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NordForsk

# Bibliometric Research Performance Indicators for the Nordic Countries

A PUBLICATION FROM THE NORIA-NET  
“THE USE OF BIBLIOMETRICS IN RESEARCH  
POLICY AND EVALUATION ACTIVITIES”

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# Preface

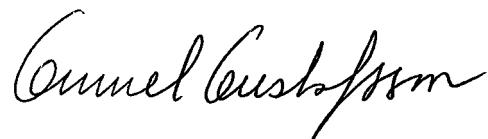
NordForsk is a platform for joint Nordic research and research policy development. The aim is to promote cooperation which adds value to what is going on nationally, and thereby contribute to the knowledge society through continuous efforts to improve the quality of Nordic research and innovation.

Within its policy role, NordForsk facilitates debate on important Nordic research and research policy issues. The basis for this is analysis of developments in the research community and how these might impact on NordForsk's advice to the Nordic Council of Ministers. NordForsk funds a number of NORIA networks with the goal to contribute to joint Nordic priorities on research and innovation policy issues, and as a consequence to sustainable collaboration and investments.

Early in 2008, a Nordic network on bibliometrics was established. It includes those with special competence in this field working at or on behalf of national research funding agencies in Denmark, Finland, Iceland, Norway and Sweden. The goal was to facilitate cross-country comparisons of research performance in bibliometric terms. Therefore the network concentrated on methodological and database issues, seeking to reach agreement on successful approaches and procedures in order to reach this goal.

This is the second report from this NORIA network. The report provides readers with essential information and perspectives on current and future possibilities to reach excellence in Nordic research. It is important because it shows in which fields the Nordic countries already are strong and in some cases even excellent. In addition, it highlights challenges and possible ways to prevent future problems.

In short, the work of NordForsk's NORIA network on bibliometrics constitutes a basis for broad discussion on the potential of Nordic collaboration to contribute to excellence in research and innovation both globally and regionally.



Gunnel Gustafsson, Director of NordForsk

# Abstract

The report investigates international research performance for the Nordic countries over a 20-year period from 1989 through 2008 using bibliometric indicators derived from the Thomson Reuters database at the Swedish Research Council. Developments in publication activity, research profiles, and relative citation impacts, both at the national and field specific levels are focused. Both fractionalized publication counting and field normalized citation scores, based on normalizations at the individual paper level, are applied.

The report has three main chapters. Chapter 1 investigates developments in publication activity. Chapter 2 investigates research profiles derived from publication output, for the Nordic countries based on the period 2004 – 2008. Finally, Chapter 3 investigates the developments in relative citation impact, both at the national and field levels, for the Nordic countries, as well as the shares of highly cited papers.

The analysis of publication activity shows a significant increase in the number of scientific articles published by Nordic researchers in the recent 20 years. Sweden has by far the largest publication output of the Nordic countries, with almost two times the publication output of the second and third most productive countries, Denmark and Finland. When publication output is measured per 1000 population, Sweden also ranks above the other Nordic countries in the most recent 5-year period (2004-2008). Furthermore, Norway and Iceland have, compared to the other Nordic countries, a significantly higher relative growth in their publication output in the most recent 5 year period.

The main findings in the research profile analysis show that the research profiles for the period 2004-2008 vary considerably between the Nordic countries. Denmark and Sweden are similar with an emphasis on clinical medicine and biomedical

research. Norway and Iceland on the other hand have a strong emphasis on geosciences, biology and agricultural research. Finland's profile is distinctive among the Nordic countries, with strong emphasis upon agriculture, biology and information, communication technology.

All the Nordic countries belong to the world's most cited countries, ranging from Denmark on fourth place to Finland on eleventh place. The developments in relative citation rates during the whole period under study show that Sweden's rates are stable some 10% above the world average. Since the mid-1990s Denmark has had a steep rise in citation impact to a current level more than 20% above the world average. Norway and Iceland have seen the largest rise in impact during the same period with a current level around 15% above the world average for Iceland and 9% for Norway. The development in citation impact for Finland has been different; a small rise in impact during the late 1980s was followed by a decline in the early 2000s, leading to a citation impact in the last period almost identical to that for the first period. Much of the increase in citation rates for Denmark and Norway can be attributed to increased citation rates of national publications. For Iceland the increase is due to increased citation rates to international publications. International publications from Finland and Sweden received lower citation rates while rates to the national ones remained constant.

The overall pattern is repeated for many of the subject categories, either on higher citation levels (*Agriculture, Biology, Materials Sciences*) or on lower (*Biomedicine, Social sciences*). However, for some subject categories the case is different. For example, in Chemistry Sweden and Denmark have considerably higher citation rates (25-50 % above the world average) than the other Nordic countries. In *Engineering* and *Physics* Denmark stands out at a stable level 30-40 % above world average, while the other Nordic countries group together around the world average. In *Mathe-*

*matics* the pattern is quite different all countries except Iceland remain on very high citation levels (15-30 % above world average). The analysis generally find that Denmark has managed to move all research fields up to or above the world average in citation impact in the last period. For Finland the field of *Geosciences* stands out with a strong development both in size and citation rates, while ICT has increased in volume but the citation rate has decreased. For Iceland the *Geosciences* stand out with a very large share of the Icelandic publications and a high citation rate as well. Norway has increased its citation rates in all fields except *Mathematics*, and stands strong in fields concerning natural resources (*Geosciences, Agriculture and Biology*). For Sweden we see a trend that all fields move towards the world average, fields that used to be strong weaken, and fields that used to be weak strengthen.

The trends for the share of highly cited papers (above the 99th percentile) are very much the same

for the Nordic countries as the trends for average citation rates, with the exception that the Swedish shows a small increase.

Finally, the methodology used in the report sets different conditions for the countries depending on the size of the publication output, the citation rates are more easily affected for small countries than for large. It is thus not surprising that Sweden generally shows the most stable trend and Iceland the most unstable trend, the statistics for Iceland is in general more unstable due to often small numbers. The Danish development is however still exceptional. Denmark has increased her citation rates dramatically, and now seems to have stabilised in the world elite, with an average citation rate 20% or more above the world average. Norway and Iceland also have had strong increases, but from lower levels than Denmark. Sweden and Finland, on the other hand, have remained on the same citation levels, or even declined.

# Introduction

This report investigates international research performance in the Nordic countries over a 20-year period. It is the third and final report from the NOIRA-net on *The use of bibliometrics in research policy and evaluation activities supported by NordForsk 2008-2009*<sup>1</sup>. Research performance is measured by bibliometric methods, and two types of measures are used; measures of research activity and *measures of research impact*. Measures of research activity are based on fractionalized publication counts, and impact measures are based on relative citation indicators. We should emphasize that citation-based performance indicators do not measure research quality per se. They may reflect important aspects of quality, but citations are primarily a formalized account of information use and can thus be taken as an indicator of reception at this level (Glänzel & Schoepflin, 1995).

Our report focuses on characterizing the trends in publication activity among the Nordic countries and identifying research profiles for these countries. It also investigates the trends in relative citation impact for the Nordic countries, both at a national level and at field-specific levels.

## Methodological considerations

The data source for the present report is the Thomson Reuters database at the Swedish Research Council, which includes: Science Citation Index Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index<sup>2</sup>. The analyses cover a 20-year period from 1989 through 2008. Publications have been restricted to include only research articles, letters, and reviews as defined by Thomson Reuters. We use the data cleaning techniques developed at the Swedish Research Council.

The 255 journal subject classes used by Thomson Reuters have been grouped into 14 main subject groups. The classification is a slight modifi-

cation of the scheme developed by Katz & Hicks (1995) (Appendix 1): clinical medicine; biomedicine; biology; agriculture<sup>3</sup>; chemistry; materials sciences; physics; geosciences; engineering; information, communication, and technology (ICT); mathematics; social science; arts and humanities; and others (i.e. a small share of Thomson Reuter's multidisciplinary journal category). Notice that publication and citation activities in the categories of *arts and humanities* and *others* are very low. Coverage of journals varies considerably from country to country. Consequently, these categories have been excluded from most analyses. To indicate their volume, we have kept the categories in some of the publication activities reported, but we have not performed exclusive citation analyses for these areas. Further, it is well known that Thomson Reuters' Social Science Citation Index is heavily biased towards American journals and covers only 5% to 15% of the research publications produced in social science fields (Sivertsen, 2009). For that reason, bibliometric analyses of the social sciences, if done at all, should be performed and interpreted cautiously. We have decided to include such analyses in the present report and will discuss the implications of the findings where needed.

