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Bibliometric Analysis of Norwegian Research Activities

Final Report

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Reports in the evaluation of the Research Council of Norway

Synthesis report
Erik Arnold, Stefan Kuhlman and Barend van der Meulen, **A Singular Council? Evaluation of the Research Council of Norway**, Brighton: Technopolis, 2001

Background reports

1. The Research Council of Norway and its different funding mechanisms: The experiences and views of researchers in universities, colleges and institutes.
Background report No 1 in the evaluation of the Research Council of Norway
Magnus Guldbransen, NIFU

2. Bibliometric Analysis of Norwegian Research Activities.
Background report No 2 in the evaluation of the Research Council of Norway
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3. RCN in the Dynamics of Research: A Scientist's Perspective.
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Background report No 16 in the evaluation of the Research Council of Norway
Sarah Teather and Erik Arnold, Technopolis

Bibliometric Analysis of Norwegian Research Activities

Methodology and Introduction

The bibliometric analysis comprises two steps. In a first step, macro indicators describing the production of scientific knowledge in Norway in total were produced. Those indicators lay the ground for a further comparison with the data that represents NFR funding activities. Furthermore, data on the other Scandinavian countries (Denmark, Finland and Sweden) as well as additional selected countries was used in order to add an international dimension to the benchmarking exercise.

The analysis is based on data retrieved from the Science Citation Index (SCI) and specific data bases produced hereof as the Norwegian National Citation Report (NCR) and the National Science Indicators on Diskette (NSIOD). Those data bases are available at NIFU. Data was recently updated and contains now all publication data up to the year 2000. In addition the online version of the SCI as offered by the host STN was used.

The number of scientific publications is used as an indicator reflecting productivity of Norwegian science. Its impact is measured using citation based indicators. Publication output and its distribution over the various scientific disciplines is also used in order to assess specialisation patterns of Norwegian science, which in addition are compared with the those of the neighbouring countries Sweden, Denmark and Finland. Furthermore, as international networking and collaboration becomes increasingly relevant in R&D, the pattern of Norwegian scientific collaboration and the partners involved are analysed based on co-authorship data.

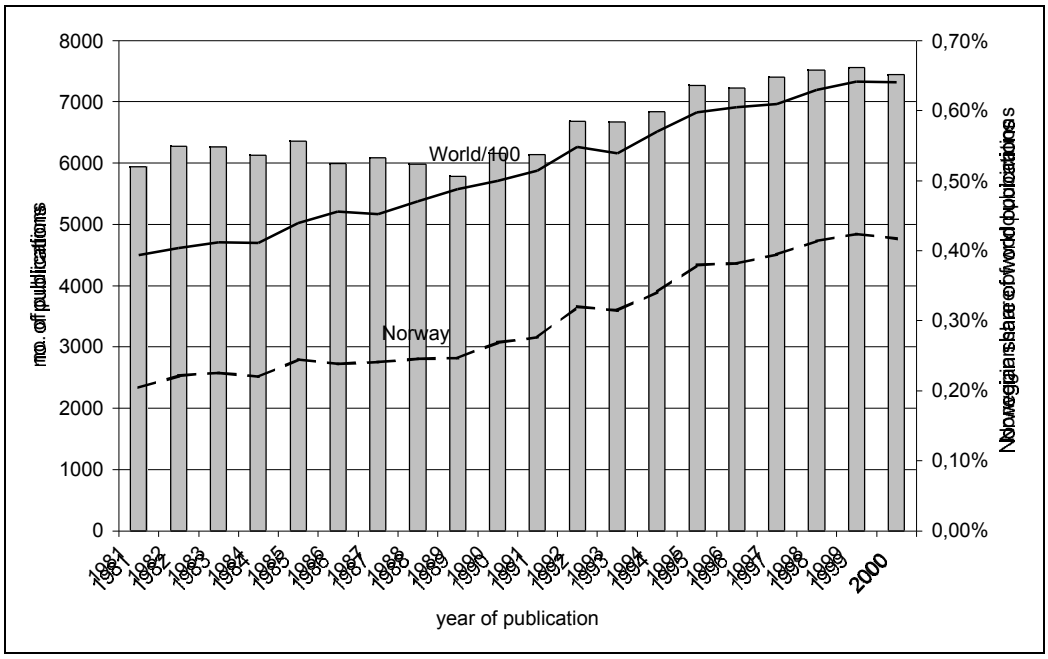
In a second step three case studies on Marine Sciences, Biotechnology and Economics were carried out, which are presented after the general description of Norwegian research activities. Those case studies are aiming at assessing the research performance of scientific activities supported by the Norwegian Research Council in those areas analysed.

Results

The number of articles published in international journals that are covered by the SCI is used a an indicator to reflect the research output of the Norwegian research system. Measured by publication output and the share of the world-wide production

of scientific papers[1], Norway is one of the smaller countries producing scientific knowledge (see Table 1). From the early nineties onwards we observe a continuous growth of number of papers published. Also the proportion of Norwegian papers covered by the SCI was increasing since 1989 (see Figure 1). A reason for the growing share of Norwegian papers covered by SCI is the increasing number of internationally co-authored papers, which at the same time is an indication for increasing international collaboration. However, if adjusting for the increase of those internationally co-authored papers the proportion of Norwegian papers remains stable over time at about 0,5 %. If the data is adjusted for international co-authorship publication in general, shares for most countries remain stable (see Figure 2).

Figure 1: Norwegian publication output 1981-2000 (Data Source: NSIOD)

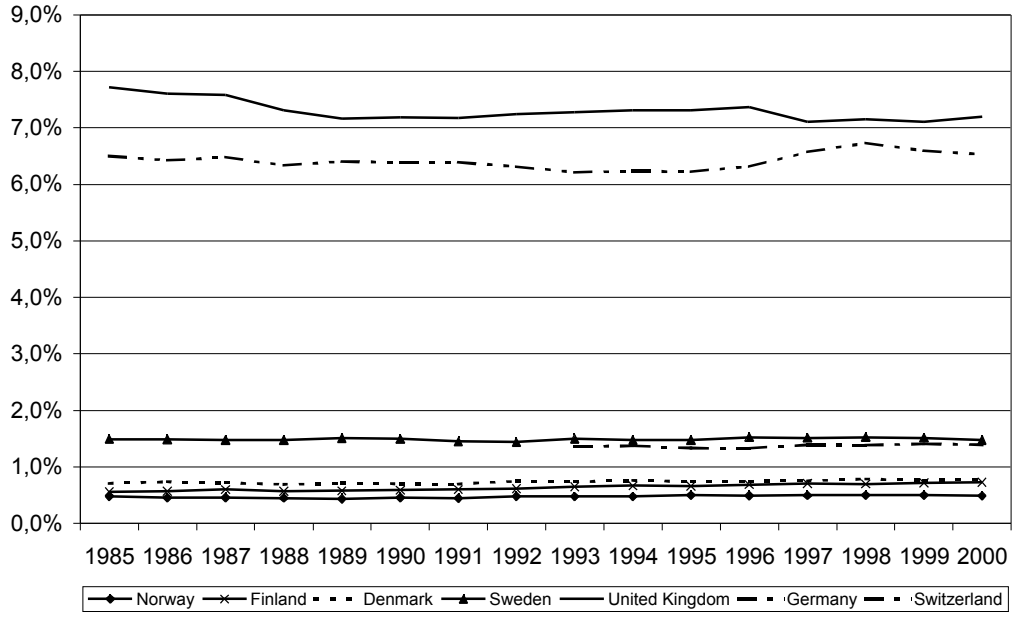


[1] World output = total number of papers included in the SCI data base; Norwegian output = total number of papers that contain at least one Norwegian address, complete count

Table 1: Publication share of the World total 1993-2000 (Data Source: SCI; NSIOD)

Country	Share of World total	No. of papers per 1000 capita[2]
Norway	0.6 %	7.9
Finland	0.9 %	10.8
Denmark	1.0 %	11.8
Sweden	1.9 %	13.6
Germany	8.4 %	5.6
United Kingdom	9.4 %	8.8
Switzerland	1.9 %	13.9

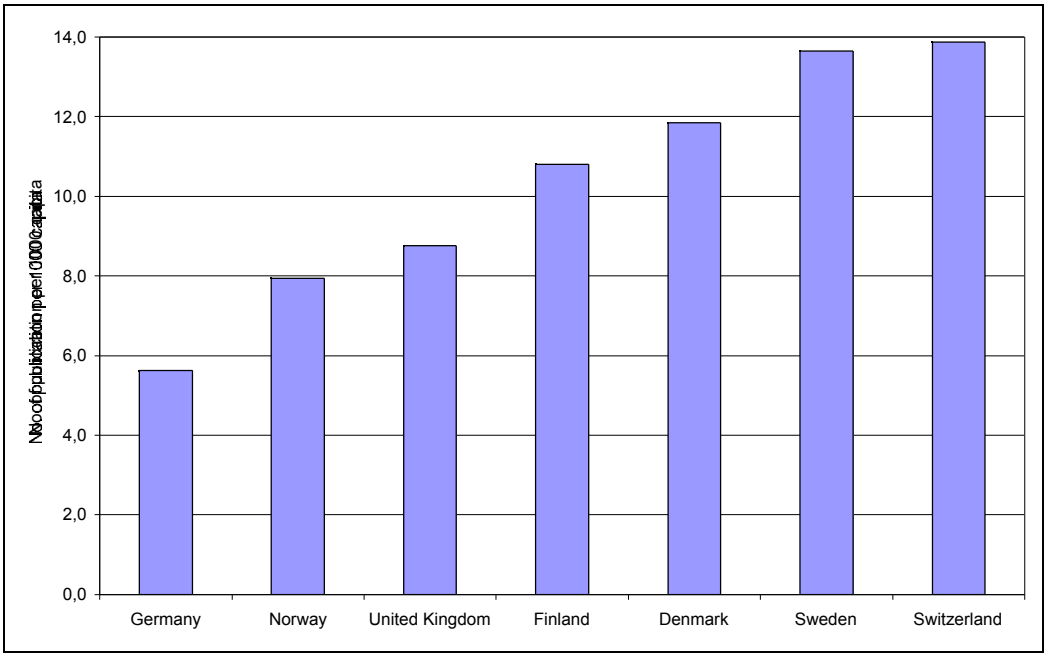
Figure 2: Publication shares in the SCI for selected countries (Data Source: NCR)



Comparing with other countries, in particular with the Scandinavian neighbours, it was found that Norway produces the lowest share of scientific papers and, if the number of papers published is adjusted to population size, again Norway is at the end of the productivity scale (see Table 1, Figure 3).

2 Population size as in 1998 was used to calculate the indicator.

Figure 3: Number of publication per 1000 capita[3] 1993-2000 (Data Source: SCI; Host: STN; Europäische Kommission (2000))



It should be mentioned that in particular Sweden is among the countries with the highest per capita production of scientific papers. Only Switzerland shows higher productivity measure with a comparable size of publication output in total. Norway's productivity measure is indeed higher than that determined for Germany and only slightly lower than that found for the UK.

