation index - journal	Citation index - field
TOTAL DEPARTMENT*	Tenured personnel	625	3348	100	127
Advanced materials and complex systems		126	488	70	96
Biophysics and medical physics		38	132	82	64
Electronics		179	703	101	100
Experimental particle physics		78	716	114	169
Nuclear and energy physics		106	1204	153	268
Physics of geological processes		27	198	90	210
Plasma and space physics		81	406	136	104
Structural physics		34	131	106	109
Theoretical physics		45	270	77	121
Post docs/researchers*		160	1120	117	174

*) In the department total and in the category for the non-tenured personnel (post docs/researchers) publications with more than 100 authors have not been included, cf. Method section.
**) Only articles in journals indexed by Thomson Reuters (ISI) are included.

Summary publication analysis

Department of Physics at the University of Oslo is the largest Physics department in Norway, both in terms of staff and number of publications. Overall, the department obtains scores on line with the national average. A strong group in terms of publication performance is the Physics of geological processes which also has a very good journal record and where the citation rate of the publications is high. Another strong group is the Advanced materials and complex systems group with high productivity of papers and a good journal record including many articles in *Physical Review Letters*. Their publications are however not very highly cited. For the other groups the picture is mixed. It should be noted that the interest and usefulness of a bibliometric analysis is limited for the Experimental particle physics group (and also to a certain extent for the Nuclear and energy physics group) due to the particular publication profile involving large-scale collaboration.

5 University of Oslo (UiO) - Department of Theoretical Astrophysics

The Department of Theoretical Astrophysics at the University of Oslo is the only department with primarily astronomical/astrophysical focus. 12 persons (tenured personnel, excluding professor IIs) are included in the evaluation. The department has three research groups: Cosmology, Solar physics and Plasma physics. The latter group consists of only one staff member and separate figures have not been calculated for this group.

5.1 Productivity indicators

During the period 2004 to 2008 the tenured personnel published 164 publications, or 54.6 items when fractionalising for co-authorship. This corresponds to 0.96 fractionalised publications per person per year and is the second highest average among the departments included in the evaluation. Particularly Cosmology group has a high average number of publications per person per year (1.12) (one very prolific person contributes significantly to this high average). We have also shown the figures for the post docs affiliated with the department. As can be seen from Table 5.1, this group of persons contributed to 31 publications while being affiliated with the department.

Table 5.1 Number of publications 2004-2008, Department of Theoretical Astrophysics, UiO

Unit		Number of persons incl.	Publications - whole counts	Publications - fractional counts	Number of publications - fractional counts per man-year
TOTAL DEPARTMENT	Tenured personnel	12	164	54.6	0.96
Cosmology		5	71	24.6	1.12
Solar physics		6	66	22.0	0.73
Post docs/researchers		9	31	10.5	–

5.2 Journal profile

We have analysed how the publication output from the period 2004-2008 is distributed on publication channels. 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 5.2.

Table 5.2 Journal profile, 2004-2008 publications (whole counts). Department of Theoretical Astrophysics, UiO

Unit		Numb. of persons incl.	Number of articles*	Avg. journal citation rate (impact factor)*
TOTAL DEPARTMENT	Tenured personnel	12	162	9.2
Cosmology		5	71	9.9
Solar physics		6	66	10.3
Post docs/researchers		9	30	8.0

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (the "standard" journal impact factor is calculated in a different way).

For the Department of Theoretical Astrophysics at the University of Oslo we find that the average impact factor (journal citation rate) of the journals (9.2) is significantly above the national average for the units encompassed by the evaluation (5.8). Both groups perform very well on this indicator.

Table 5.3 The most frequently used journals, number of publications (whole counts) 2004-2008 by groups/sections, Department of Theoretical Astrophysics, UiO (tenured personnel)

Group/section	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Cosmology	ASTROPHYSICAL JOURNAL	20	12.5	2
	PHYSICAL REVIEW D	15	9.8	1
	MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOC.	11	10.5	1
Solar physics	ASTROPHYSICAL JOURNAL	31	12.5	2
	ASTRONOMY & ASTROPHYSICS	14	8.1	2
	SOLAR PHYSICS	6	4.7	1

*) The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (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 5.3 shows which journals the staff most often published their articles in and the journal citation rates and levels of the respective journals.

5.3 Citation indicators

Finally, we have analysed the citation frequencies of the publications. The results are given in Table 5.4. The analysis shows that the 162 articles (ISI-indexed) published by the tenured personnel have received more than 2400 citations. This corresponds to a field citation index of 218. In other words, the articles have been cited 118 % more than the world average in the fields where the department is active. This is far above all other departments included in the evaluation. Particularly the Cosmology group has an extremely high citation rate. Because the staff at the department tend to publish in high impact journals, the journal based citation index is significantly lower than the field based citation index.