Bibliometric analyses in this report are based on journal articles and reviews. Hence, subject areas such as engineering and ICT may be underrepresented because these areas have conference proceedings as their main publication source. Hence, results from these areas should also be interpreted cautiously.

Many publications are internationally co-authored and result from collaborative efforts involving more than one country. Furthermore, bibliometric studies apply different principles and counting methods. The most common is *whole* counting, i.e. no fractional attribution of credit (every country gets full



credit for internationally co-authored papers). A second alternative is fractionalized counting where the credit is divided equally between all the contributing authors/countries. For example, if an article has one author from Denmark and one from Iceland, each country would receive a value of 0.5 paper. One can argue that these counting methods are complementary: The whole or integer count gives the number of papers in which the country *participated*. A fractional count gives the number of papers *creditable* to the country, assuming that all authors made equal contributions to a co-authored paper and that all contributions add up to one (Moed, 2005). Contrary to most large-scale, national, bibliometric analyses, we apply fractionalized counting and use a complete-normalized counting scheme (Olesen Larsen, 2008).

Another note of caution: small data sets are more vulnerable to fluctuations due to greater variability.

Highly skewed distributions, which are common in bibliometrics, influence relative citation rates. Hence, a few highly cited papers can influence average citation rates considerably, especially when the data set is small. Changes in small research areas or in small countries may therefore be more visible, but less important. Increases and decreases in publication and citation patterns may also be influenced by changes in the selection of journals indexed in the citation databases, which determines the “world size” of the research area.

The report is presented in three chapters. The first chapter addresses publication activity of the Nordic countries for the given period. The second chapter characterizes the research profile for each of the Nordic countries, while the final chapter uses a variety of relative indicators to investigate the citation impact concerning the Nordic countries.

# 1. Publication activity

This chapter aims to review the trends in publication activity in the Nordic countries over a 20-year period, from 1989 through 2008. The chapter presents both absolute and relative indicators to characterize the trends and enable comparisons between the countries. We focus only on the total publication activity for the countries. Hence, all subject areas are combined to produce aggregated publication numbers at 5-year intervals. As described in the introduction, contrary to most national-level bibliometric analyses, we apply a fractional publication counting scheme. Consequently, the figures in our report deviate from some of the other published indicators, e.g. those presented in national science and technology indicator reports, which are based on whole counts of each country's contributions to internationally co-authored articles. The number of publications is much lower when each country only receives its fractionalized share of each publication. This also holds for the citation indicators. We apply a fractionalized counting scheme where all the basic units (addresses) in a publication share 1 credit, and where a country gets 1 fraction each time it appears in the address list. For example, in an article with 4 Swedish addresses and 1 Danish address, Sweden receives  $4/5$  and Denmark  $1/5$  of the credit for the article. Citations to the articles are allocated in the same manner.

Apart from the mathematically appealing property of fractional counting, where the sum of the publication counts of all countries equals the number of publications in the world, this also prevents differing co-publication patterns from affecting the publication counts. When whole counts are used, a country with a high share of international co-publication will have a higher publication count than a country with a low share of international co-publications, all else being equal. Although international co-publication may be interesting, important, and even desirable,

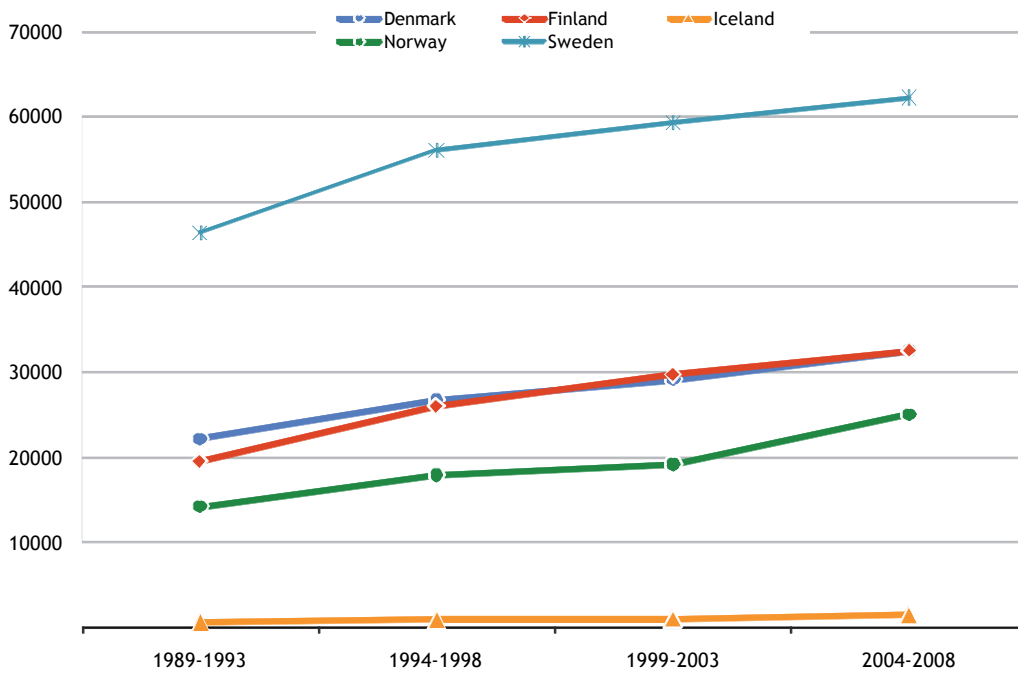
it should be kept separate from publication volume. International research cooperation by the Nordic countries is analysed in a separate report (Gunnarsson et al 2010).

First, we describe the total publication activity in fractionalized numbers. Then we present the relative growth in publication activity, followed by the Nordic share of the world total publication activity. Finally, we present a relative indicator of publications per capita in the Nordic countries, and a related economic indicator of research expenditure per capita in the Nordic countries.

## **Total production**

Total publication activity is calculated for four, 5-year periods. FIGURE 1 illustrates the trends in total publication activity for the 20-year period, abridged to four, 5-year periods. TABLE 1 presents the actual numbers. FIGURE 2.1 in Gunnarsson et.al (2010) shows annual publication activity.

**FIGURE 1: DEVELOPMENT IN TOTAL PUBLICATION ACTIVITY, TOTAL PRODUCTION IN FRACTIONALIZED PUBLICATION COUNTS.**



**TABLE 1: PUBLICATION ACTIVITY, TOTAL PRODUCTION IN FRACTIONALIZED PUBLICATION COUNTS.**

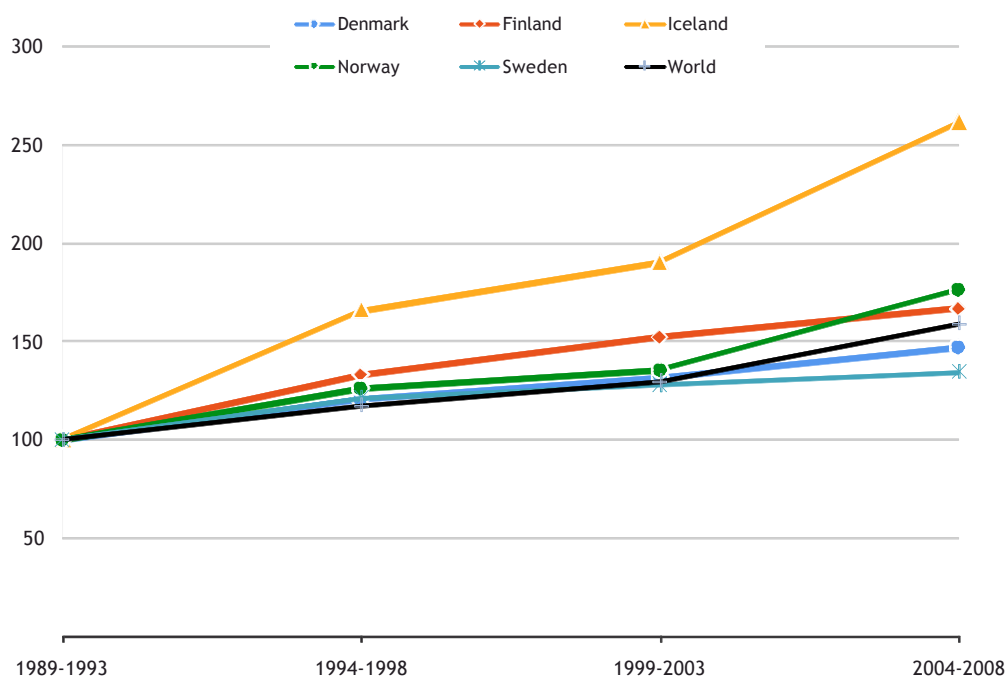
	Denmark	Finland	Iceland	Norway	Sweden
1989-1993	22 125.8	19 498.9	563.4	14 200.7	46 327.9
1994-1998	26 685.8	25 975.7	934.0	17 920.4	56 030.2
1999-2003	29 120.3	29 683.2	1069.4	19 187.4	59 234.0
2004-2008	32 448.4	32 466.7	1470.0	25 013.8	62 199.2

We see a clear rise in publication activity for all countries during the 20-year period. Among the Nordic countries, Sweden consistently has by far the largest publication activity during the whole period, with nearly twice the publication output of the second- and third-most productive countries, Denmark and Finland.