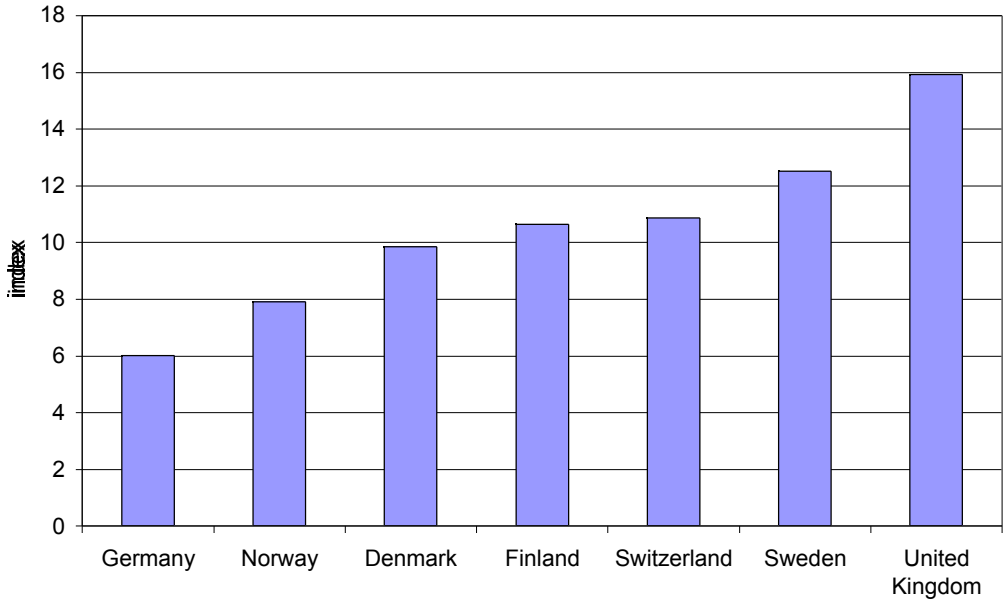
Differences between the countries, that do influence scientific productivity measures, are also obvious comparing the countries based on main science and technology input indicators.

In order to compare R&D spending and output in form of scientific papers it is crucial to determine the relevant input data representing the part of the national R&D budget that is relevant for producing scientific publications. Countries differ in the way they spent their R&D budget. In some countries a considerable share of the budget is spent on defence purposes, an area where research results are less likely to be published. The same applies to business development programmes or space programmes, because public money is primarily spent by enterprises or invested in technical equipment. Thus, the R&D budget used for international comparisons has to be adjusted for those differences by reducing it by the share spent on defence, space and business-related R&D (Grupp et al. 2001). Figure 4 gives the results for comparing the relation of SCI publications to publication-relevant public R&D

[3] Data on population size for 1998, Europäische Kommission (2000)

spending in selected countries. According to this indicator, which can be seen as a approximation to measure cost-effectiveness, Norway is again behind the other Scandinavian countries.

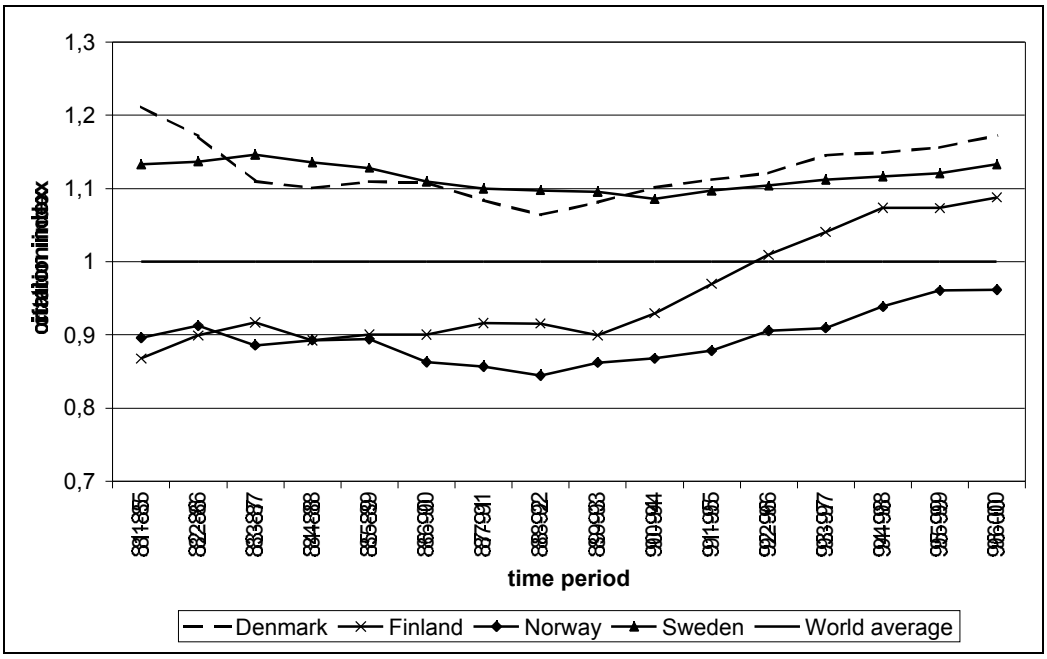
Figure 4: Relation of SCI publications in 2000 to publication-relevant public R&D expenditures in selected countries (index relates publication numbers to million current PPP US $ in 1998) (Data Source: SCI, NSIOD; OECD 2001)



Citation data provided by the SCI was used to analyse the impact Norwegian science has internationally. Citation frequencies differ significantly between disciplines, thus a country's citation rate depends on its engagement in the different disciplines and the relative distribution of papers published in those disciplines. The weighted citation index, which was used as an indicator to analyse the impact of Norwegian science, takes into account those national differences, and thus allows international comparison and a benchmark against the world average (1,0). The results are given in Figure 5.

It was found that in recent years Norway is the only Scandinavian country with indicator values below the international average. Reaching around the same indicator values as Finland until the late eighties, Finland succeeded in increasing the international visibility of its science since 1992-96 more effectively, however, also Norway is closing the gap. The other Scandinavian countries are clearly above the international average.

Figure 5: Weighted citation index (Data Source: SCI; NSIOD)



Using the Revealed Literature Advantage (RLA)[4] Indictor the specialisation profile for Norwegian R&D was analysed. This measure indicates whether within a country's publication activities a particular field has a higher share than its share in total world production. Thus, the indicator shows whether a country engages in a particular sub-field to an extent below or above average relative to its other publication activities. Indicator values above 0 indicate above average engagement, negative indicator value point to below-average activities. Is the RLA value 0 the country's activities is reflecting activities at an average level. The maximum indicator value is +100, the minimum –100.

Figure 6 represents the specialisation profile determined for Norway. Three different periods of time are shown – 1990-1992, 1993-1996 and 1997-2000. The analysis was carried out using a classification system based on SCI subject codes, which was developed by Fraunhofer ISI and is frequently used in competitiveness analyses carried out for the German Federal Ministry for Education and Research. As the classification scheme is based on the SCI subject codes the field assignment is based on a journal classification, this means the whole journal, depending on its content, was assigned to a specific subject code, not the single paper. For the classification scheme used, which consists of 28 fields, the subject codes were aggregated. Only minor changes were introduced compared to the original Fraunhofer ISI

4 RLA=100*tanh ln $(P_{ij}/\Sigma_i P_{ij})/(\Sigma_j P_{ij}/\Sigma_{ij} P_{ij})$ with: Pij=number of publications in country i for sub-field j; $\Sigma_i P_{ij}$=number of all publications in country i; $\Sigma_j P_{ij}$=number of all publications in sub-field j; $\Sigma_{ij} P_{ij}$=number of all publications of all countries in all sub-fields

schemes in order to take specific focus areas of Norwegian R&D activities into account – as for instance Marine Sciences. Sizewise fields differ. Particularly large is the Medical field. Internationally in the period 1997-2000 this field accounts for about 39 % of the publications covered by the data base. Biotechnology and Biology are also large with 11 % and 13 % of the total.

Visible in Figure 6 becomes the strong above-average specialisation in the areas Marine and Geosciences as well as Ecology and Environmental Sciences. Those areas were the main focus of Norwegian Science during the whole period analysed. Clearly below-average are the Norwegian Activities in the engineering sub-fields like Mechanical Engineering, Nuclear Engineering, Electrical Engineering, Process Engineering and also Telecommunication. Also below average are the Chemical sub-fields as well as the Material Sciences.

Glänzel (2000), who used a different, much less disaggregated classification scheme, introduced "four basic paradigmatic patterns in publication profiles":

- the "western model", with specific focus on Clinical Medicine and Biomedical Research,
- the pattern followed by former socialist countries, which is characterised by the dominance of Chemistry and Physics,
- the "bio-environmental model", favouring Biology and Earth Sciences, which is „most typical for developing and more ‚natural' countries (e.g. Australia, South Africa)" and
- the "Japanese model" with its specific focus on Engineering and Chemistry.

According to Glänzel the specialisation profile determined for Norway could be interpreted as representing a mixture of the „bio-environmental" and the "western model" with a tendency to change towards the "bio-environmental model" while the rest of Scandinavia is rather moving towards the "western model".

Figure 6: Specialisation profile of Norwegian Science (Data Source: SCI; Host: STN)