Table 5.4 Citation indicators, 2004-2008 publications (whole counts). Department of Theoretical Astrophysics

Unit		Number of articles*	Total number of citations	Citation index - journal	Citation index - field
TOTAL DEPARTMENT	Tenured person-nel	162	2405	169	218
Cosmology		71	1658	240	319
Solar physics		66	697	110	140
Post docs/researchers		30	217	125	126

*) Only articles in journals indexed by Thomson Reuters (ISI) are included.

Summary publication analysis

The Department of Theoretical Astrophysics at the University of Oslo performs extraordinary well on all the bibliometric indicators presented. Both groups analysed (Cosmology and Solar physics) obtain high scores on productivity, journal profile and citation rates.

6 Norwegian University of Science and Technology (NTNU) - Department of Physics

The Department of Physics at the Norwegian University of Science and Technology (NTNU) is the second largest department in terms of number of tenured personnel included in the evaluation (38). There are five divisions: Division of Applied Physics and Physics Education, Division of Biophysics and Medical Technology, Division of Complex Materials, Division of Condensed Matter Physics, and Division of Theoretical Physics. Separate analyses are provided for each of the divisions.

6.1 Productivity indicators

In total the 38 staff members published 444 publications during the period 2004-2008, or 146.6 publications fractionalised for co-authorship, cf. Table 6.1. The Division of Theoretical Physics is the largest division in terms of publication output. The division consists of two research groups, the Condensed matter theory group and the Astroparticle Physics group, which account for 77% and 23%, respectively, of publication output of the division. The Division of Applied Physics and Physics Education consists of three research groups, but one of them, the Applied Optics and Laser Physics accounts for the majority of the publication output of the division (77%). Finally, the Division of Biophysics and Medical Technology consists of two research groups, the Biophysics for medical technology group and the Biophysics of biosystems group. These groups contribute with almost equal shares to the publication output of the division.

The average productivity per person per year at the department is 0.89 (fractionalised counts), which is above the national average for the population of staff included in this evaluation (0.73). There are not large differences in the productivity levels between the different divisions. But at groups levels the Condensed matter theory group stands out with a particular high productivity and the Energy and Environmental Physics group with a low.

Table 6.1 Number of publications 2004-2008, Department of Physics, NTNU

Unit		Number of persons incl.	Publications - whole counts	Publications - fractional counts	Number of publications - fractional counts per man-year
TOTAL DEPARTMENT	Tenured personnel	38	444	146.6	0.89
Division of Applied Physics and Physics Education		9	74	22.1	0.76
Division of Biophysics and Medical Technology		8	97	32.5	0.81
Division of Complex Materials		6	87	28.8	0.96
Division of Condensed Matter Physics		6	72	18.7	0.81

Division of Theoretical Physics		9	128	44.4	1.06
Post docs/researchers		23	63	19.8	–

There is a significant number of post docs and other researchers at the department. As can be seen from Table 6.1, this group of persons contributed to 63 publications while being affiliated with the department.

6.2 Journal profile

We have analysed how the publication output from the period 2004-2008 is distributed on publication channels. 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 6.2.

Table 6.2 Journal profile, 2004-2008 publications (whole counts). Department of Physics, NTNU

Unit		Numb. of persons incl.	Number of articles*	Avg. journal citation rate (impact factor)*
TOTAL DEPARTMENT	Tenured personnel	38	404	6.5
Division of Applied Physics and Physics Education		9	56	5.4
Division of Biophysics and Medical Technology		8	90	6.1
Division of Complex Materials		6	83	4.8
Division of Condensed Matter Physics		6	61	5.3
Division of Theoretical Physics		9	128	8.8
Post docs/researchers		23	57	6.2

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (the "standard" journal impact factor is calculated in a different way).

For the department as a whole we find that the average impact factor (journal citation rate) of the journals (6.5) is slightly above the national average for the units encompassed by the evaluation (5.8). Particularly the Division of Theoretical Physics stands out with a high average (8.8).

Table 6.3 shows which journals the staff most often published their articles in and the journal citation rates and levels of the respective journals.