Growth in the Thompson Reuters database and in the science system itself may explain the increases. The number of journals and their annual volumes of articles have been increasing in the database (Testa 2010; 2008 Journal Citation Reports 2010), but the science system in general has also been expanding

from year to year. More funding is being spent on research activities, and these activities involve an increasing number of scientists. This too is reflected in the publication counts. It is difficult to assess whether the increase in database coverage correlates with the increase in the total scientific literature globally, but at least some part of the increase can be seen as a database artefact (Aksnes & Hessen 2009). To further investigate this aspect we calculated the relative growth in publication activity for the Nordic countries compared to the relative growth of the world, which actually corresponds to the growth in the database.

**FIGURE 2: RELATIVE GROWTH IN PUBLICATION ACTIVITY; INDEX 100 IS THE 1989-1993 PUBLICATION OUTPUT; WORLD IS EQUAL TO GROWTH IN THE DATABASE COVERAGE FOR THE PERIOD.**



### Relative growth

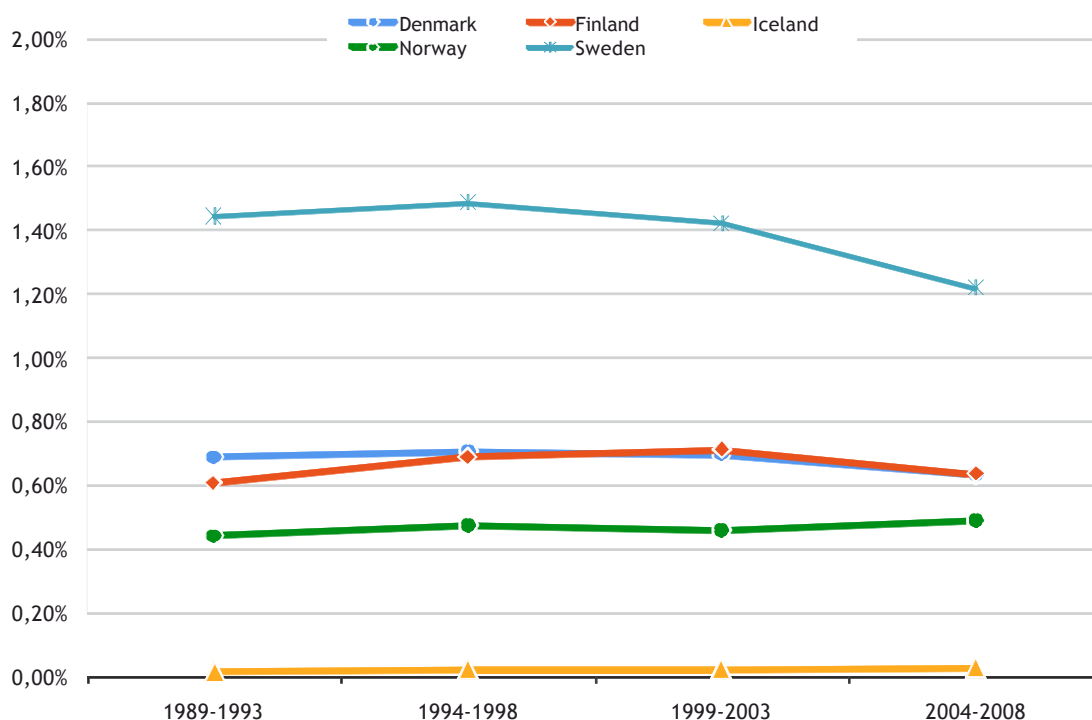
FIGURE 2 illustrates the relative growth in publication activity, where relative growth is represented as an index. Index 100 is the aggregated publication activity for the 5-year period of 1989 through 1993.

As explained above, the growth in publication activity reflects two things: 1) growth in the database coverage, and 2) actual growth in research publications. Most likely several reasons are behind the growth in the database as a whole. In some cases, existing journals have changed to meet the Thomson Reuters inclusion criteria (better peer review procedures, authors from other countries, more regular issues, etc.), or new journals of high standards have appeared, and Thomson Reuters have added these to the database. This would reflect actual growth in the international research system. In other cases, journals have been added to the database without having changed to meet the inclusion criteria, either because they already met the criteria and Thomson Reuters became aware of this, or because the inclusion criteria changed or were reinterpreted in favor of the journal (e.g. adding Chinese journals to the database). Changed or reinterpreted inclusion criteria could have also enabled the inclusion of new journals that previously would have been left out of the database. Hence, part of the database growth reflects a growth in database coverage. Since we do not know how much of the database growth comes from growth in the international research system,

and how much comes from increased database coverage, we have no stable reference to which we can compare the growth in the Nordic countries. It is reasonable to assume some actual growth in the international research system, and that this growth is somewhat smaller than that depicted by the world trend line (black line) in FIGURE 2, at least for the last period. It is also reasonable to assume that the growth in database coverage affects all Nordic countries in the same way.

By comparing the black line to the other trend lines we see the growth in the Nordic countries relative to the growth in publications in Thompson Reuters' citation databases for the given period. We can see that all countries have experienced a growth in publication activity for the entire period. But we also see that the growth in publication activity in Sweden and Denmark, especially during the last period, is lower than the growth for the world, which in this period is somewhat affected by the database's inclusion of several new Asian and Latin American journals (where Nordic researchers seldom publish). The growth in publication activity for Finland and Norway exceeded the relative growth for the world. Norway has markedly increased its relative growth in productivity during the last period and has thereby overtaken Finland, which reported more continuous growth in all periods. Iceland has clearly seen the highest relative growth in each period and in total, going from index 100 in 1989-1993 to index 261 for

**FIGURE 3: SHARE OF WORLD PUBLICATIONS FROM THE NORDIC COUNTRIES.**



**TABLE 2: SHARE OF WORLD PUBLICATIONS FROM THE NORDIC COUNTRIES.**

	Denmark	Finland	Iceland	Norway	Sweden
1989-1993	0.689%	0.607%	0.018%	0.442%	1.443%
1994-1998	0.708%	0.689%	0.025%	0.475%	1.486%
1999-2003	0.698%	0.712%	0.026%	0.460%	1.420%
2004-2008	0.636%	0.636%	0.029%	0.490%	1.218%

the last period (2004-2008). In 2004, Norway implemented a new funding model for higher education institutions. The funding of these institutions is now based partially on the measurement of their scientific and scholarly publishing. It is likely that the model has contributed to part of the increase by impacting incentives, although the actual contribution of this effect is difficult to establish<sup>4</sup>.

Collectively, FIGURES 1 and 2 show a general increase in publication productivity for all Nordic countries. While this is not so visible in FIGURE 1, Iceland has in fact had the highest relative growth among the Nordic countries.

#### **Publications from the Nordic countries as a share of the world total**

FIGURE 3 shows each Nordic country's share of the total publications in the world (i.e. Thompson Reuters' publication databases).

FIGURE 3 supplements the information depicted in FIGURES 1 and 2. Sweden's relative share of world publications has diminished markedly during the last period. TABLE 2 below shows the actual percentage shares for each country in each period.