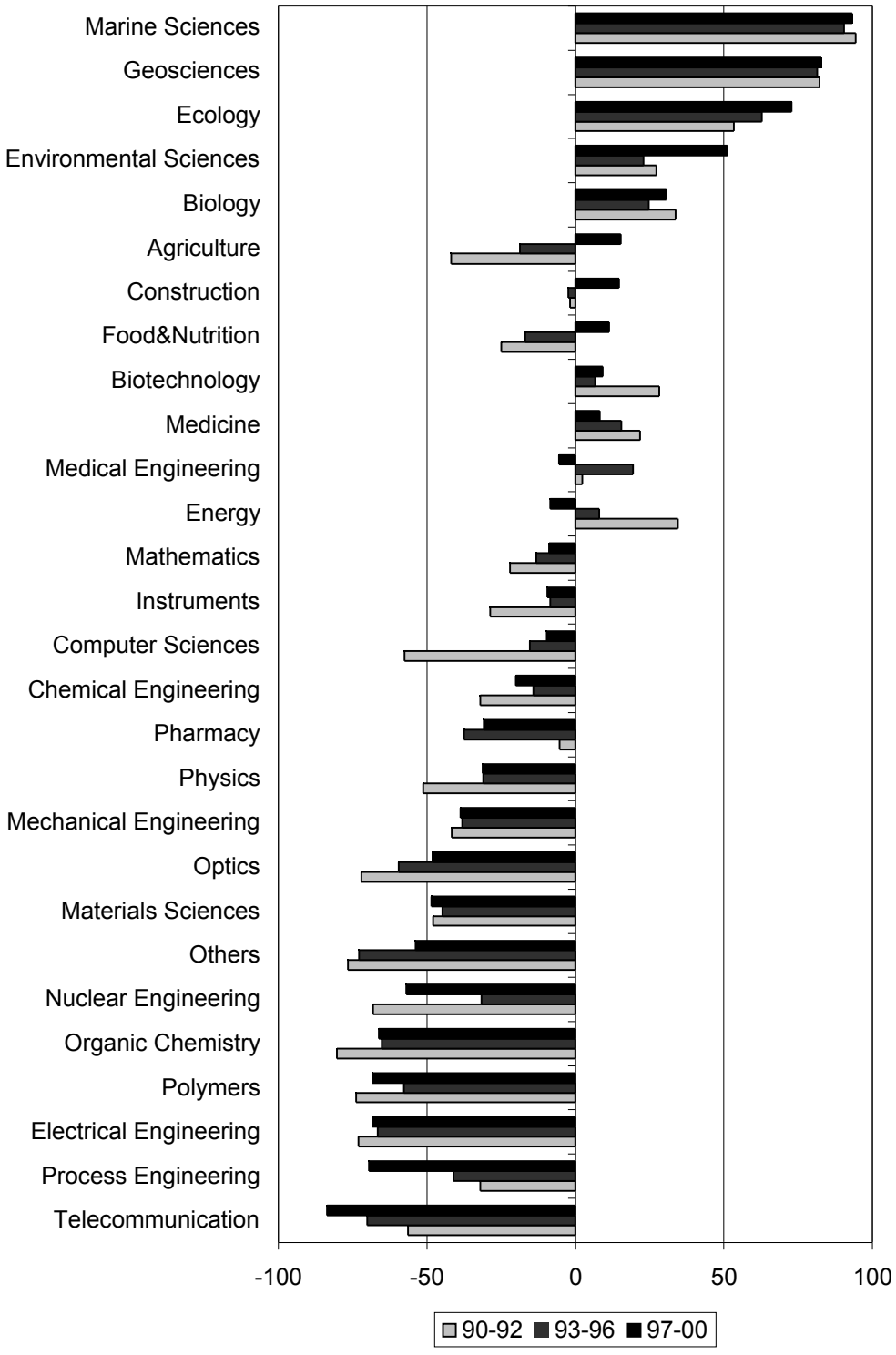
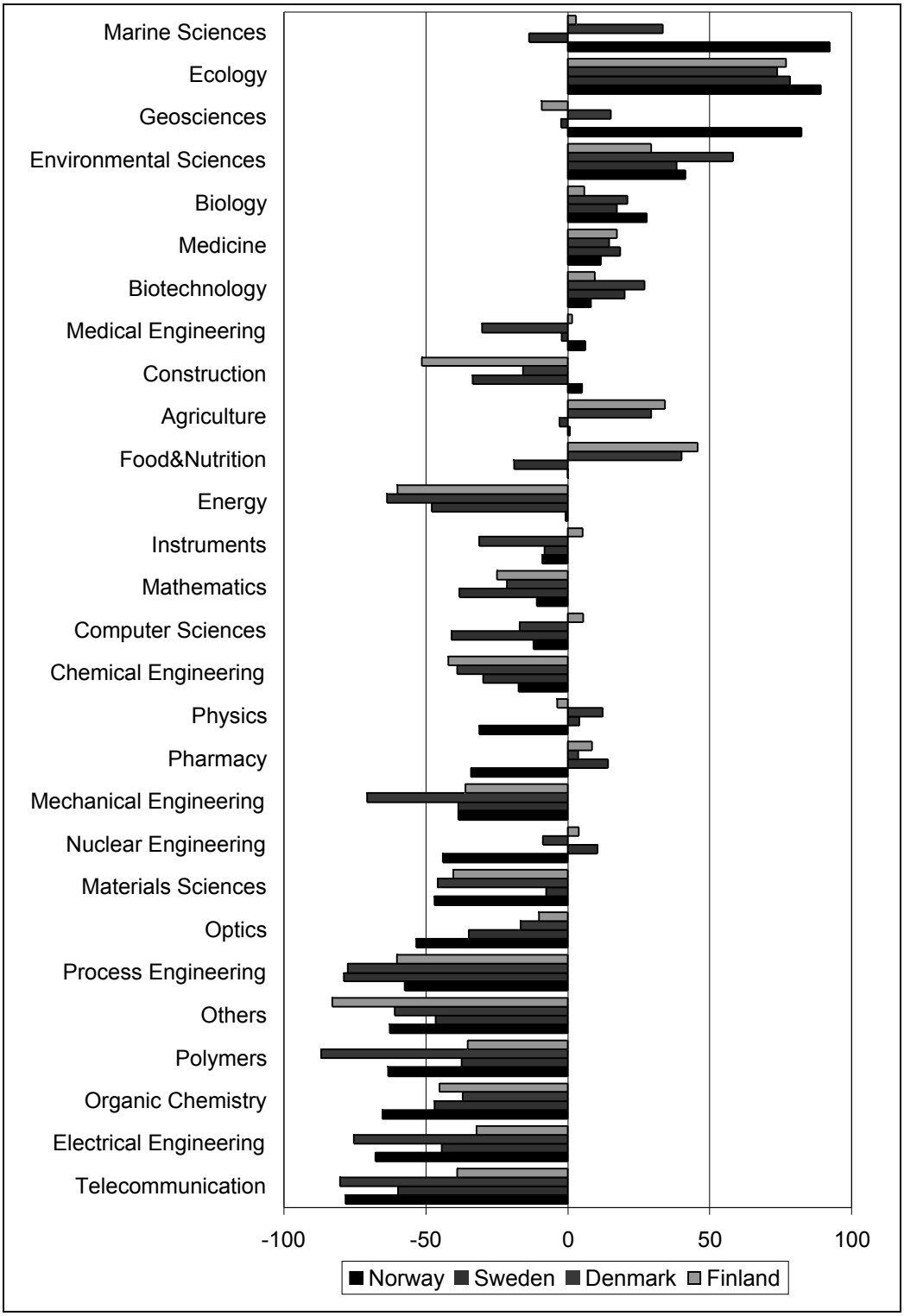


Figure 7: Specialisation profile of Scandinavian Countries (Data Source: SCI; Host: STN)



Comparing the Norwegian specialisation profile with its Scandinavian neighbours (Figure 7) we found that Norway shows indeed a more pronounced orientation on topics like Marine Science and Geosciences. Those areas are, with the exception of Denmark but to a much lower extent, not in the focus of research in those countries. While all four Scandinavian countries show distinct activities in Ecology. Also Environmental Sciences is dealt with clearly above average. Denmark, Sweden and Finland show a stronger emphasis on medical topics and also Biotechnology is pursued to a higher extent. For Finland and Denmark specific focus is also on Agriculture and Food & Nutrition. As for Norway research on the Engineering subfields is carried out to a below average extent, even if the negative specialisation is not in all fields as distinct as it was found for Norway. Due to the slightly stronger focus on medical research that was found for Sweden, Denmark and Finland according to Glänzel's classification, those countries follow the „western model". Whether those differences found by analysing the data could indeed justify the conclusion that Norway follows a different model remains - from our point of view - open for discussion.

In Figure 8 in addition to the sciences the specialisation profile for the social sciences is given. As the Sciences Citation Index does not cover the social sciences for calculating the specialisation index here the National Citation Report for Norway was used as data source, which covers all Norwegian publications in all areas of scientific activity. The specialisation index was calculated taking into account all subfields and thus activities in the social sciences are seen also in relation to those focussing on the sciences. The subfields represented are aggregated subfields which were formed based on the subject categories given in the data base. The problem related to the social sciences that has to be mentioned is that the data basis is rather limited. National sources, which form a more important medium for publishing research results in the social sciences if compared to the sciences are not well covered by the data base. Thus the indicators have to be used and interpreted with care. Keeping in mind those limitations the following results were found. In the most recent period Economics & Management is the only area with activities above average. Specialisation on the area developed from clearly below to above average indicator values within the time period studied. Also improving seems to be the position in Psychology while for History & Philosophy and Sociology & Education decreasing indicator values were determined.

Generally, collaboration, including international collaboration, becomes an increasingly important feature of R&D (see Figure 9). Bibliometrically, international collaboration is measured using co-authorship data. It is assumed that if a paper is written by more than one author, the underlying research was carried out in collaboration between those authors and thus the institutions they work at.

Figure 8: Norwegian Specialisation in the social sciences (Data Source: National Citation Report – Norway)

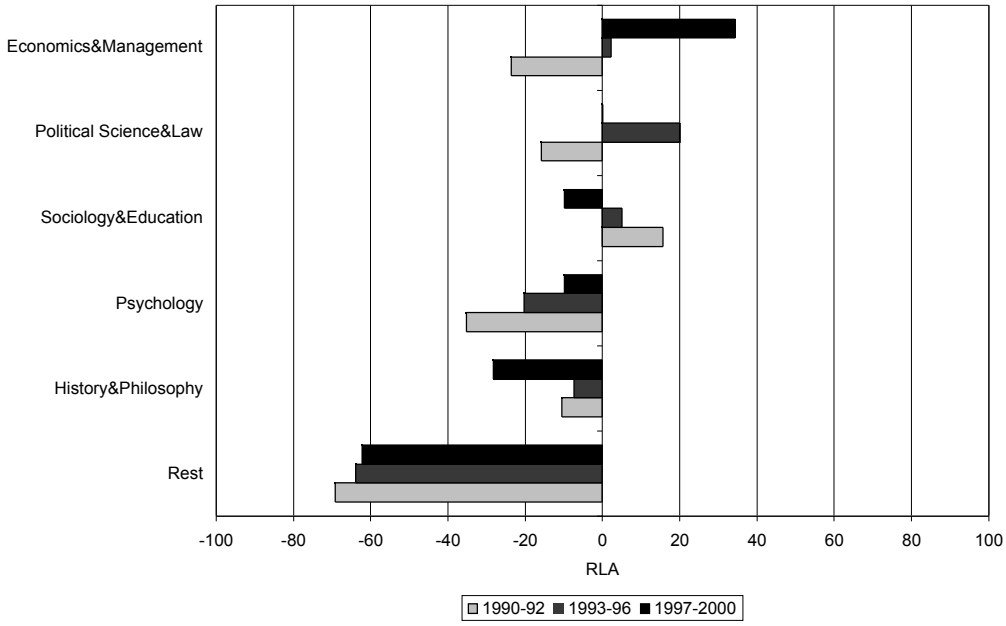
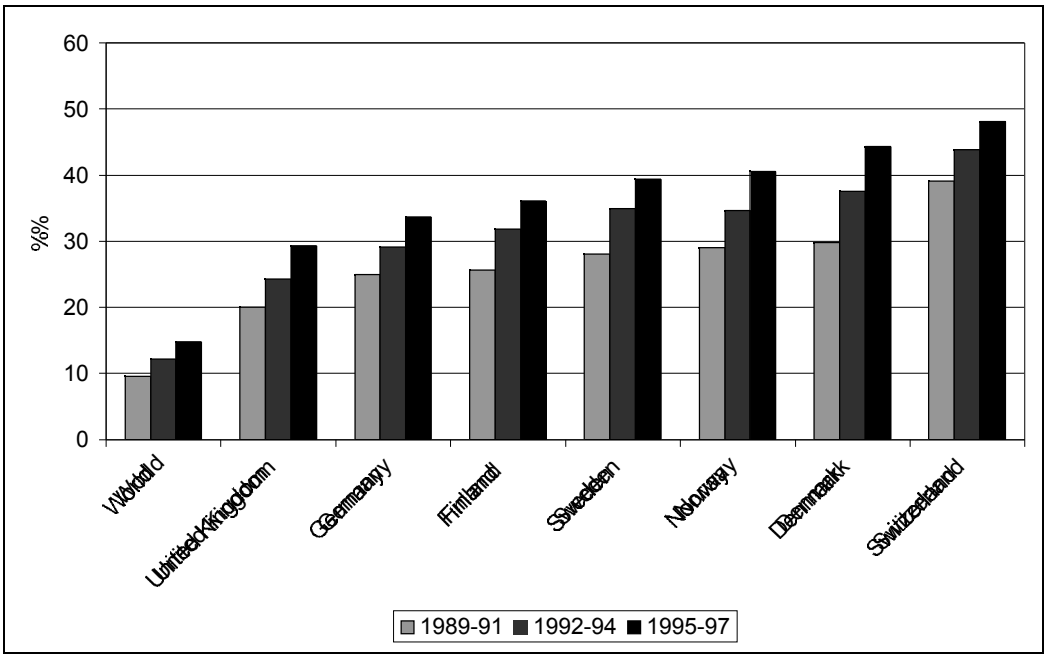