Table 6.3 The most frequently used journals, number of publications (whole counts) 2004-2008 by groups/sections, Department of Physics, NTNU (tenured personnel)

Unit	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Division of Applied Physics and Physics Education	SURFACE SCIENCE	4	3.6	1
Division of Biophysics and Medical Technology	BIOMACROMOLECULES	7	8.5	1
	JOURNAL OF BIOMEDICAL OPTICS	7	3.9	2
	BIOPOLYMERS	6	5.2	1
Division of Complex Materials	PHYSICAL REVIEW E	14	4.6	1
	PHYSICA A-STATISTICAL MECHANICS AND ITS APPLICATIONS	5	2.9	1
	PHYSICAL REVIEW LETTERS	5	13.7	2
Division of Condensed Matter Physics	PHYSICAL REVIEW B	5	6.5	2
Division of Theoretical Physics	PHYSICAL REVIEW B	50	6.5	2
	PHYSICAL REVIEW LETTERS	23	13.7	2
	PHYSICAL REVIEW D	10	9.8	1

*) The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (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.

6.3 Citation indicators

The analysis of the citation frequencies shows that the 404 ISI-indexed articles published by the tenured personnel have received more than 2000 citations cf. Table 6.4. This corresponds to a field citation index of 119. In other words, the articles have been cited 19 % more than the world average in the fields where the department is active. This is an intermediate position among the departments included in the evaluation and somewhat below the average level of 133. Because the staff at the department tend to publish in journals with higher than average impact, the journal based citation index is lower than the field based citation index. In fact, this index is 89, that is, below the average for these journals.

At section levels, the Division of Theoretical Physics has a very good citation record, and their publications are cited 79% above the field average. This high citation rate can be attributed the Condensed matter theory group within the division. The other group, the Astroparticle group, has a citation index below world average. We find a similar divergence within the Division of Biophysics and Medical Technology. Here, the Biophysic for Medical Technology group has a citation index of 150 while the other group, Biophysics of Biosystems, obtains an index of only 43. Also the Division of Complex Materials has a low citation index (65).

Table 6.4 Citation indicators, 2004-2008 publications (whole counts). Department of Physics, NTNU

Unit		Number of articles*	Total number of citations	Citation index - journal	Citation index - field
TOTAL DEPARTMENT	Tenured personnel	404	2044	89	119
Division of Applied Physics and Physics Education		56	202	103	105
Division of Biophysics and Medical Technology		90	595	108	106
Division of Complex Materials		83	236	63	65
Division of Condensed Matter Physics		61	148	76	88
Division of Theoretical Physics		128	894	88	179
Post docs/researchers		57	251	104	117

*) Only articles in journals indexed by Thomson Reuters (ISI) are included.

Summary publication analysis

The Department of Physics at the Norwegian University of Science and Technology (NTNU) is the second largest department both in terms of staff included and number of publications. Overall, the department performs relatively well on the bibliometric indicators. The productivity is good with many papers being published in the highly ranking journals. The citation rate is slightly below the national average. A very strong Division in terms of performance on these indicators is the Division of Theoretical Physics with a relatively high productivity of papers and a very good journal record, including many articles in *Physical Review Letters,* as well as a high citation index.

7 University of Bergen (UiB) - Department of Physics and Technology

The Department of Physics and Technology at the University of Bergen is the third largest department in terms of number of tenured personnel included in the evaluation (35). The department is organised in nine research groups: Acoustics, Electronics and Measurement Science, Nano Physics, Optics and Atomic Physics, Petroleum and Process Technology, Science Education and Outreach, Space Physics, Subatomic Physics, and Theoretical Physics, Energy and Process Technology.

7.1 Productivity indicators

In total the tenured staff encompassed by the evaluation published more than 300 publications during the period 2004-2008 (excluding publications with more than 100 authors), or 104 publications fractionalised for co-authorship, cf. Table 7.1. This is 0.66 fractionalised publications per person per year, slightly below the national average for the population of staff included in this evaluation (0.73). The average productivity is highest at the Petroleum and Process Technology group (1.17) and lowest at the Acoustics group (0.06). The latter group has mainly published papers in conferences proceedings and these are not included in the analysis.

We have also shown the figures for the post docs affiliated with the department. As can be seen from Table 7.1, this group of persons contributed to 49 publications while being affiliated with the department (excluding publications with more than 100 authors).