Denmark and Finland have also witnessed a slight decrease in shares, whereas Norway and Iceland have been rather stable with a small increase in shares. The latter corresponds to the positive growth rates especially for the last period, as depicted in the previous figures for these two countries. Declining shares obviously mean an increasing growth for other countries. We know that the shares of publications from China, India, Brazil, and other large countries have increased considerably during the last 10 years. Given this situation, a decline in most other countries is expected. A stable or slight increase, as in the case of Iceland and Norway, could in fact be considered as a significant rise in the relative contribution to world science. The decline for Sweden in the latest period is also notable. Since part of the database growth is due to increased coverage, the trends depicted in FIGURE 3 should be interpreted as an indication of relative stability for the Nordic countries, except perhaps for Sweden.

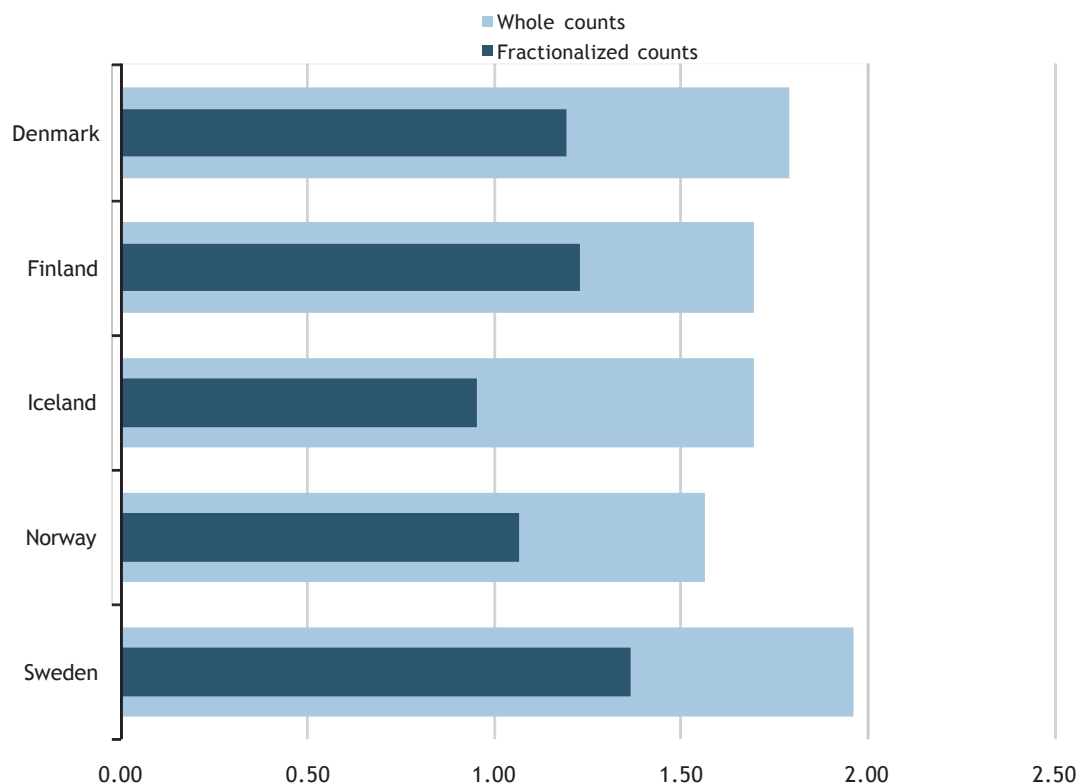
### Publications per capita

No international data are available to reliably compare output in terms of publications to input in terms of number of researchers. Instead, publication output is usually compared to the size of the population in the different countries – although differences in population do not necessarily reflect differences in research efforts.

Much of the difference among countries in publication output shown above can be attributed to differences in country size and investments in research. To better compare differences in publication output this and the next section present statistics on per capita production and total investments in research.

We have analyzed the average number of publications per 1000 population in each Nordic country for the last period, 2004-2008. In FIGURE 4 we have shown both whole and fractionalized counts to investigate potential differences that could be attributed to international collaboration in publications.

**FIGURE 4: AVERAGE NUMBER OF PUBLICATIONS PER 1000 POPULATION FOR THE PERIOD 2004-2008. \***



\*Dark blue bars indicate fractional publication counts and light bars indicate whole publication counts. Population statistics from OECD data, 2007.

It is of interest to note the difference in rank order between whole and fractionalized counts for the Nordic countries. When we look at whole counts, Sweden has an average of 1.97 publications per 1000 population, followed by Denmark with 1.79, with Finland and Iceland tied at 1.69, and finally Norway with 1.56. The rank order changes somewhat when we use fractionalized counts. Sweden remains the most productive country per 1000 population, with an average of 1.26 publications. However, Finland has overtaken Denmark with an average of 1.23 publications per 1000 population compared to 1.19 for Denmark. Furthermore, Norway has overtaken Iceland with an average of 1.07 publications per 1000 population compared to 0.95 for Iceland.

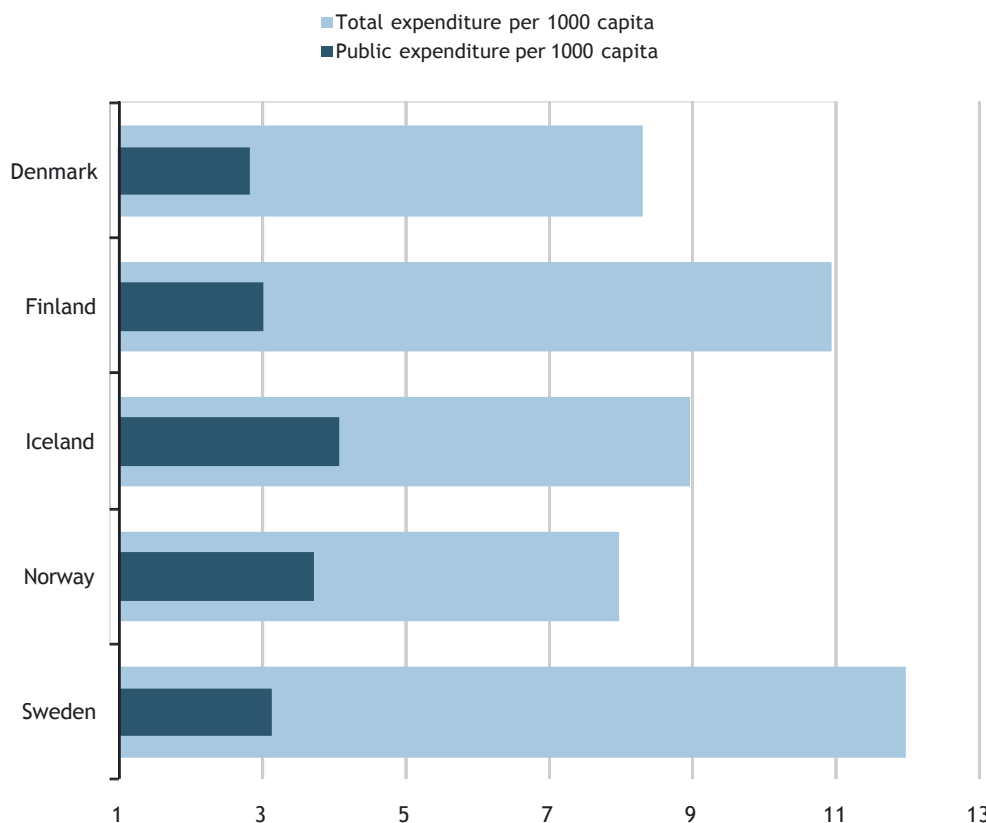
What do these differences indicate? The largest gap between whole and fractionalized publication counts is found for Iceland. The gap indicates that Iceland has a much higher proportion of international collaboration in their publications compared to the

other Nordic countries. This is confirmed in the first of our reports published by Nordforsk (Gunnarson et al., 2010), for example in FIGURE 2.4. In other words, the number of countries involved in the publications is lower for the other Nordic countries, as fractionalized counting on a country level obviously reduces the share of publication counts if international collaboration is present in a publication.