Figure 9: International Collaboration – all fields (National Science Board 2000)



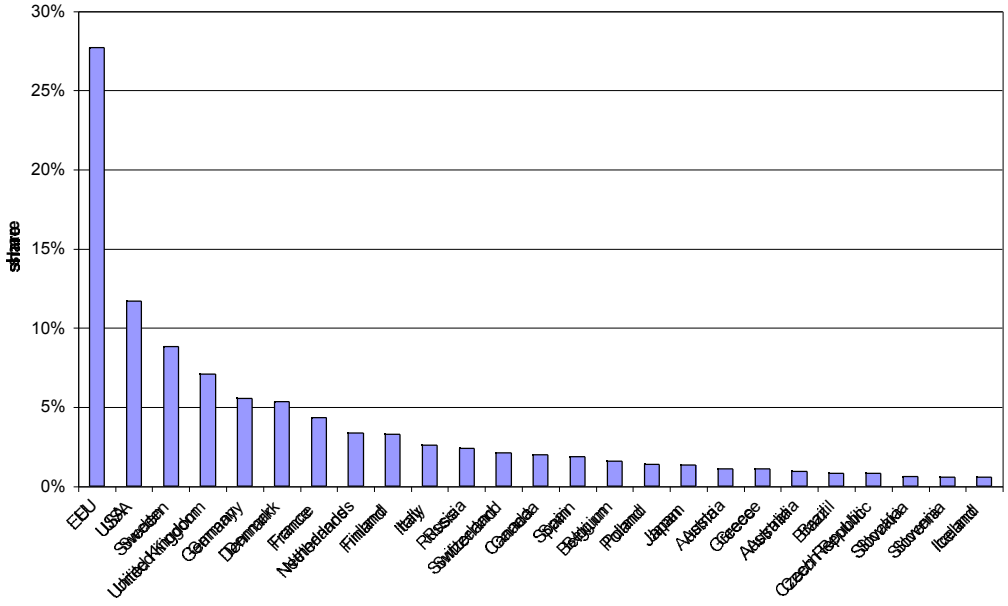
International collaboration is assumed when a paper is written by authors from more then one country. This indicator is frequently used for the analysis of research collaboration. It should, however, be taken into consideration that, as Katz and Martin

put it, it is by no means perfect (Katz et al. 1997). Co-authorship should only be seen as an „partial indicator“ because only those collaborations, which eventually lead to a joint publication, are taken into account. Not all collaborations, however, result in publications and, conversely, a joint paper does not always mean that the results presented are based on research collaboration.

Using the co-authorship indicator it was found that Scandinavian countries in general collaborate internationally to a clearly higher degree than most other nations (Figure 9).

World-wide between 1995-1997 about 15 % of all papers were written jointly between authors from different countries, while between 1989-1991 it was less than 10 %. In the most recent period more than 40 % of the Norwegian papers were internationally co-authored. In 1989-1991 the share was 29 %. Among the Scandinavian countries only Denmark collaborates to a higher extent, with more than 44 % internationally co-authored papers between 1995-1997. In former studies see for instance (Luukkonen et al. 1992) it was found that in particular smaller countries seem to collaborate internationally more intensively than larger countries. E.g. although the USA is for most countries the or at least one of the most important countries to collaborate with only 18 % of its own publications are written in international collaboration between 1995-1997.

Figure 10: Most important co-authoring countries of Norwegian researchers 1993-2000 (Data Source: SCI, Host: STN)



The countries Norwegian papers are co-authored most frequently with are shown in Figure 10. Norwegian Researchers are extensively co-operating with colleagues from the EU member countries. 28 % of all Norwegian papers are co-authored with research institutions from those countries. As for most countries US-american researchers are very important partners for Norwegian scientists. In the period 1993-1999 12 % of all Norwegian papers had at least one US-american co-author. About 9 % of the Norwegian papers are co-authored with Sweden, which is thus the second most important individual country concerning co-authorship. Other important countries following are the United Kingdom (7 %), Germany and Denmark (6 %), France (4 %), Netherlands and Finland (3 %). Thus, the institutions from other Scandinavian countries are among the top most important collaborating partners for Norwegian science.

Summary

Norway was able to increase its share of world-wide publication output since the end of the 80s, which is a result of increasing international collaboration, adjusted for the effects of international co-authorship the proportion of Norwegian output remains stable over time. It was found that Norwegian scientific productivity is lower than that of its Scandinavian neighbours in particular if based on population size. Publication output per capita is, however, higher than it is for Germany and only slightly behind the UK. Taking the relation between R&D input and publication output as an approximation for cost-effectiveness it was found that Norway is following behind its Scandinavian neighbours too.

Visibility and the impact Norwegian science has internationally stayed behind in comparison to Sweden, Finland and Denmark too and is still slightly below international average. However, the gap is closing.

Norway focuses its scientific activities predominantly on areas like Marine and Geosciences. Also Ecology and Environmental Sciences are intensively followed. Thus, Glänzel characterises the Norwegian specialisation pattern in science as the „bio-environmental“ model.

International collaboration, which is becoming increasingly important world-wide is even more relevant for the Scandinavian countries. All Scandinavian countries are at a comparable high level if the degree of international collaboration is concerned. For Norway partnerships with member countries of the European Union are crucial. About 28 % of all Norwegian scientific papers are co-authored with scientists from EU countries.

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Case studies on selected sub-fields

Methodology

Three different case studies were performed, aiming at analysing the performance of NFR relevant scientific activities. Three areas were selected. These areas are marine sciences, biotechnology and economics. Marine sciences was selected because it is one of the main areas of interest in Norwegian science in general and also one of the priority areas of NFR funding activities. The role of biotechnology among the priorities set in Norwegian research was changing. Originally, biotechnology was an area with high priority in Norway and the NFR, later its importance decreased, but recently biotechnology is again among the important areas to be dealt with in Norwegian research. The support for biotechnology is quite considerable, activities are spread over different NFR divisions, which are co-operating in this area.

The third area analysed is economics. The rational to chose economics was, among others, to select one area representing the social sciences and humanities within the broad spectrum of NFR funding activities. From a bibliometric point of view this choice is rather challenging. Data availability and data coverage is compared to the natural sciences less complete - meaning that a smaller proportion of the scientific output is covered and consequently used for bibliometric analysis. For instance in the social sciences books are more frequently used as a media for publication than is the case in the natural sciences. This has in particular consequences for citation counts as citations to books are not comprehensively covered. Citations from books are not covered at all. Furthermore, the social sciences are stronger nationally oriented and not many national journals are covered by the data bases (Hicks 1999). Kyvik (1988) found for the period 1979-1981 that 54 % of Norwegian social scientists published in a foreign language while in the natural sciences the share was 80 %. In contrast, in Norwegian published 75 % of the social scientists while only 35 % of the natural scientists did. Hicks is pointing out that there are indications that also social sciences become more internationalised and economics is, however, a field that is, if compared with other disciplines of the social sciences, more international in scope (Ingwersen 2000) and better represented in the data base. In general comparing visibility of the Scandinavian countries in the citation data bases Ingwersen (2000) found that the Norwegian world in selected areas of social sciences is comparable to its share in the natural sciences concluding that the Social Science Citation Index, although biased towards the US ”is increasingly relevant as a tool for international informetric analyses” (Ingwersen 2000, p. 60)

In marine sciences, Norwegian activities are well represented in the Science Citation Index (SCI)[1] and biotechnology is a field well covered by the database too.

The following methodological approach was chosen for the analysis: In order to analyse NFR activities, in all three fields we had to identify those publications included in the Citation Indices that were related to NFR funding. Thus, in a first step we had to identify NFR based activities in those fields. For this purpose we used the FORISS project data base, which contains the NFR funding data.

For the identification of relevant projects from the FORISS data base we applied various selection criteria (see also Table 1). The first criteria to be used were the time period and the status of the project. As the Norwegian Research Council in its present form was founded in 1993, we decided to select only projects from the FORISS data base that were approved and funded (status of project) by the NFR in the time period 1993 to 1999. These projects had been categorised in the data base as ”granted” or ”finished” within the time period considered.

In addition, in order to select those projects relevant to the respective fields we followed a multiple step procedure, which was varied depending on the specific requirements of the areas dealt with. First, we identified the relevant NFR funding programmes for each area and selected the projects funded under those schemes. Second, from those projects identified in the first step, we retrieved all institutions that carried out the projects. In the areas of marine sciences and economics for those institutions with 10 or more projects assigned, after checking those institutions, we assumed that their main area of research is in the respective area and thus, we determined all projects in the database that were carried out by those institutes. All the projects retrieved were included into our sub-set of relevant projects. For biotechnology we did not include this step of the selection procedure as the institutions contributing to biotechnology research were assessed as focussing not on biotechnology only but were actively involved in much wider R&D activities.

In marine sciences in addition to the previously described steps a keyword approach was followed. Keywords were used to search the titles of the projects in order to identify additional relevant projects from the FORISS database. The titles were manually checked for relevance to the field. Irrelevant projects were deselected. Duplicates were eliminated. All the projects identified were added to the sub-set of marine sciences relevant projects.

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1 SCI data was retrieved from the National Citation Report (NCR) for Norway, containing detailed data for all Norwegian articles in the SCI as well as the other citation indices (Social Science Citation Index and Art&Humanities Citation Index), and the National Science Indicators (NSI), containing macro counts for all nations. The data retrieval and basic analysis following our methodology was performed by NIFU.

For economics and biotechnology on the other hand we additionally started from the citation data base and identified the Norwegian authors included in the data base. As a basis for selecting the authors in the data base we delimited the fields economics and biotechnology. economics was delimited by selecting relevant subject codes which are assigned to each journal by the data base producer. In the case of biotechnology we used a search strategy that combined keywords and subject codes. The search strategy was developed by Fraunhofer ISI based on a classification scheme for biotechnology developed by Fraunhofer ISI together with SPRU, University of Sussex and TNO, The Netherlands (see European Commission 1999/2000) and which has been successfully applied in a number of projects on biotechnology before (see for instance Menrad et al. 2001). From the data retrieved we selected the authors and matched them with the data on the principle investigators given in FORISS to identify NFR relevant publications.