Table 7.1 Number of publications 2004-2008, Department of Physics and Technology, UiB

Unit		Number of persons incl.	Publications - whole counts	Publications - fractional counts	Number of publications - fractional counts per man-year
TOTAL DEPARTMENT*	Tenured personnel	35	304	104.2	0.66
Acoustics		3	2	0.7	0.06
Electronics and Measurement Science		5	29	12.4	0.59
Nano Physics		2	18	3.6	0.73
Optics and Atomic Physics		4	45	11.3	0.57
Petroleum and Process Technology		3	38	17.5	1.17
Science Education and Outreach		2	11	8.0	0.80
Space Physics		4	33	7.0	0.41
Subatomic Physics		6	409	15.4	0.51
Theoretical Physics, Energy and Process Technology		6	75	29.7	0.99
Post docs/researchers*		14	49	11.6	–

*) In the department total and in the category for the non-tenured personnel (post docs/researchers) publications with more than 100 authors have not been included, cf. Method section.

It should be noted that one of the groups (Subatomic Physics) mainly publishes CERN-papers. These publications typically have several hundred authors and accordingly the fractionalised credit to each author is close to zero. The usefulness and interest of a bibliometric analysis is limited for this group since the UiB contribution evidently is extremely small. (It is also difficult to provide exact indicators for this group since the databases applied not always index all authors of these publications.)

7.2 Journal profile

We have analysed how the publication output from the period 2004-2008 is distributed on publication channels. 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 7.2.

For the department as a whole we find that the average impact factor (journal citation rate) of the journals (5.4) is almost identical with the national average for the units encompassed by the evaluation (5.8).

Table 7.2 Journal profile, 2004-2008 publications (whole counts). Department of Physics and Technology, UiB

Unit		Numb. of persons incl.	Number of articles*	Avg. journal citation rate (impact factor)*
TOTAL DEPARTMENT*	Tenured personnel	35	278	5.4
Electronics and Measurement Science		5	27	3.6
Nano Physics		2	18	4.7
Optics and Atomic Physics		4	45	5.2
Petroleum and Process Technology		3	29	4.3
Space Physics		4	32	3.9
Subatomic Physics		6	407	10.3
Theoretical Physics, Energy and Process Technology		6	71	4.8
Post docs/researchers*		14	46	5.2

*) In the department total and in the category for the non-tenured personnel (post docs/researchers) publications with more than 100 authors have not been included, cf. Method section.
**) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (the "standard" journal impact factor is calculated in a different way).

Table 7.3 shows which journals the staff most often published their articles in and the journal citation rates and levels of the respective journals.

Table 7.3 The most frequently used journals, number of publications (whole counts) 2004-2008 by groups/sections, Department of Physics and Technology, UiB (tenured personnel)

Group/section	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Electronics and Measurement Science	MEASUREMENT SCIENCE & TECHNOLOGY	5	2.3	1
	IEEE TRANSACTIONS ON NUCLEAR SCIENCE	4	2.1	1
Optics and Atomic Physics	PHYSICAL REVIEW A	7	5.9	2
	PHYSICAL REVIEW B	4	6.5	2
	PHYSICAL REVIEW LETTERS	4	13.7	2
Petroleum and Process Technology	PHYSICAL CHEMISTRY CHEMICAL PHYSICS	5	7.8	2
	FLUID PHASE EQUILIBRIA	3	3.1	2
Space Physics	ANNALES GEOPHYSICAE	12	2.8	1
	JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	12	4.9	2
Subatomic Physics	PHYSICAL REVIEW D	165	9.8	1
	PHYSICAL REVIEW LETTERS	128	13.7	2
	EUROPEAN PHYSICAL JOURNAL C	46	5.7	1
Theoretical Physics, Energy and Process Technology	PHYSICAL REVIEW C	11	6.2	1
	CHEMICAL ENGINEERING SCIENCE	8	3.3	2
	JOURNAL OF PHYSICS G-NUCLEAR AND PARTICLE PHYSICS	7	13.4	1

*) The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (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.

7.3 Citation indicators

The analysis of the citation frequencies shows that the 278 articles published by the tenured personnel (ISI-indexed) have received almost 1500 citations cf. Table 7.4. This corresponds to a field citation index of 127. In other words, the articles have been cited 27 % more than the world average in the fields where the department is active. This is an intermediate position among the departments included in the evaluation (average 133). It is, however, the publications by the Subatomic Physics groups that contribute to most of the citations received. All other groups, with the exception of the Nano Physics group, have a citation indexes below world average. Space Physics has the lowest index with 64.

Table 7.4. Citation indicators, 2004-2008 publications (whole counts). Department of Physics and Technology, UiB

Unit		Number of articles*	Total number of citations	Citation index - journal	Citation index - field
TOTAL DEPARTMENT	Tenured personnel	278	1455	109	127
Electronics and Measurement Science		27	59	97	90
Nano Physics		18	95	151	178
Optics and Atomic Physics		45	161	77	81
Petroleum and Process Technology		29	78	72	73
Space Physics		32	127	88	64
Subatomic Physics		407	4279	107	190
Theoretical Physics, Energy and Process Technology		71	192	80	78
Post docs/researchers		46	139	72	76

*) Only articles in journals indexed by Thomson Reuters (ISI) are included.