#### Research expenditure per capita

As background information, we have provided data on research expenditures in the Nordic countries. FIGURE 5 shows the research and development (R&D) expenditures measured per capita for 2007. Sweden is by far the most research-intensive country, followed by Finland. However, the large majority of R&D expenditures can be attributed to the *business enterprise sector*. Most of the expenditures in this sector are for developmental work, and very little of this activity results in scientific publications. In Norway,

**FIGURE 5: 2007 RESEARCH EXPENDITURE PER 1000 POPULATION IN NORWEGIAN KRONER IN 2007.\***



\*Light blue bars are total expenditures and dark blue bars are expenditures attributed the Higher Education Sector and the Governmental Sector; based on OECD figures published in "Report on Science & Technology Indicators for Norway 2009".

for example, only 4% of the journal articles can be attributed to this sector. Hence, it is more relevant to look at the R&D spending in the *higher education sector* and the *government sector* (dark blue bars). Here, the picture changes. Iceland and Norway spend a significantly higher amount on R&D per capita than do Sweden, Finland, and Denmark.

The patterns of expenditures and publications per capita differ markedly (cf. FIGURES 4 and 5). Most notably, Norway and Iceland spend more but publish less. Nevertheless, the evidence is insufficient to conclude that Norwegian and Icelandic researchers are less productive than their Nordic colleagues. Basically, these datasets are difficult to compare since they do not cover the same domains. For instance, the social sciences and humanities, which are relatively large areas in terms of public expenditures, are poorly covered by the Thomson Reuters data. Moreover, the publication counts include articles from industry. Although this sector contributes modestly to the overall national publication output, it is nevertheless a factor that needs to be considered since the size of the sector differs significantly between the

Nordic countries. Further analyses would therefore be required to provide reliable conclusions on the scientific productivity of the countries.

### **Conclusions from chapter 1**

The number of scientific articles published by Nordic researchers has increased markedly in the recent 20 years. Sweden has by far the largest publication output of the Nordic countries, with almost twice the publication output of the second and third most productive countries, Denmark and Finland. Also when measured on a per capita basis, Sweden ranks above the other Nordic countries, with 1.26 publications (fractionalized) per 1000 population during the most recent 5-year period (2004-2008). However, the difference is not large, and Finland and Denmark follow as second and third with 1.23 and 1.19 publications per 1000 population, respectively. Norway and Iceland have somewhat lower productivity numbers with 1.07 and 0.95 publications. The two latter countries have, nevertheless, a significantly higher relative growth in their publication output during the recent period than do the other Nordic countries.



## 2. Research profiles

This chapter aims to break down the overall publication activity of the Nordic countries into main subject areas to characterize each country's research profile. We have restricted the presentation of research profiles to only the last and most recent 5-year period (2004-2008). Two analyses are presented. First we present the percentage shares of fractionalized publication counts distributed among the 14 major subject areas for each country for the period 2004 through 2008. Subsequently we present Relative Specialization Indices for each country to characterize their research profiles more distinctly.

### Percentage of fractionalized publications per research field for each Nordic country

TABLE 3 below presents the percentage share of fractionalized publication counts distributed among major subject areas for each Nordic country. Further, we have included two reference units to compare against the Nordic country profiles; the aggregated unit of EU-15 countries and the United States. Notice that in this analysis we include *all* 14 subject areas. The first row shows the total fractionalized publication counts for the period, and the successive rows present the percentage distributions by subject area.

**TABLE 3: PERCENTAGE DISTRIBUTION OF FRACTIONALIZED PUBLICATIONS PER RESEARCH FIELD FOR THE NORDIC COUNTRIES, EU-15, AND USA DURING 2004-2008.**

	Denmark	Finland	Iceland	Norway	Sweden	EU-15	USA
Total publications (fractionalized)	25 666.8	25 810.7	1121.1	19 348.6	49 739.5	1 198 220	1 089 285.8
Clinical Medicine	31.0%	29.2%	29.2%	29.1%	32.1%	29.0%	29.2%
Biomedicine	19.6%	15.3%	15.8%	12.9%	17.7%	15.1%	18.0%
Biology	4.6%	4.8%	8.0%	7.0%	4.2%	3.4%	4.0%
Agriculture	9.5%	8.9%	9.1%	9.7%	6.2%	6.0%	5.2%
Chemistry	6.3%	6.7%	2.7%	5.2%	7.5%	8.9%	6.1%
Materials Science	1.6%	2.9%	0.8%	1.6%	3.0%	2.8%	1.9%
Physics	7.6%	8.7%	4.8%	4.9%	8.8%	10.8%	8.5%
Geosciences	2.9%	2.3%	13.2%	6.3%	2.3%	2.8%	2.7%
Engineering	4.5%	4.4%	2.0%	5.3%	5.3%	4.6%	4.2%
ICT <sup>5</sup>	4.4%	8.1%	2.6%	4.8%	4.6%	6.0%	4.9%
Mathematics	1.8%	2.1%	2.2%	2.4%	2.2%	2.9%	2.3%
Social Sciences	4.9%	5.4%	7.4%	8.7%	5.2%	5.4%	9.4%
Art & Humanities	1.4%	1.4%	2.1%	2.0%	0.9%	2.3%	3.3%
Other	0.1%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%

The numbers presented in TABLE 3 confirm that clinical medicine is by far the largest research field for all countries investigated (including EU-15), with around one third of all publications belonging to this subject area. Further, with slightly more variation in percentages among the countries, biomedicine is undoubtedly the second largest research field for all countries investigated, again including EU-15. Together clinical medicine and biomedicine account for somewhere between 42% and 50% of the publications for the countries investigated. At a more detailed level, TABLE 3 also shows that the share of publications for Sweden and Denmark is somewhat larger in clinical medicine and biomedicine compared to the other Nordic countries, the EU-15, and the United States (except for Denmark and USA in biomedicine). Denmark, Finland, Iceland, and Norway have a relatively large share of their publications in the agricultural research field, compared to Sweden, EU-15, and the United States. Whereas the share of physics publications is somewhat lower for Norway and Iceland compared to the other countries, but their share of geoscience publications is markedly higher. Geoscience constitutes 13.2% of Iceland's publications for the period, which makes it the third largest research area in Iceland when measured in publication output. Social science constitutes 8.7% of Norway's publications for the period, which is slightly higher than Denmark, Finland, and Sweden, but not the United States. In Chapter 3 we address the issue of low coverage and bias towards the United States in the social sciences. However, we should emphasize that the figures for the arts, humanities, and social sciences should be treated with caution. Analyses from Norway, based on complete publication output data from national research institutions, indicate that the overall share of publications from these fields is larger than depicted in TABLE 3, which is a consequence of the rather poor and biased coverage in the Thompson Reuters database for arts & humanities and some social science fields. Finally, publication activity in the *Other* category is meagre for all countries. This area contains a small and lowly -cited share of publications in multidisciplinary journals, e.g. *Science*, *Nature*, and *PNAS*, namely the publications that could not be categorized into one or more of the other subject areas by the subject re-classification algorithm used by the Swedish Research Council (Gunnarsson et al., 2008).

To conclude, from TABLE 3 it appears that Norway and Iceland, and to some extent Sweden and Denmark, have similar research profiles. The next section investigates this in greater detail, where we present Relative Specialization Indices for each country to characterize their relative research profiles more accurately.

### Relative specialization index

The publication profile of national research in the Nordic countries is expressed by the Relative Specialization Index (RSI), defined in *REIST-2* (1997). RSI indicates whether a country has a relatively higher or lower share in world publications in particular fields of science than its overall share in the world total of publications. The symmetric RSI is a relative indicator based on the Activity Index (AI). The Activity Index is defined as:

$$AI = \frac{\text{the share of given field in the publications of the given country}}{\text{the share of given field in the world total of publications}}$$

The RSI is then defined as:

$$RSI = \frac{AI - 1}{AI + 1}$$

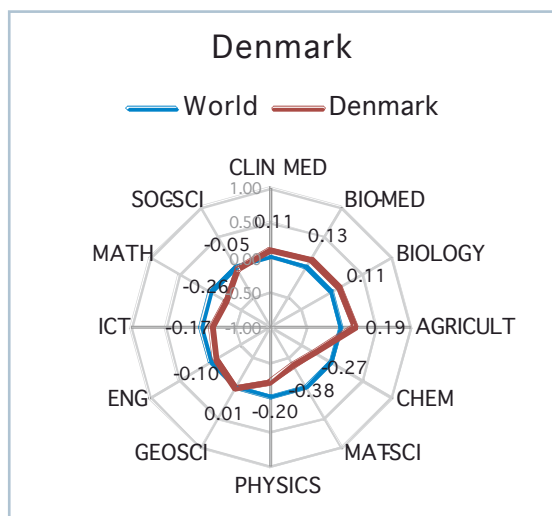
RSI takes its values in the range  $[-1, 1]$ . It indicates whether a country has higher-than-average activity in a scientific field ( $RSI > 1$ ) or a lower-than-average activity ( $RSI < 1$ ).  $RSI = 0$  reflects a completely balanced situation. It is important to note that RSI reflects a certain internal balance among the fields in the given country, i.e. positive RSI values must always be balanced by negative ones (no country can have its RSI values all positive or all negative). Furthermore, low values indicate homogenous distributions between the various research fields.