Table 1: Selection criteria for projects from the FORISS database – marine science

Selection criteria	**Column in FORISS**	**Status in FORISS**
Time period	First year of funding	1993-1999
Status of project	Funding	Granted (‘Bevilgning’) Finished (‘Avsluttet’)
Funding programme	Subject	**marine sciences** Fisheries (‘Fiskeri’, Fiskerifangst’ and ‘Andre Fiskeri’) Aquaculture Fish health (‘Fiskehelse’) Fish biology (‘Fiskeribiologi’) Limnology (‘Limnologi’) Marine Biology (‘Marin Biologi’) Marine Botany (‘Marin Botanikk’) Oceanography (‘Oseanografi’) **biotechnology** biotechnology (‘Bioteknologi’) in addition the following ”ACTIVITIES” were selected: Capitalisation of biotechnology

		Basic biotechnology Cell- and gene technology Molecular medicine and gene technology biotechnology Environmental consequences of biotechnology Marine biotechnology in Tromso **economics** economics (‘Okonomi’) economics of the private sector and companies (‘Bedriftsokonomisk Analyse’) National and public economics (‘Sosia-lok./Samfunnsokonomie’) Environmental and resource economics (‘Miljo og ressursokonomi’) Developmental economics (‘Utvilingsoko-nomi’) Organisational psychology (Organisas-jonspsykologi’)
Institutions	Institution	Those institutions that appeared in the pre-selected data set with >10 projects (marine sciences and economics)
Keywords	Title	**marine sciences** Fisk/Fish Marin/Marine

From those projects identified in the FORISS data base the names of the Principle Investigators (PI) were selected and used to identify relevant SCI[2] publications by matching PI names with the author names given in the SCI too.

Due to the fact that the FORISS data base is in Norwegian, for the matching process we had to adapt the data - meaning that we had to take spelling variations of the Norwegian author names into account. Thus, spelling variations were created that would most likely appear in international scientific journals. Those variations were used in the matching procedure.

2 Data was gathered from National Citation Report (NCR) for Norway, which contains not only the SCI data but also those from the other Citation indices products as the Social Science Citation Index (SSCI) and the Arts&Humanities Citation Index (A&HCI), thus economic literature is included in the data base.

As in a first step only author names were used for the matching between the FORISS and the SCI data, the data retrieved were checked for relevance again. The analysis of the SCI subject codes[3] that were assigned to the papers showed that various scientific fields appeared. Not all of them seemed to bear relevance for the selected sub-fields. Thus, manually we compared the author affiliations as given by the SCI data base and the institutional affiliation of the PIs, which was given by the FORISS data base. Only those publications for which a correspondence between the affiliation data was found were included in the final bibliometric data set that formed the input data for the following bibliometric analysis.

As it is impossible to exactly identify those publications that go back to a certain research project funded by the NFR, we used all publications that were published by a principal investigator after he/she received the first funding through the NFR, assuming that this funding would be influential to the overall scientific activities of the individual researcher. Thus, based on the information about the first funding year, all those publications were selected that had been published by the respective author in that year or in later years. The basic set of SCI publication contains articles published between 1993 and 2000. Citation data used for the impact analysis were collected for the same period 1993-2000. The citation window (years to pass) would thereby depend on the publication year, but differences were adjusted for in the final calculations, as we shall see below.

Indicators

The bibliometric analysis was focussed on studying productivity, impact and collaboration patterns within the selected scientific areas. A number of bibliometric indicators were constructed from the data set received after applying the described selection, matching and data cleaning procedures. The following indicators were calculated:

- Number of papers published (P)
- Number of citations received by those papers (C)
- Average number of citations per paper (CPP)
- Percentage of papers not cited (%Pnc)
- Expected citation rate for NFR related marine science papers, which is calculated based on the average citation rate of world-wide all papers published in the same journal set, in the same year, and of the same document type as the identified papers in the data set. (XCR)

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3 Subject codes are assigned to each journal according to its thematic focus.

- Norwegian citation rate, calculated by weighting the actual citation rate received by Norwegian papers using the same distribution over the sub-fields as it was found for NFR related marine sciences. (NACR)
- Field dependent expected citation rate, calculated by weighting the XCR for the individual sub-fields appearing in the NFR related marine science publication using the same distribution over the sub-fields as it was found for NFR related marine sciences. Sub-fields are defined by SCI subject codes. (FXCR)
- Impact of NFR related marine science publications compared to the expected citation rate of the respective journal set. (CPP/XCR)
- Impact of NFR related publications compared to Norwegian field dependent citation rate.(CPP/NACR)
- Impact of Norwegian publications resembling a field similar to that found for NFR related marine science compared to the international average in such a field (NACR/FXCR)
- Share of internationally co-authored papers
- Main countries co-authoring NFR related scientific publications
- Research level of NFR related scientific publications

The level of research of NFR related activities was analysed using a methodology developed by the National Science Foundation together with CHI Research Inc. (see Narin et al. 1976 or Pinski et al. 1976). The method is based on a journal classification scheme that differentiates between four levels of research - starting from basic research (level 4) up to applied technology (level 1). Most journals are assigned to one of those categories depending on their main focus of coverage. For the scientific papers included in the basic data set of our analysis we determined the distribution over those levels of research. The results give some information concerning the position of the research carried out within the general innovation process.

Results - marine sciences

Productivity and Impact

In marine sciences 3358 NFR relevant publications[4] (P) were identified and retrieved from the SCI data base. Due to the methodology of identifying relevant publications, which started from the FORISS database, we do not have a defined data set for the overall Norwegian publication output in marine sciences thus, in

4 Only publications with the document type article, letters, notes, reviews and proceeding papers were taken into account.

order to get some idea about what proportion of the Norwegian marine science publication output was NFR related we have to create an approximate value. Aquatic Sciences was the subject code most NFR related marine science papers were assigned to (about 30 %). Thus, we compared the proportion of those papers classified as Aquatic Sciences in the SCI identified as NFR relevant to the overall Norwegian papers in this area. About 55 % of the Aquatic Science papers in the data base were NFR related. Thus, it was assumed that quite a considerable part of publication output in the marine sciences was NFR related.

The number of scientific publications was increasing between 1993 and 1998 and decreasing in recent years. Not only absolute numbers of NFR related marine science papers were growing between 1993 and 1998 but also their proportion in relation to the overall Norwegian output of scientific papers. Were in 1993 only about 2 % of all Norwegian papers related to NFR marine science activities this share increased to about 15 % in 1998, beginning in 1999 this proportion too started to decrease to about 10 % in 2000.

Here another methodological remark has to be made, which applies to all three case studies carried out. As mentioned before it is hardly possible to identify those publications that can be directly traced back to NFR funding. Thus, in our data sets we included all publications from a principle investigator (PI) after he/she received their first funding (starting in 1993). As a result the number of persons contributing to the publication output grew over time, which could explain some of the increase in the publication output. Thus, in order to get additional information allowing to assess productivity trends we analysed the average number of papers contributed per PI. In marine sciences for 1993 45 different principle investigators were identified, in 1999 this number was 207. As a result an increasing number of publications over time is at least partly a result of the increasing number of contributing researchers. Between 1993 and 1998 not only the number of researchers contributing to the scientific output grew but also the number of papers published by principle investigator per publication year (1993: 1.5 papers per PI; 1998: 2.7 papers per PI), indicating an increasing productivity. In 1999 a decrease (2.2 papers per PI) can be observed also for this indicator. Thus, based on those results a decreasing productivity in form of output of scientific publications beginning in 1999 was found.

In a study carried out recently (Sarpebakken & Lehmann-Sundnes 2001) it was found that Norwegian R&D expenditure devoted to fisheries, which is not reflecting marine science in total and thus can only be used as a rough approximation for comparison, in the Higher Education Sector and in the Research Institutes Sector was decreasing since 1993. For NFR activities for marine science projects was calculated based on the project selection used for the bibliometric analysis from the FORISS data base. Again decreasing R&D funding was determined after 1995, except in 1997 when we found more resources devoted to marine sciences. But, due to incomplete data in the FORISS data base –not for all projects R&D funding is given

- this can also be a rough proxy only. But, at least partly decreasing R&D input could be one reason contributing to decreasing publication output.

In Figure 1, the distribution of NFR related marine science papers over the different disciplines is given. The disciplines are delimited according to the subject codes given by the Science Citation Index (SCI). Clearly visible is the dominance of papers classified as ”Aquatic Sciences”, since 30 % of all papers identified belong to this sub-area. Significantly behind follow ”Environment/Ecology” (9 %) and ”Earth Sciences” (5 %). About 5 % of all papers were not classified according to the given classification scheme (”No category”). A variety of disciplines were found contributing to marine sciences at a comparable level of about 1 %.

Figure 1: Distribution of subject codes in NFR related marine science Papers (1993-2000) (Source: NCR)

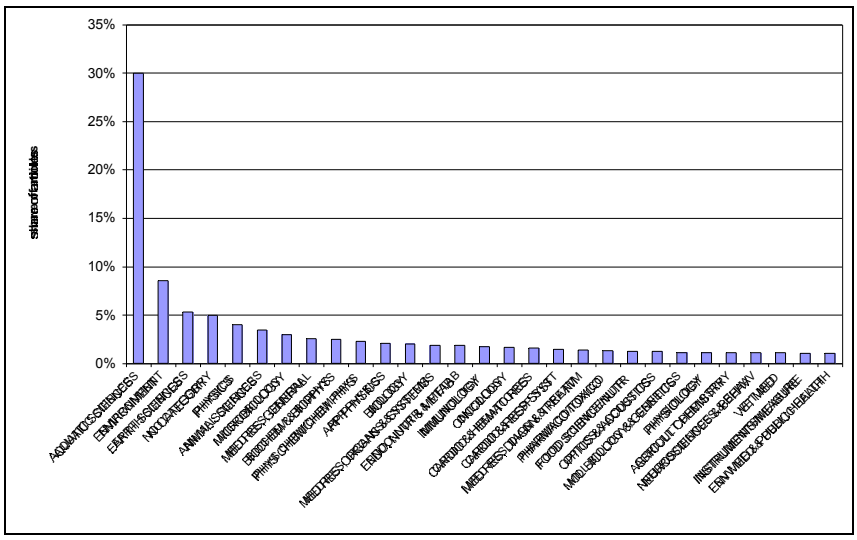


Table 2 gives the results for all the individual indicators calculated. The publications identified as NFR related received in total 18213 citations (C) in the period 1993-2000. Thus, the average number of citations per publication (CPP) is 5,42. 30 % of all papers did not receive any citations during the period analysed.

Significant differences exist in the publication and also the citation behaviour between individual disciplines or sub-fields. As a result quite different CPP values can be observed for different fields and which is also the case for those fields studied in the present investigation (see other case studies). Thus, additional indicators have to be introduced to allow a comparison between the calculated indicator values for NFR related papers and national and international standards, respectively. Those indicators take the relative distribution over different sub-fields into account. The first indicator used is the expected citation rate (XCR). As described above, the expected citation rate determines the number of citations a paper published in a certain

journal, in a certain year and with a certain document type would receive on average, if compared internationally. The ratio between the CPP indicator and the XCR indicator then expresses whether the impact of NFR related papers is above or below the average. Indicator values above 1,0 are indicating that the papers identified are cited more frequently than the average publication in a comparable journal set. For NFR related marine science papers the indicator value is 1,17. It can be concluded that the impact of NFR related marine science papers is higher than the international average.