Summary publication analysis

The Department of Physics at the University of Bergen is the third largest department both in terms of staff included and number of publications. Overall, the department obtains scores on the bibliometric indicators slightly below the average for the units included in the evaluation. None of the research groups at the department stands out in a national context. Some of the groups have a rather poor performance in terms of publication and citation output, most notably the Acoustics group with only a negligible scientific journal production. With the exception of the Subatomic Physics group and the Nano Physics group the citation rates of the other groups are quite low.

8 University of Tromsø (UiT) - Department of Physics and Technology

The Department of Physics and Technology at the University of Tromsø is organised in four research groups: Space Physics, Electrical Engineering, Complex systems, and Quantum mechanics. Below we present an analysis of this department. The two latter groups consist of only one tenured staff member and separate analyses are not provided for these groups.

8.1 Productivity indicators

In total, the tenured staff encompassed by the evaluation published 116 publications during the period 2004-2008, or 42.7 publications fractionalised for co-authorship, cf. Table 8.1. This is 0.55 fractionalised publications per person per year, below the national average of the population of staff included in this evaluation (0.73). The productivity is even lower at the Space Physics group (0.44). We have also shown the figures for the post docs affiliated with the department. As can be seen from Table 8.1, this group of persons contributed to 20 publications while being affiliated with the department.

Table 8.1 Number of publications 2004-2008, Department of Physics and Technology, UiT

Unit		Number of persons incl.	Publications - whole counts	Publications - fractional counts	Number of publications - fractional counts per man-year
TOTAL DEPARTMENT	Tenured person-nel	18	116	42.7	0.55
Electrical Engineering		8	39	16.3	0.54
Space Physics		8	54	16.1	0.44
Post docs/researchers		7	20	3.7	–

8.2 Journal profile

We have analysed how the publication output from the period 2004-2008 is distributed on publication channels. 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 8.2.

Table 8.2 Journal profile, 2004-2008 publications (whole counts). Department of Physics and Technology, UiT

Unit		Numb. of persons incl.	Number of articles*	Avg. journal citation rate (impact factor)*
TOTAL DEPARTMENT	Tenured person-nel	18	111	4.9
Electrical Engineering		8	38	2.9
Space Physics		8	50	6.1
Post docs/researchers		7	20	4.4

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (the "standard" journal impact factor is calculated in a different way).

For the department as a whole we find that the average impact factor (journal citation rate) of the journals (4.9) is somewhat lower than the national average for the units encompassed by the evaluation (5.8).

Table 8.3 shows which journals the staff most often published their articles in and the journal citation rates and levels of the respective journals.

Table 8.3 The most frequently used journals, number of publications (whole counts) 2004-2008 by groups/sections, Department of Physics and Technology, UiT (tenured personnel)

Group/section	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
Electrical Engineering	IEEE TRANSACTIONS ON SIGNAL PROCESSING	3	2.7	2
	PATTERN RECOGNITION	3	1.8	2
	OPTICS EXPRESS	3	6.2	2
	IEEE SIGNAL PROCESSING LETTERS	3	1.4	1
	IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING	3	5.9	2
Space Physics	ANNALES GEOPHYSICAE	13	2.8	1
	JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	6	4.9	2
	JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	4	7.3	2

*) The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (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.

8.3 Citation indicators

Finally, we have analysed the citation frequencies of the publications. The results are given in Table 8.4. The analysis shows that the 111 articles published by the tenured personnel (ISI-indexed) have received 365 citations. This corresponds to a field citation index of 75. In other words, the articles have been cited 25% less than the world average in the fields where the department is active. This is a level significantly below the average for the units encompassed by the evaluation which is 133. There are large differences between the two groups. The index values are 112 and 59 for Electrical Engineering and Space Physics, respectively.

Table 8.4 Citation indicators, 2004-2008 publications (whole counts). Department of Physics and Technology, UiT

Unit		Number of articles*	Total number of citations	Citation index - journal	Citation index - field
TOTAL DEPARTMENT	Tenured person-nel	111	365	75	75
Electrical Engineering		38	117	124	112
Space Physics		50	180	59	59
Post docs/researchers		20	26	54	48

*) Only articles in journals indexed by Thomson Reuters (ISI) are included.

Summary publication analysis

Overall, the Department of Physics and Technology at the University of Tromsø obtains scores on the bibliometric indicators below the average for the units included in the evaluation. This holds for all indicators presented: productivity, journal profile and citation rates.