A benchmark used for all research fields is  $RSI = 0$ , which corresponds to the *world standard case* and is graphically visualized by a regular dodecagon<sup>6</sup>. Any country's deviation from this standard therefore results in more or less characteristic deformation of the regular dodecagon.

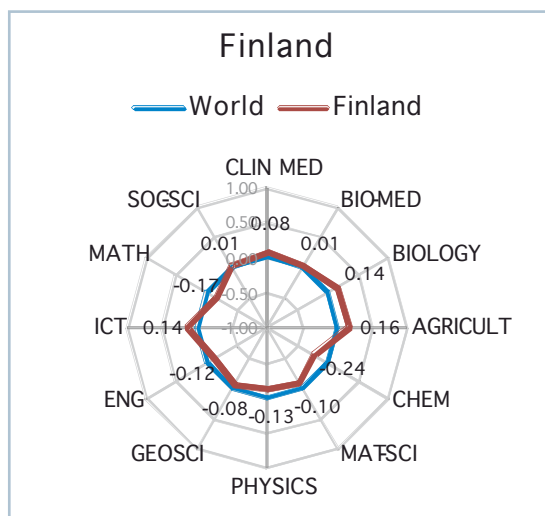
Glänzel (2000) identified four basic paradigmatic patterns in publication profiles based on RSI:

- Type I: *Western model*, which is the characteristic pattern of developed Western countries with clinical medicine and biomedical research as dominating fields.
- Type II: Characteristic pattern of the former socialist countries, present economies in transition, and China with excessive activity in chemistry and physics.
- Type III: *Bioenvironmental model*, which is the pattern most typical for developing and more natural-resource-oriented countries (e.g. Australia, or South Africa) that focus mainly on biology and earth and space sciences.
- Type IV: *Japanese model*, now also typical for other developed Asian economies where engineering and chemistry are predominant.

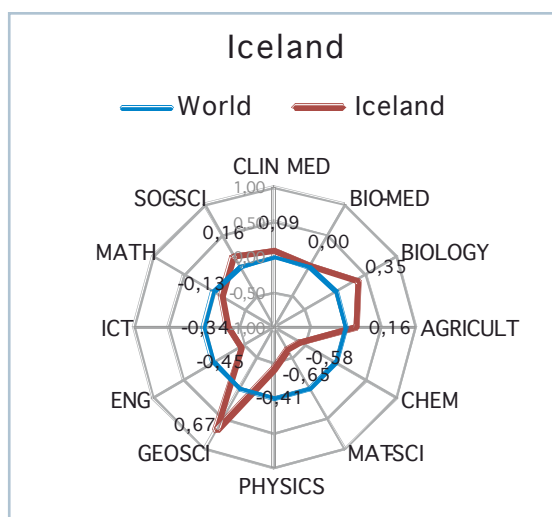
**FIGURE 6:  
RSI FOR DENMARK, 2004-2008**



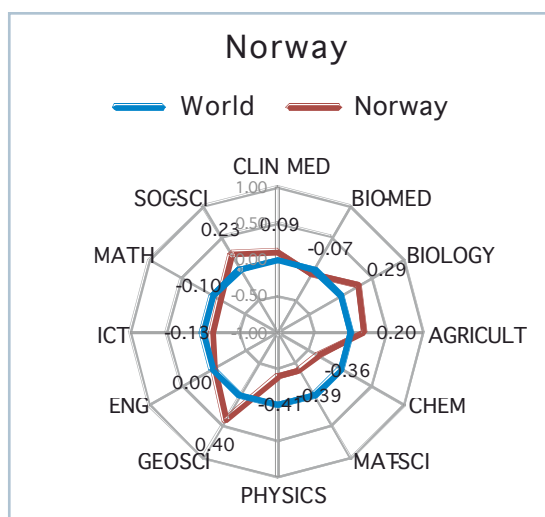
**FIGURE 7:  
RSI FOR FINLAND, 2004-2008**



**FIGURE 8:  
RSI FOR ICELAND, 2004-2008**



**FIGURE 9:  
RSI FOR NORWAY, 2004-2008**



It should be noted that Glänzel's (2000) "paradigmatic patterns" are derived from categorization of research fields in eight major areas, excluding *social sciences and arts & humanities*. The major research fields include: clinical medicine, biomedical research, biology, chemistry, physics, mathematics engineering, and earth and space sciences. This is important to consider when interpreting the present Nordic country publication profiles.

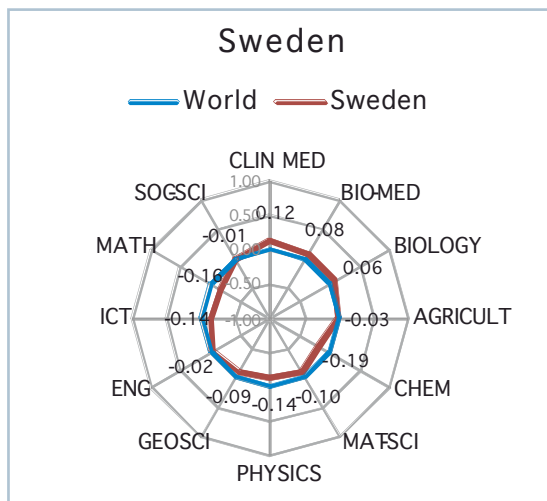
Similar to Glänzel (2000), we have excluded *arts & humanities* and the other (multidisciplinary) subject areas. We have included the social sciences, however, since publication activity is visible. Otherwise, the definitions of groups vary to some degree, but we should be able to characterize the Nordic countries based on Glänzel's "paradigmatic patterns".

We have calculated RSI publication profiles for the Nordic countries: Denmark (FIGURE 6), Fin-

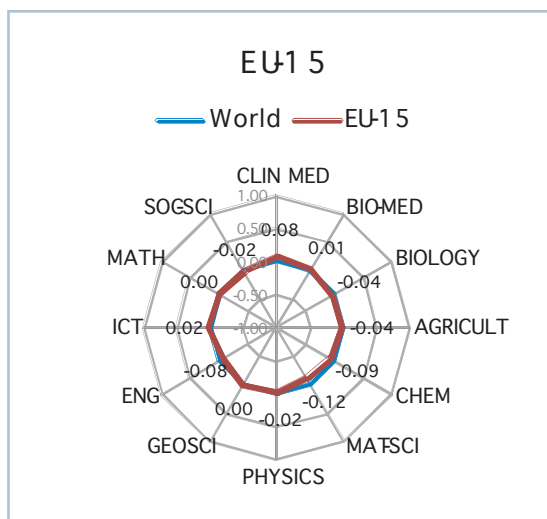
land (FIGURE 7), Iceland (FIGURE 8), Norway (FIGURE 9), and Sweden (FIGURE 10). We also calculated RSI publication profiles for EU-15 (FIGURE 11) and the United States (FIGURE 12). The figures illustrate that:

- The Danish dodecagon stretches towards the *northeast*, as Denmark has positive RSI values in clinical medicine, biomedicine, biology, and agriculture, with markedly negative RSI values in chemistry, materials science, physics, ICT, and mathematics. It appears that the Danish research profile can be characterized as a Type I *western model*, with a mix of the Type III *bioenvironmental model*.
- Finland has a more *balanced* dodecagon with positive deviations in RSI values for biology, agricul-

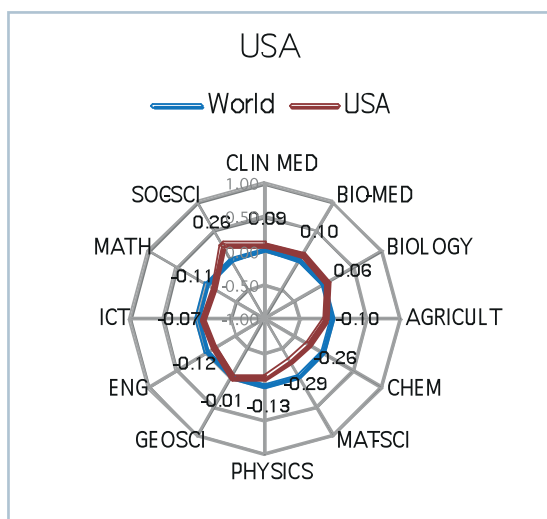
**FIGURE 10:  
RSI FOR SWEDEN, 2004-2008**



**FIGURE 11:  
RSI FOR EU-15, 2004-2008**



**FIGURE 12:  
RSI FOR USA, 2004-2008**



ture, and ICT. Correspondingly, Finland has negative values especially for chemistry, and less so for materials science, physics, and mathematics. It seems that the research profile for Finland can be characterized as primarily a Type III *bioenvironmental model*, with a mix of both Type I *western model* and Type IV, the latter due to the relative high visibility in the ICT research area.