Table 2: Indicators of publication output and impact (1993-2000)

Indicator	Indicator Value
P	3358
C	18213
CPP	5.42
%Pnc	30.02
XCR	4.63
NACR	4.89
FXCR	4.51
CPP/XCR	1.17
CPP/NACR	1,11
CPP/FXCR	1.20
NACR/FXCR	1,08

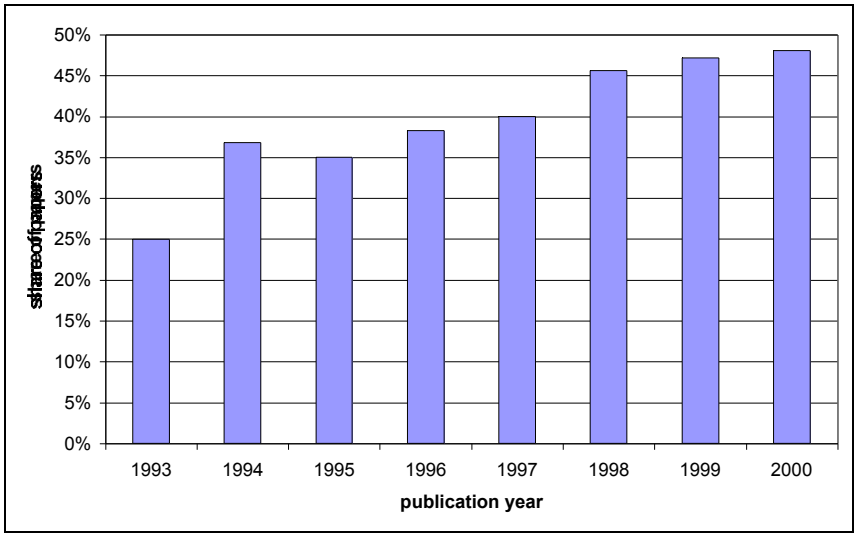
To compare the impact of the identified NFR related marine science publications with actual Norwegian standards, we calculated the NACR indicator, which is a weighted indicator that takes the field distribution in the NFR related publication set into account. The field distribution is used to weigh the citation rate as calculated for the individual sub-fields in Norwegian science. The NACR indicator is 4,89. Again, calculating the ratio between the CPP indicator and the NACR indicator shows that compared to the overall Norwegian publication activities in a comparable, those publications identified as NFR related receive slightly above average citation values. The indicator value is 1,11. Thus, the impact of the NFR related activities in marine science is also slightly above Norwegian standard.

The field dependent expected citation rate (FXCR) also takes into account the field distribution found for NFR related marine science papers. As the expected citation rate by this calculation is 4,51, both the NFR related papers and the Norwegian papers in general in the same fields exceed those field dependent expected values. Thus the impact of the NFR related papers as well as those of the overall Norwegian papers is – in the latter case at least slightly - above the world average. The ratio values are 1,20 if NFR papers are compared to all SCI papers (CPP/FXCR), and 1,08 – if compared to total of Norwegian papers (NACR/FXCR).

Collaboration in marine sciences

The share of international co-authored scientific papers is an indicator that at least partly[5] reflects international scientific collaboration. The indicator is used widespread to analyse scientific collaboration. In general, we found that international collaboration plays an important role in Norwegian science (see also chapter "Bibliometric Analysis of Norwegian Research Activities). During the period 1995-1997, about 40 % of all Norwegian scientific publications were produced jointly between Norwegian scientists and colleagues abroad (National Science Board 2000). For the NFR related marine science publications, the share of internationally co-authored papers was 42,5 % between 1993-2000.

Figure 3: Papers with international co-authorship as share of all NFR related marine science papers 1993-2000 (Source: NCR)



As Figure 2 shows, the proportion of internationally co-authored papers increased significantly between the early nineties and the most recent years. While in 1993, 25 % of all papers were written jointly between Norwegian and other countries' scientists, the proportion reached more than 48 % in 2000.

Figure 3 shows the distribution of the countries participating in the NFR related papers. The highest share of papers is written together with US institutions (30 %), followed by research institutions in the United Kingdom (23 %). Sweden (20 %) and Denmark (16 %), the Scandinavian countries in general are, as expected from the general collaboration pattern of Norwegian science, important collaborators as well.

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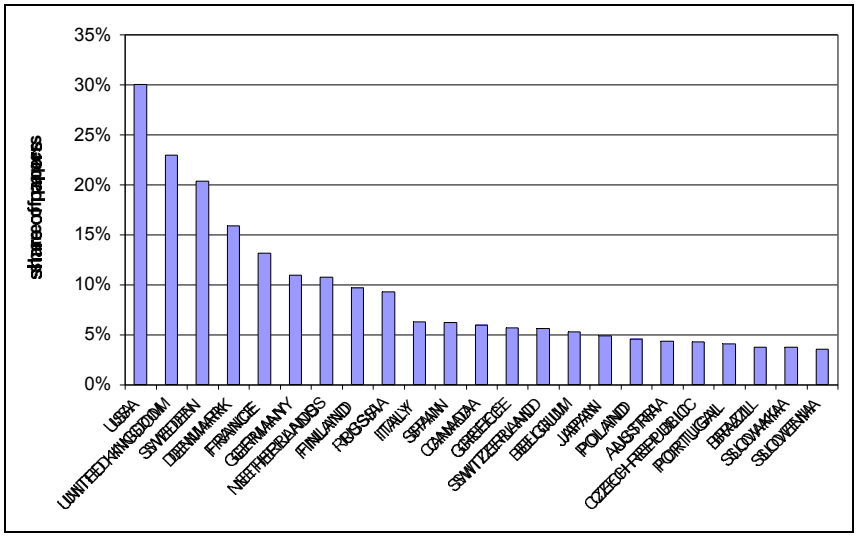
5 Co-authorship should only be seen as an "partial indicator", because only those collaborations which eventually lead to a joint publication are taken into account. Not all collaborations, however, result in publications and, conversely, a joint paper does not always mean that the results presented are based on research collaboration (Katz et al. 1997)

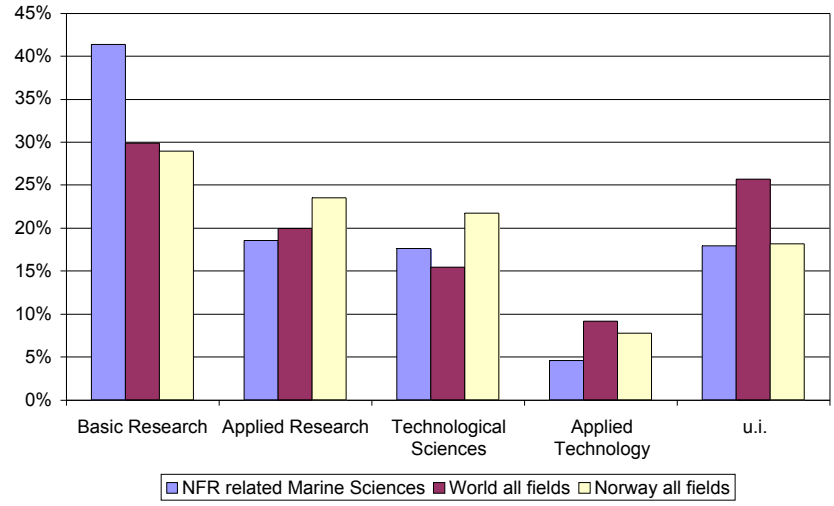
Figure 3: Collaborating countries in NFR related marine sciences (Source: NCR)



Research level in marine sciences

Figure 4 shows the results received analysing the NFR related marine science publications concerning their level of research. It was found that the vast majority of papers (41 %) was published in journals representing mainly basic research. 19 % of the publications can be classified as applied research and 18 % are focussed on technological sciences. 5 % of all papers may be considered as dealing with applied technology. The graph also shows that compared to the world-wide average as well as the Norwegian average for all disciplines NFR related marine science papers were found to be more basic sciences oriented. It has to be mentioned that about 18 % of all papers cannot be classified (u.i.) at all as the journals the papers appeared in are not covered by the classification scheme. However, comparing only those papers assigned to the subject code ”Aquatic Sciences”, about one third of the marine science papers are assigned to this category, it was found that Norwegian activities are oriented towards applied R&D activities more intensively than it is the case for the Scandinavian countries in total. 57 % of the Norwegian publications were published in journals classified as basic science while for Scandinavia in general it was 71 %.

Figure 4: Research level of NFR related marine science activities



Conclusions

In this case study the performance of NFR activities in the area of marine sciences has been analysed using a set of bibliometric indicators. In general marine sciences is an important area of NFR funding. In the period 1993-1999[6] 9 % (1553) of all projects that are covered by the FORISS database were identified as relevant to marine sciences. Based on this subset of projects in total 3358 NFR related marine science publications were identified in the Science Citation Index. Increasing publication activity – in absolute and relative terms – was found between 1993 and 1998. Also the average number of publications per principle investigator was increasing. After 1998 decreasing publication activities were found which might be related to decreasing funding.

NFR related marine sciences performs at a high level if the impact of this research is concerned. It was found that either compared to Norwegian as well as international standards NFR related activities are above average.

Most of the research carried out is focussing on basic research. The degree of basic research in NFR related marine sciences is higher than it is the case for overall scientific activities in Norway. Application orientation seems to play a less prominent role. However, at least parts of the research activities undertaken point to a stronger focus towards industrial application than is the case for the other Scandinavian countries.

6 Only projects that were granted or completed within that period were considered.

An increasing share of the research is carried out in international collaboration. In marine sciences the share of collaborative activities was found to exceed the overall average found for Norwegian research.

Results – biotechnology

Between 1993 and 2000 in biotechnology 1962 NFR related scientific publications[7] (P) were identified. This is about 31 % of the total Norwegian publication output in biotechnology, which was determined online, using the search strategy as described above. Increasing publication activities are found from 1993 onwards until 1998. For 1999 and 2000 a slightly decreasing publication output was determined. The share of NFR related scientific publications in biotechnology was also increasing between 1993 and 1998 - from about 3 % to slightly above 7 %. As it was found for marine sciences from 1999 onwards a decrease in the proportion of NFR related biotechnology activities can be observed (1999: about 6 %; 2000: about 5 %). In biotechnology too the number of principle investigators contributing to knowledge generation was increasing between the beginning and the end of the period analysed (1993: 62; 1997: 138; 1998: 145; 1999: 119), influencing the increase in the number of scientific papers. In contrast to the marine sciences in biotechnology a decreasing average number of publications published per principle investigator was detected (1993: 4.4; 1999: 3.5) pointing to decreasing productivity if the number of principle investigators is used for normalisation.

R&D expenditure calculated based on the project selection from the FORISS data base, points to decreasing resources devoted to biotechnology since 1996 which may be one reason for decreasing publication output since 1999. Again the data on R&D expenditure in the data base is incomplete thus the data can only be seen as proxy values.

Publications are spread over various fields. Most biotechnology papers (14 %) appear in journals classified under the subject code “Biochemistry/Biophysics”, 12 % are classified in “Molecular Biology/Genetics” and 10 % in “Oncology”, Microbiology” (9 %) and “Immunology” (7 %) are following behind. About 5 % of the publications were not assigned to any subject code (“No Category”). The distribution of biotechnology publications over a range of subject codes is not unusual. Aksnes et al. (1999) based on an analysis on Norwegian microbiology found that although the subject codes cover highly relevant papers in their key areas, they are by no means comprehensive. Relevant contributions are published outside those key subject areas too. In particular areas crossing the borderlines of traditional disciplines are bound to diverging publication patterns also in the sense that the results are published in a wide range of journals and thus covered by various subject areas.