9 Other universities

This chapter contains analyses of the other university departments included in the evaluation: the Department of Mathematics and Natural Sciences at the University of Stavanger (UiS), Department of Mathematical Sciences and Technology at the Norwegian University of Life Sciences (UMB) and the Department of Arctic Geophysics at the University Centre in Svalbard (UNIS). It should be noted that these are small departments in terms of number of persons included. Also the conditions and traditions for doing research may differ from the traditional universities. We do not present separate analyses for the research groups at the departments (size limitations).

9.1 Productivity indicators

UiS has 7 persons included in the evaluation and UMB 6 persons (tenured personnel). The production of publication, however, is highest at UMB. During the period 2004-2008 the staff members at UMB have published 29 publications, corresponding to 12.8 items when fractionalising for co-authorship. This amounts to 0.56 fractionalised publications per person per year, below the national average for the population of staff included in this evaluation (0.73). The productivity at UiS is only 0.21 fractionalised publications per person per year, which is the lowest level of all the departments included in the evaluation.[8] Only three persons are included as tenured personnel from UNIS. Their productivity, however, is the highest of the three units with 0.61.

Table 9.1 Number of publications 2004-2008, departments at other universities

Unit		Number of persons incl.	Publications - whole counts	Publications - fractional counts	Number of publications - fractional counts per man-year
UiS - Department of Mathematics and Natural Sciences	Tenured personnel	7	18	6.6	0.21
UMB - Department of Mathematical Sciences and Technology	Tenured personnel	6	29	12.8	0.56
UNIS - Department of Arctic Geophysics	Tenured personnel	3	30	7.3	0.61
UMB- Post docs/researchers		2	6	1.6	–

9.2 Journal profile

We have analysed how the publication output from the period 2004-2008 is distributed on publication channels. We have calculated the average citation rate (impact factor) for the

[8] It should be noted, however, that the University of Stavanger has obtained its university status quite recently (in January 2005). Until then, the school was a state university college with teaching as the main activity, and has gradually developed a research agenda to obtain university status.

journals the staff have published their articles in (weighted average). The results are given in Table 9.2.

Table 9.2 Journal profile, 2004-2008 publications (whole counts), departments at other universities

Unit		Numb. of persons incl.	Number of articles*	Avg. journal citation rate (impact factor)*
UiS – Dep. of Mathematics and Natural Sciences	Tenured personnel	7	12	3.1
UMB – Dep. of Mathematical Sciences and Technology	Tenured personnel	6	24	3.9
UNIS – Dep. of Arctic Geophysics	Tenured personnel	3	28	3.8
UMB- Post docs/researchers		2	6	5.0

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (the "standard" journal impact factor is calculated in a different way).

For all the departments we find that the average impact factor (journal citation rate) of the journals (3.1-3.9) is significantly lower than the national average for the units encompassed by the evaluation (5.8).

Table 9.3 shows which journals the staff most often published their articles in and the journal citation rates and levels of the respective journals.

Table 9.3 The most frequently used journals, number of publications (whole counts) 2004-2008, departments at other universities (tenured personnel)

Group/section	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
UiS – Dep. of Mathematics and Natural Sciences	CLASSICAL AND QUANTUM GRAVITY	3	6.5	1
UMB – Dep. of Mathematical Sciences and Technology	THEORETICAL AND APPLIED CLIMATOLOGY	3	2.8	1
UNIS – Dep. of Arctic Geophysics	JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	7	4.9	2
	ANNALES GEOPHYSICAE	6	2.8	1
	GEOPHYSICAL RESEARCH LETTERS	5	5.0	1

*) The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (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.

9.3 Citation indicators

Finally, we have analysed the citation frequencies of the publications. The results are given in Table 9.4. The analysis shows that the publications from UiS are hardly cited at all. Also the publications from UMB and UNIS obtain poor citation indexes with 45 and 42, respectively (citation index-field). This means that they are cited far below the world average (=100) in the fields where the departments are active and even further below the national average for the units encompassed by the evaluation (137).

Table 9.4 Citation indicators, 2004-2008 public. (whole counts), departments at other universities

Unit		Number of articles*	Total number of citations	Citation index - journal	Citation index - field
UiS – Dep. of Mathematics and Natural Sciences	Tenured personnel	12	3	15	14
UMB – Dep. of Mathematical Sciences and Technology		24	52	58	42
UNIS – Dep. of Arctic Geophysics		28	49	70	45
UMB- Post docs/researchers		6	13	147	109

*) Only articles in journals indexed by Thomson Reuters (ISI) are included.