■ The dodecagon for Iceland (FIGURE 8 below) is deformed considerably with substantial positive RSI values for geosciences and biology, and less so for agriculture and social sciences. Consequently, some areas, chemistry, materials science, physics, engineering, ICT, and to a lesser degree mathematics have notable negative RSI values. The research profile for Iceland is clearly a Type III *bioenvironmental model*.

■ The dodecagon for Norway (FIGURE 9) resembles that of Iceland. The dodecagon stretches towards geosciences in the *southwest*, biology-agriculture in the east, and with a positive deviation in the social sciences. These are exactly the same fields in which Iceland has positive RSI values. Further, Norway has negative values in chemistry, materials science, physics, and less so in ICT and mathematics. Like Iceland, the research profile for Norway also seems to be a Type III *bioenvironmental model*.

■ Finally, of the Nordic countries, the dodecagon for Sweden seems to be the one closest to the regular form. Deviations, positive and negative, from the regular form are small. There are small positive RSI values in clinical medicine, biomedicine, biology, and agriculture. All other research fields have small to very small negative RSI values. Most notably among the negative RSI values are chemistry, materials science, physics, ICT, and mathematics. The research profile for Sweden is less manifest, but it seems to be a Type I *western model* with emphasis on clinical and biomedicine.

■ EU-15, which is an aggregate of 15 countries, not surprisingly shows a balanced dodecagon close to the regular form for the *world-standard*. However, there are small deviations, where the positive RSI values go to clinical medicine, biomedicine, and ICT. The research profile for EU-15, while less manifest, seems to be a Type I *western model*.

■ The United States is somewhat different. While the USA has positive RSI values in clinical medicine, biomedicine, and biology (as expected), the social sciences have by far the largest positive RSI value. This is most likely an artifact of the

database. When we include the social sciences, we know that this area is biased towards American publications; hence, the US profile will reflect this. We think it would be fair to consider the research profile of the United States as a Type I *western model*.

### **Conclusions from chapter 2**

According to Glänzel (2000), in 1997 Denmark, Sweden, Finland, and Norway all corresponded to the Type I *western model*. Glänzel, however, argued that Norway's profile could be considered a mix of Type I and Type III, changing increasingly towards a Type III profile. The findings in this report support Glänzel's suggestions for Norway. Only Denmark and Sweden can be considered Type I research profiles. Finland is more of a mix between Type I and Type IV, whereas the research profiles of Norway and Iceland can be considered Type III with a focus on natural resources. Consequently, the research profiles vary considerably between the Nordic countries. Another conclusion is that the four basic paradigmatic patterns in publication profiles suggested by Glänzel (2000) are not very useful in describing the recent publication activities of the Nordic countries; only Iceland and Norway fit the model well.

# 3. Relative citation impact of the Nordic countries

The aim of this chapter is to investigate the trends in relative citation impact of the Nordic countries for the 19-year period<sup>7</sup>. We present several citation analyses. First we investigate the overall field normalized citation rates for the countries with highest impact in world, including the Nordic countries, for the last period (2004-2007). This analysis aggregates all research fields into one overall citation score. Next we investigate the trends in overall citation rates for the Nordic countries. Again, this is done for all fields combined. Subsequently, we investigate the trends in citation rates for the Nordic countries in 12 of the 14 research fields; *arts & humanities* and *other* are excluded from the analyses (cf. Appendix 1). Then we compare each Nordic country's relative citation rates in the different fields to their publication activity in the same fields. This is done for the first and last periods, combined in a single graph. Finally, we investigate the share of highly cited publications from the Nordic countries.

All citation analyses presented in this report are conducted according to the following procedure and calculation:

- Field normalized citation rates,
- Including self-citations,
- Three-year citation windows.

Relative citation scores are calculated in a way similar to the well-known “crown indicator”<sup>8</sup>. The citation rates per publication type for each year in the citation window are compared to the average citation rates for the same type of publications in the same years for the specific research field. Consequently, citation rates are normalized according to publication type, citation year after publication, and field-specific citation patterns. This enables comparison of relative citation indicators between research fields, publication types, and publication years.

We report relative citation rates as index values, where index 100 is the *world average* for the field; values above or below index 100 can be interpreted as percentage differences from the world average.

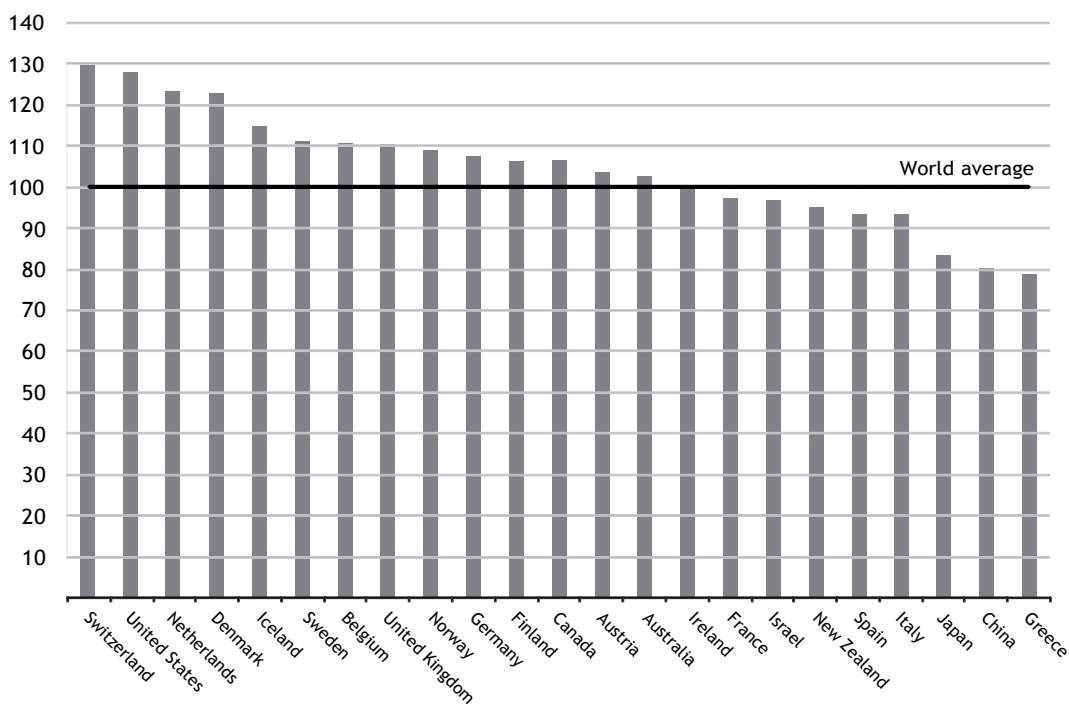
In the present analyses, self-citations have not been excluded, since they will most likely not affect country-level analyses. In other words, it is expected that national self-citation rates will level out.

We chose 3-year citation windows since we found that longer windows did not alter the trends already identified in the 3-year windows. Note that the last period is reduced to 4 years; the material published in 2008 had been cited for one year only when the study was compiled, which is a too short a period to be meaningful. Further, the citation window for publications from 2007 is only 2 years.

Small data sets reflect greater variation and are less reliable than larger data sets; this is one of the axioms of statistics. Since Iceland generally has small data sets, we have chosen not to show Iceland in all graphs below; the variation in some cases is so high that the statistics would not be meaningful. This required us to use different scales, and some graphs show Iceland's citation rates to fluctuate considerably. The latter mostly being an artifact of small numbers, the influence of few highly cited papers, leading to larger variation.