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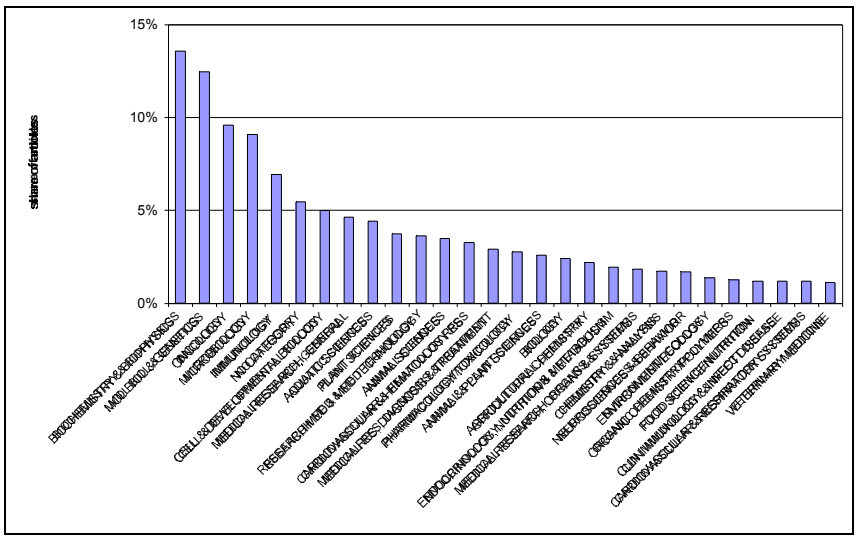
7 Only publications with the document type article, letters, notes, reviews and proceeding papers were taken into account.

Figure 5: Distribution of subject codes in NFR related biotechnology Papers (1993-2000) (Source: NCR)



In Table 3 the results for the indicators calculated as described above are given.

Table 3: Indicators of publication output and impact (1993-2000)

Indicator	Indicator Value
P	1962
C	19960
CPP	10.17
%Pnc	21.92
XCR	9.20
NACR	8.19
FXCR	7.85
CPP/XCR	1.11
CPP/NACR	1.24
CPP/FXCR	1.30
NACR/FXCR	1.04

The 1962 publications (P) in biotechnology received in total 18213 citations (C). On average 10.17 citations per paper (or actual citation rate) (CPP) are received. About 22 % of all papers did not receive any citation within the period analysed. The expected citation rate[8] (XCR) in biotechnology is 9.20. Thus, the ratio between the actual and the expected citation rate is 1.11, which indicates that the NFR related publications in biotechnology are cited more frequently than the average publication in this area and thus their impact is above the international average.

8 For a short introduction to the indicators used see the general chapter as well as the case study on marine sciences.

The NACR indicator, which indicates the Norwegian standard citation rate, taking into account the field distribution of the NFR related papers, is 8.19. The ratio between the CPP and NACR of 1.24, expresses that NFR related biotechnology papers draw a higher impact compared to the Norwegian biotechnology papers in total too.

The NFR related papers also exceed the field dependent expected citation rate (FXCR), thus the impact of the biotechnology papers is above the international average found for the field in general. The ratio CPP/FXCR is 1.30. The indicator value is only very slightly above average if the Norwegian publications in total are taken into account (NACR/FXCR). Thus, Norwegian biotechnology activities in general receive an impact that is comparable to the world average.

Collaboration in biotechnology

Also in biotechnology international collaboration is an important feature of research activities. Between 1993-2000 on average more than 40 % of all papers were internationally co-authored and thus assumed to be based on international collaboration. An increasing trend was found over time (Figure 6). In 1993 34 % of all biotechnology papers were found to be internationally co-authored while at the end of the period analysed, in 2000, already 45 % of the papers were internationally co-authored.

Taken the overall standing of the USA in biotechnology R&D, it is not surprising that the USA is the most important country for scientific collaboration in biotechnology for Norwegian scientists. In 29 % of all internationally co-authored papers at least one US institution was participating (Figure 7). Following behind are Sweden (20 %), which is again underlining the specific role scientific collaboration among the Scandinavian countries. Other important partners for collaboration in biotechnology are Germany (14 %), France (14 %) and the United Kingdom (13 %).

Figure 6: Papers with international co-authorship as share of all NFR related biotechnology papers 1993-2000 (Source: NCR)

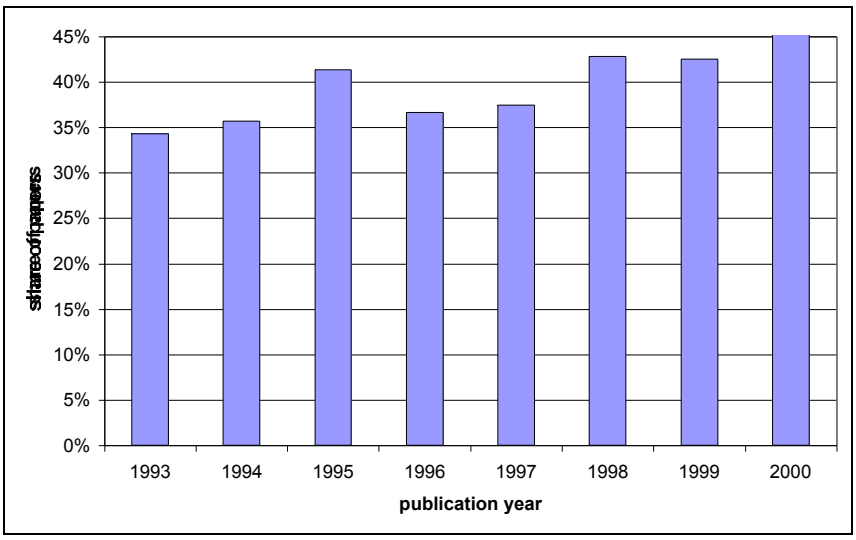
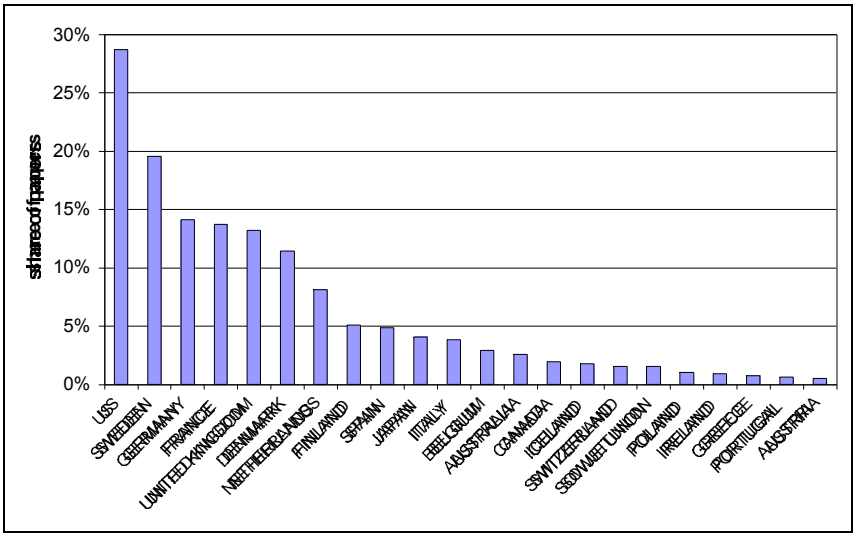


Figure 7: Collaborating countries in NFR related biotechnology (Source: NCR)

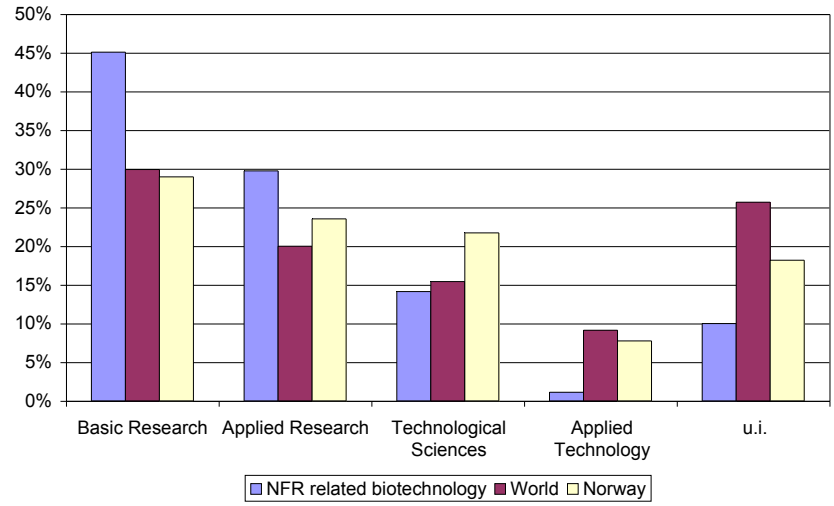


Research level in biotechnology

NFR related activities in biotechnology are strongly focussing on basic research. 45 % of all publications were published in journals that were classified as basic research (Figure 8). About 30 % of the publications are classified as applied research and 14 % are dealing with technological sciences, indicating also an strong orientation towards industrial application of the activities funded. About 10 % of the publications were published in journals that were not covered by the classification

scheme (u.i.). Compared to the world-wide average as well as the Norwegian average for all disciplines NFR related biotechnology papers were found to be clearly more basic sciences oriented.

Figure 8: Research level of NFR related biotechnology activities (Data Source: NSIOD; CHI classification)



Conclusions

In total a 1962 NFR related biotechnology publications were identified in the Science Citation Index. Increasing publication activity – in absolute and relative terms – was found between 1993 and 1998. Afterwards a slight decrease was determined. Decreasing was the production of scientific papers per principle investigator – an indication for decreasing scientific productivity in the area. One factor influencing decreasing publication activities might be a decrease in funding activities.

Also NFR related biotechnology performs at a high level if the impact of this research is concerned. Again it was found that either compared to Norwegian as well as international standards NFR related activities are above average, while overall Norwegian biotechnology activities reach an impact equal to the world average.

An important part of NFR related biotechnology is focussing on basic research. The degree of basic research in NFR related biotechnology is higher than it is the case for overall scientific activities in Norway. However more then one third of the publications are oriented towards applied research and technological sciences indicating significant orientation towards industrial application.

Increasing is the proportion of research that is carried out in international collaboration. In biotechnology the share of collaborative activities was found to exceed the overall average found for Norwegian research.

Results – economics

In economics 320 (P) scientific publications[9] were identified for the period 1993-2000. Following the approach used for the marine sciences to determine a proxy to get some idea about what proportion of the Norwegian publication output was NFR related we created an approximate value. Economics was the subject code most NFR related economics papers were assigned to (about 45 %). Thus, we compared the proportion of those papers classified as economics in the SCI identified as NFR relevant to the overall Norwegian papers in this area. Within the period 1993-2000 we found that about 30 % of the Norwegian economics papers were NFR related.

The number of NFR related publications in economics is growing over the total period analysed (1993-2000). The same was found for the share of NFR related economics publications. Until 1998 R&D expenditure for economics research spent by the NFR, which was calculated based on the project selection from the FORISS data base, was increasing too, only in 1999 a decrease was found. This is to recent as it could have any bearing on the publication output. Again the funding data was incomplete.

The number of principle investigators in economics, which were used to determine the data set, grew too. In 1993 22 PI were selected and in 1999 83 PIs were determined. In economics the number of scientific papers published by the PIs remained more or less constant (1993: 1.2; 1999: 1.4) indicating a stable productivity.

Economics is a rather small area in terms of publication output covered by the database. This is not only true for the share of the NFR related publications but also in total publications in economics form a rather small part of the Norwegian scientific output covered by the citation indices. Thus the rather small share of NFR related economics publications is not surprising. Also internationally economics[10] contributes only about 1.3 % to the publications covered by the database.