Summary publication analysis

The three departments analysed are small both in terms of number of persons included and publication output. Together they account for only 4 percent of the publication output of the units encompassed by the evaluation. The departments also appear as weak units in terms of performance on the bibliometric indicators with low productivity and poor journal and citation records. The UNIS department, nevertheless, appears as a stronger unit than the other two departments.

10 Research institutes

This chapter contains analyses of the three independent research institutes that are included in the evaluation: The Physics Department at the Institute for Energy Technology (IFE), the Material Physics group at the Department of Synthesis and Properties at SINTEF Materials and Chemistry and three research groups at the Norwegian Defence Research Establishment (FFI): The Flow Physics and Turbulence Group at the Protection Division, the Space Physics and Atmosphere Physics group and the Laser group at the Land and Air System Division. As a general remark it should be noted that the conditions for doing research differ between the Higher Education departments and the independent research institutes. The activity of the latter institutes is typically dominated by contract research and the results are often published as "grey literature" like reports and less often as articles in international journals. Nevertheless, as is evident below, the institutes included in this evaluation perform quite well compared to the Higher Education departments.

10.1 Productivity indicators

Table 10.1 shows the number of publications for the period 2004-2008 for the permanent staff members included in the evaluation. The numbers for the non-permanent staff is shown in separate rows.

Table 10.1 Number of publications 2004-2008, research institutes

Unit		Number of persons incl.	Publications - whole counts	Publications - fractional counts	Number of publications - fractional counts per man-year
TOTAL FFI	Permanent staff	18	60	23.5	–*
Flow Physics and Turbulence Group	Permanent staff	5	12	6.5	0.30
Laser group	Permanent staff	9	15	8.1	–*
Space Physics & Atmosphere Physics	Permanent staff	4	33	8.9	0.44
IFE - Physics Department	Permanent staff	5	118	34.9	1.40
SINTEF - Material Physics	Permanent staff	10	92	22.1	0.71
FFI – Non-permanent group members		2	5	1.9	–
IFE- Non-permanent group members		9	26	6.6	–

*) Due to lack of information (individual CVs) for the members of the Laser group, productivity indicators have not been calculated.

The FFI is the largest institute in terms of number of persons included, but IFE has nevertheless a total higher publication output. The staff at IFE have 118 publications or 34.9 publications fractionalised for co-authorship. This corresponds to 1.40 fractionalised publications per person per year, the highest productivity level of all the departments included in the evaluation. One particularly prolific researcher at the institute contributes significantly to the high average. The SINTEF group has 92 publications corresponding to 22.1 publications when fractionalising for co-authorship. This amounts to 0.71 fractionalised publications per person per year, almost equal to the national average for the population of staff included in this evaluation (0.73). The FFI groups have on the other hand significantly lower productivity levels.

10.2 Journal profile

We have analysed how the publication output from the period 2004-2008 is distributed on publication channels. 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 10.2.

The permanent personnel at FFI published in journals with an average impact factor (journal citation rate) of 6.0 almost identical with the national average for the units encompassed by the evaluation (5.8). The average is particularly high for the Space Physics & Atmosphere Physics groups. The levels for the SINTEF and IFE groups are lower than the national average, 4.4 and 4.6.

Table 10.2 Journal profile, 2004-2008 publications (whole counts), research institutes

Unit		Numb. of persons incl.	Number of articles*	Avg. journal citation rate (impact factor)*
TOTAL FFI	Permanent staff	18	58	6.0
Flow Physics and Turbulence Group		5	12	3.0
Laser group		9	14	4.9
Space Physics & Atmosphere Physics		4	32	7.7
IFE - Physics Department		5	107	4.6
SINTEF - Material Physics		10	79	4.4
FFI - Non-permanent group members		2	5	2.3
IFE- Non-permanent group members		9	24	3.9

*) Only articles in journals indexed by Thomson Reuters (ISI) are included. The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (the “standard” journal impact factor is calculated in a different way).

Table 10.3 shows which journals the staff most often published their articles in and the journal citation rates and levels of the respective journals.

Table 10.3 The most frequently used journals, number of publications (whole counts) 2004-2008, research institutes (tenured personnel)

Group/section	Journal	Numb. of articles	Journal citation rate (impact factor)*	Level**
FFI	ASTROPHYSICAL JOURNAL	7	12.5	2
	ANNALES GEOPHYSICAE	6	2.8	1
	OPTICS EXPRESS	5	6.2	2
IFE - Physics Department	JOURNAL OF ALLOYS AND COMPOUNDS	29	2.9	1
	JOURNAL OF PHYSICAL CHEMISTRY B	7	8.1	2
	PHYSICAL REVIEW B	6	6.5	2
SINTEF - Material Physics	CORROSION SCIENCE	5	3.8	2
	SURFACE AND INTERFACE ANALYSIS	5	2.2	1

*) The average journal citation rate is here based on the 2006 articles published in the respective journals and their citation rates in the period 2006-2008 (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.

10.3 Citation indicators

The analysis of the citation frequencies shows that the all institutes obtain citation rates above the world average and also somewhat higher than the average for the units included in the evaluation (133). The field citation index for FFI is 146. In other words, the articles have been cited 46 % more than the world average in the fields where the institute/groups are active. Particularly the Laser group obtains high score with an index of 231. IFE and SINTEF obtain citation indexes of 136 and 134.

Table 10.4 Citation indicators, 2004-2008 publications (whole counts), research institutes

Unit		Number of articles*	Total number of citations	Citation index - journal	Citation index - field
TOTAL FFI	Permanent staff	58	389	106	146
Flow Physics and Turbulence Group		12	19	82	95
Laser group		14	149	170	231
Space Physics & Atmosphere Physics		32	221	86	121
IFE - Physics Department		107	614	129	136
SINTEF - Material Physics		79	228	117	134
FFI - Non-permanent group members		5	9	86	158
IFE- Non-permanent group members		24	127	190	179

*) Only articles in journals indexed by Thomson Reuters (ISI) are included.

Summary publication analysis

The three institutes analysed together account for 13 % of the publication output of the units encompassed by the evaluation. The institutes perform relatively well on the bibliometric indicators. The group at IFE has a very good productivity of scientific publications. The SINTEF group obtains scores on most of the indicators close to the national average. The FFI groups have a low productivity of scientific publications per person but perform better on citation rates. The latter particularly holds for the Laser group.

Appendix 1 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 ISI-database.[9]

The ISI-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 Reuters company, the most well-known product the *Science Citation Index Expanded* today covers 6,600 journals. 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 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.

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

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 accordingly be calculated for aggregated publications representing, for example, research units, departments, or scientific fields.

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).

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.

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.

There are also 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 cannot 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.

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. Firstly, a peer-evaluation will usually consider a much broader set of factors than those reflected through bibliometric indicators. Secondly, 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).[10]

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

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

interpreted will still provide valuable information in the context of research evaluation. Performance, quality and excellence can also be assessed through peer review, but despite 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.

Co-authorship as an indicator of collaboration[11]

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

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

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

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

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

Scientific collaboration across national borders has also increased significantly 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.

Appendix 2 – "Level 2" journals

List of "level 2" journals within Physics*

Advances in Physics
AIAA Journal
Annales Scientifiques de l'Ecole Normale Supérieure
Annual Review of Astronomy and Astrophysics
Annual Review of Earth and Planetary Science
Annual Review of Fluid Mechanics
Annual Review of Nuclear and Particle Science
Applied Physics A: Materials Science & Processing
Applied Physics B
Applied Physics Letters
Archive for Rational Mechanics and Analysis
Astronomy and Astrophysics
Astrophysical Journal
Astrophysical Journal Supplement Series
Carbon
ChemPhysChem
Communications in Mathematical Physics
Engineering Fracture Mechanics
Experimental heat transfer
Heat and Mass Transfer
IEEE Journal of Quantum Electronics
IEEE Journal of Selected Topics in Quantum Electronics
IEEE Photonics Technology Letters
IEEE Transactions on Electron Devices
Infinite Dimension Analysis Quantum Probability & Related Topics
International journal of hydrogen energy
Journal of Acoustical Society of America
Journal of Applied Physics
Journal of Fluid Mechanics
Journal of High Energy Physics (JHEP)
Journal of Optics B-Quantum & Semiclassical Optic
Journal of Physics D: Applied Physics
Journ of the Optical Soc of Ameri B, Optical Physics
Nanotechnology
Nuclear Physics B
Optics Express
Optics Letters
Organic electronics
Physica D : Non-linear phenomena
Physical Review A. Atom, Mol, and Optical Physics
Physical Review B. Cond Matter and Materials Phys
Physical Review Letters
Physics of fluids
Physics reports
Progress in optics
Reports on progress in Physics (Print)
Reviews of geophysics
Reviews of Modern Physics
Structural Safety

*) Journals accredited as level 2 journals by UHR's National Councils (ref. 01.01. 2009). In the analysis also "level 2" journals in other subjects are included.

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