According to Figure 9, Economics (about 45 %) is the main subject area where the scientific publications appear. However, relevant publications are also found within "Agriculture/Agronomy" (about 7 %), "Environmental Studies" (about 6 %) and Political Sciences & Public Administration (about 5 %). 11 % of the papers were not assigned to any category ("No category") as the journals they appeared in were not assigned a subject code respectively.

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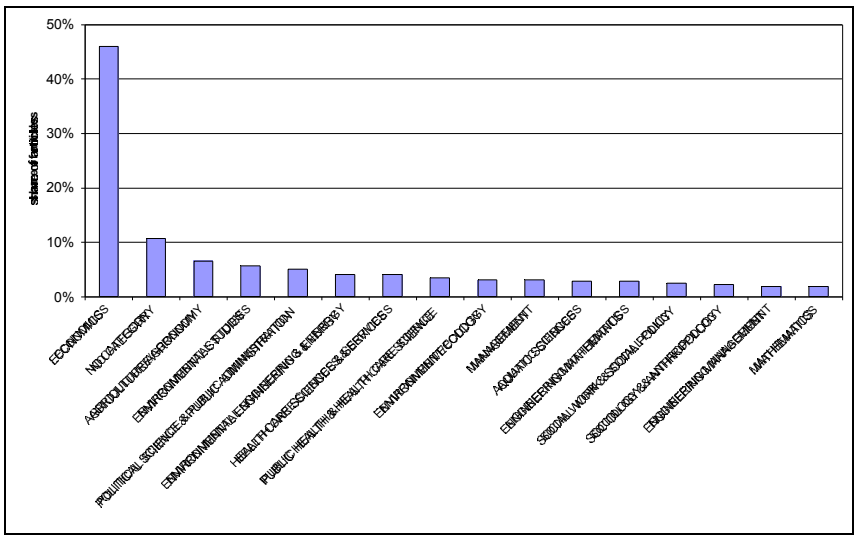
9 Only publications with the document type article, letters, notes, reviews and proceeding papers were taken into account.

10 For comparison we used the aggregated data of the ISI subject codes economics and Management for the period 1993-2000 as given by the database National Science Indicators (NSI).

Figure 9: Distribution of subject codes in NFR related economics Papers (1993-2000) (Source: NCR)



In Table 4 the indicator values as calculated are given.

Table 4: Indicators of publication output and impact (1993-2000)

Indicator	Indicator Value
P	320
C	663
CPP	2.07
%Pnc	55.00
XCR	1.99
NACR	2.36
FXCR	2.30
CPP/XCR	1.04
CPP/NACR	0.88
CPP/FXCR	0.90
NACR/FXCR	1.03

The 320 publications (P) in economics identified received in total 663 citations(C). On average this results in 2.07 citations per paper (CPP), with 55 % the share of papers receiving no citations at all is significantly higher than in the other areas analysed. This is also underlining field specific differences in publication and citation behaviour.

The expected citation rate (XCR) calculated is 1.99 and thus it is hardly different compared to the actual citation rate calculated for the NFR relevant publications, which is also expressed by the ratio value (CPP/XCR) of 1.04. Thus, NFR relevant

economics publications are cited as often as an average paper appearing in the same journals and consequently a comparable impact can be concluded.

Compared with the Norwegian standards NFR related economics publications seems to yield a lower impact. The ratio between the actual citation rate (CPP) and the Norwegian standard value (NACR) is 0.88 indicating that the NFR papers draw less citations than the Norwegian economics papers in general.

Also compared to the field dependent expected citation rate (FXCR) the actual value observed for the NFR papers is lower, the ratio between the two indicators (CPP/FXCR) is 0.90, indicating that the NFR papers do not have the same impact as comparable papers if the field distribution is taken into consideration for normalising the data. The impact of Norwegian economics papers in general is about the same as the world average. The ratio NACR/FXCR comes to 1.03.

Considering the CPP/XCR indicator and the CPP/FXCR indicator together the results indicate that Norwegian economists select journals for their publications that have a lower impact than the average for the field economics.

However, due to low numbers in the field and in the NFR related subset the results have to be interpreted with care. Already the appearance of a few papers with high citation counts (”highly cited papers”) could change the results. Thus, although for international comparison the Social Science Citation Index is, as described above, becoming increasingly important, the analysis of subsets due to low numbers remains- at least in the case study undertaken – to be limited.

Collaboration in economics

Collaboration patterns also vary between the various fields. In economics scientific collaboration does not reach the same extent as in the marine sciences and biotechnology. It is also lower then it is in Norwegian research in general. Over the total period analysed only in about 17.5 % of all NFR related economics papers international co-authorship was found. The development over time is shown in Figure 10 but as numbers are very low conclusions have to be drawn with care as already very few papers could change the picture dramatically. According to the results of the analysis co-authorship was decreasing in NFR related economic research. In 1993 in about 25 % of the publications international partners were involved, while in recent time this proportion dropped to about 11 %. The highest proportion of internationally co-authored papers was found in 1996 (35 %), in 1997 numbers dropped dramatically.

Figure 10: Papers with international co-authorship as share of all NFR related economics papers 1993-2000 (Source: NCR)

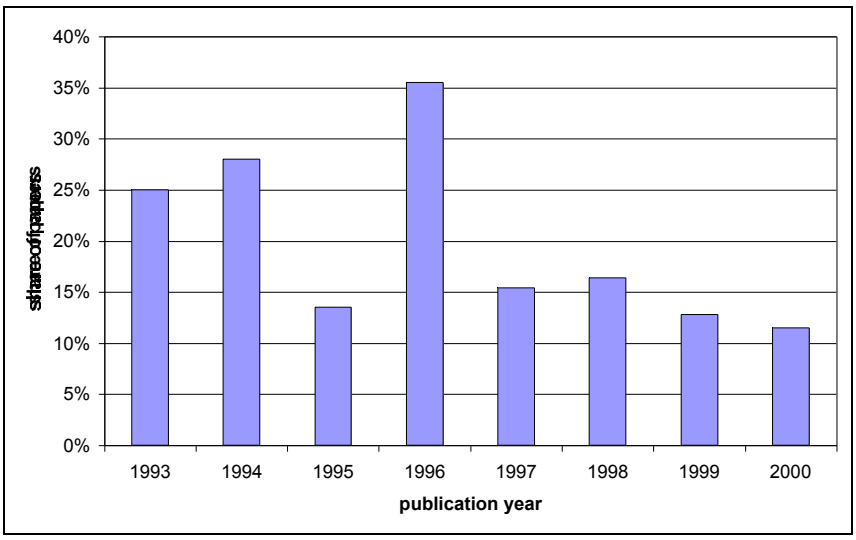
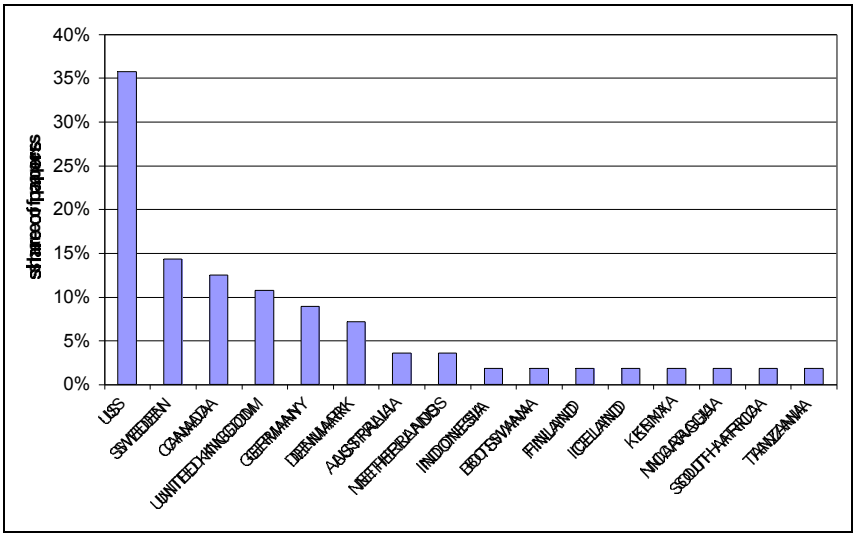


Figure 11: Collaborating countries in NFR related economics (Source: NCR)

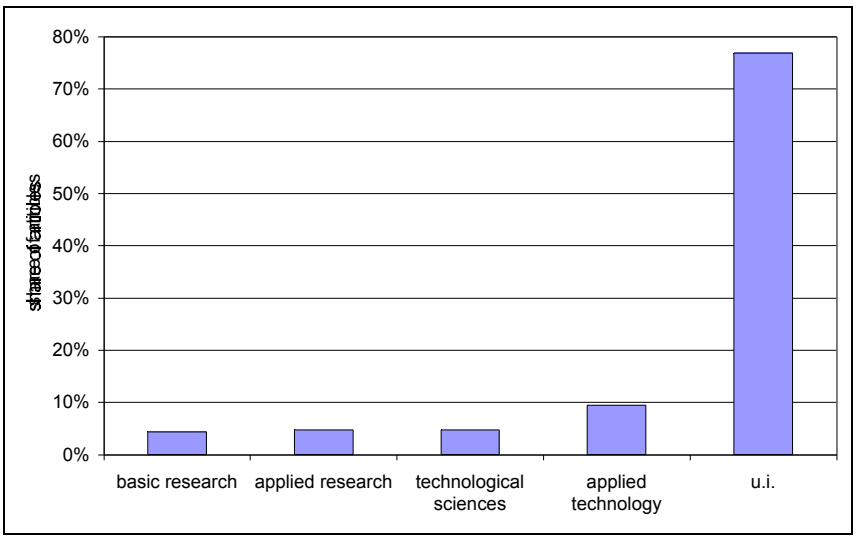


As in most fields the USA seems to be the country Norwegian Researchers are publishing with most intensively. Sweden follows as the second most important country, in 14 % of the identified papers that were published together with other nations Swedish institutions were involved. Researchers from Canada, the United Kingdom, Germany and Denmark were relevant partners for Norwegian Economists as well.

The analysis concerning the research level of NFR related economics research yielded due to lack of data no satisfying results. The vast majority of the journals where economic research results are published are not covered by the classification

scheme – as can be see in Figure 12. Thus, interpretation of the results of this analysis are not meaningful.

Figure 12: Research level of NFR related economics activities



Conclusions

Economics is a rather small field, which is not only the case for Norwegian economics as it is represented in the data base but also at the international level. However for the analysis of an subset of national data for a rather small country namely Norway this leads to methodological problems due to low publication and citation numbers. Indicator values have to be handled with care as already very few papers can change the results significantly, thus it is hardly possible to draw any valid conclusions.

In total we identified 320 NFR related scientific publications in economics. Increasing publication activities – in absolute and relative terms - were found over the whole period investigated. Constant remained the average number of publications per principle investigator.

NFR related economics performs at the international average if compared on the basis of the journal set research results are published in. Compared to Norwegian average and field dependent international standards NFR related publications seem to receive lower impacts but due to low numbers this result has to be taken with care and cannot be used to conclude that NFR related economics research systematic leads to below average impact results.

International collaboration – measured using co-authorship data - in economics is lower then it is in overall Norwegian science. In contrast to other areas analysed and

the results yielded for the Norwegian situation in general international co-publication is decreasing in economics since 1996. This result seems to contradict earlier findings and may be due to low publication numbers.

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