First we present the combined field normalized citation rates for the countries with the highest impact in the world (including the Nordic countries) for the last period. We then present the trends in overall citation rates for the Nordic countries for the entire period.

**FIGURE 13: AGGREGATED (ALL FIELDS COMBINED) FIELD NORMALIZED CITATION RATES FOR THE COUNTRIES WITH HIGHEST IMPACT IN WORLD, INCLUDING THE NORDIC COUNTRIES, FOR THE LAST PERIOD (2004-2007).**

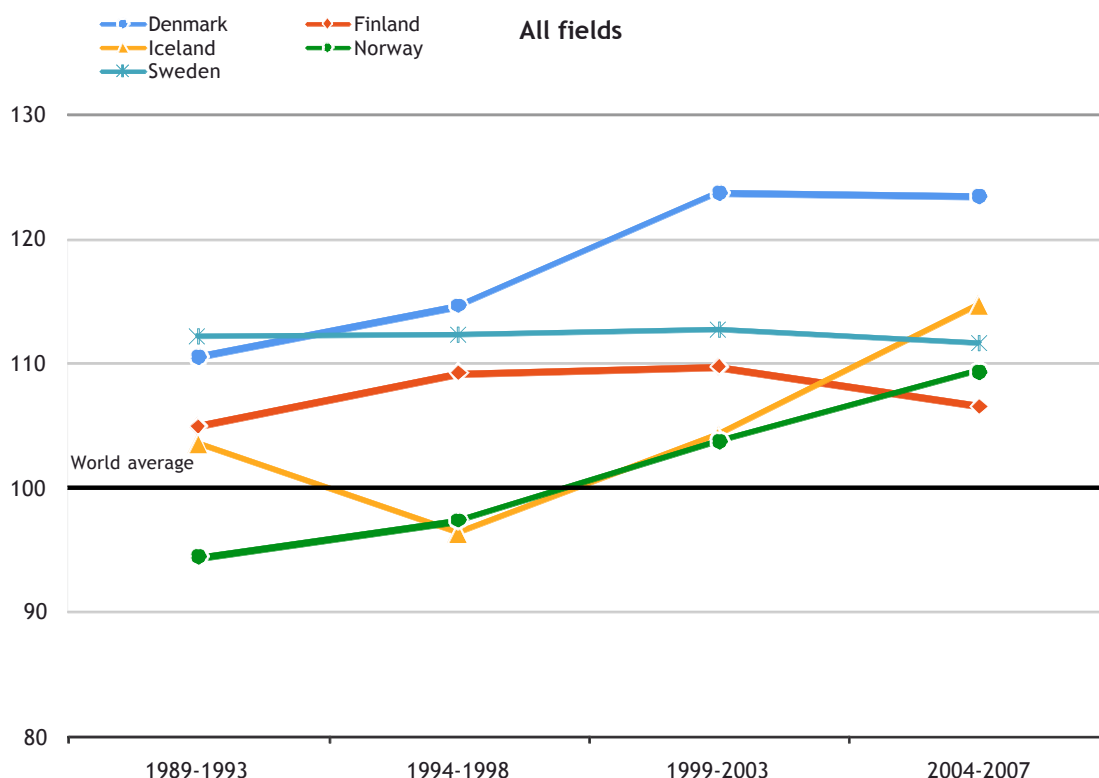


**Overall field normalized citation rates for selected countries for 2004-2007**

FIGURE 13 ranks countries according to highest impact (left to right). The black line at index 100 is the overall *world average* relative citation rate.

Switzerland, the United States, the Netherlands, and Denmark rank highest with an impact above index 120. Thereafter, we find Iceland and Sweden and further down are Norway and Finland, in descending order. Notice that all Nordic countries have a relative citation impact above the world average for the present period. The question is: How have the rates changed over time?

**FIGURE 14: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR ALL FIELDS. WEIGHTED AVERAGE ACCORDING TO FIELD SIZE; INDEX 100 IS THE WORLD AVERAGE IN THE GIVEN PERIOD.**



**TABLE 4: MEAN RELATIVE CITATION IMPACT FOR NATIONAL AND INTERNATIONAL PUBLICATIONS.**

Country	National publications			International publications		
	1989-1993	2004-2007	Change	1989-1993	2004-2007	Change
Denmark	1.00	1.12	0.12	1.62	1.48	-0.13
Finland	0.97	0.97	0.01	1.53	1.33	-0.20
Iceland	0.85	0.81	-0.04	1.47	1.60	0.13
Norway	0.87	0.97	0.11	1.32	1.36	0.03
Sweden	1.05	1.02	-0.03	1.48	1.34	-0.14

**Trends in national citation rates for the Nordic countries**

FIGURE 14 illustrates the trends in national citation rates for the Nordic countries. We see that Sweden and Denmark were nearly at the same level in the first period. Sweden later experienced a slight decline, whereas Denmark shows a considerable increase in citation rates during the period studied. For Finland, we see a rise and later a decline to the original level. Iceland and Norway, on the other hand, have experienced considerable increases in citation rates, especially during the last three periods.

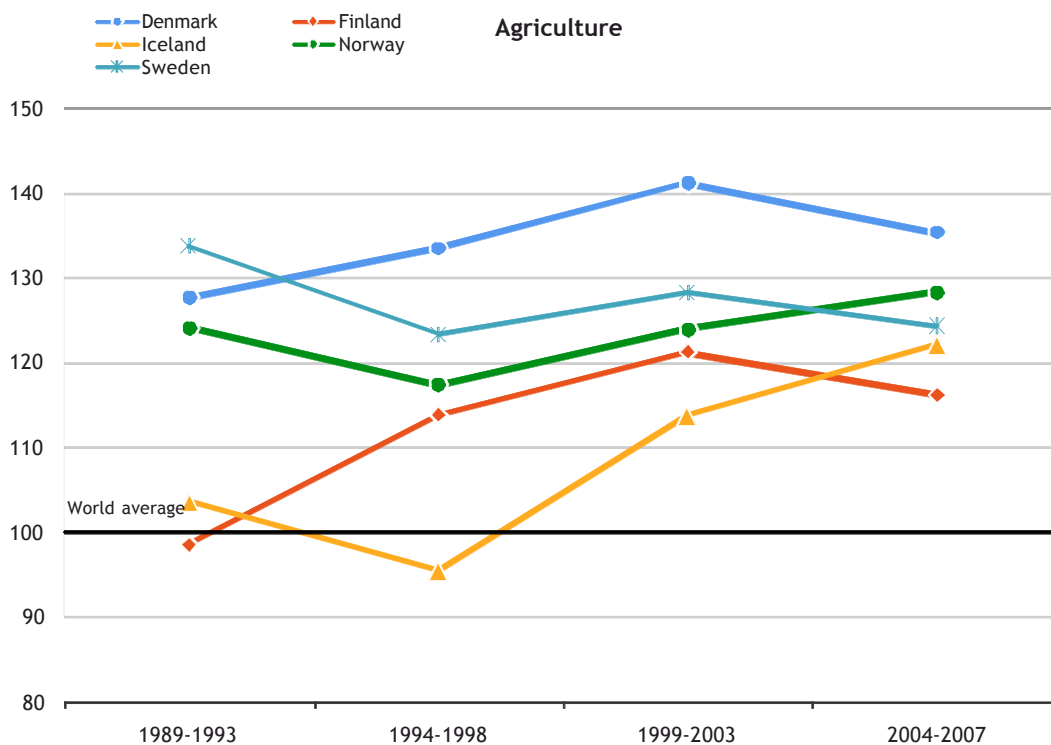
There is some indication that one reason for the variation in smaller countries is the influence of highly cited papers; see FIGURES 32 and 33 for shares of highly cited papers.

One approach to understand the patterns found in FIGURE 14 is to split the data into national publications (all author addresses within the same country) and international publications (authors represent more than one country). TABLE 4 shows the mean relative citation impact for national and international publications for the first and last period. Much of the increase in the national mean citation rates for Denmark and Norway can be attributed to increased citation rates of national publications. For Iceland, the increase is due to increased citations of international publications, while Finland and Sweden experienced a decreasing citation impact of their international publications and a constant impact regarding their national ones.

In the next section we break down the national level into fields and investigate the trends in field citation rates for the Nordic countries.



**FIGURE 15: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF AGRICULTURE; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**

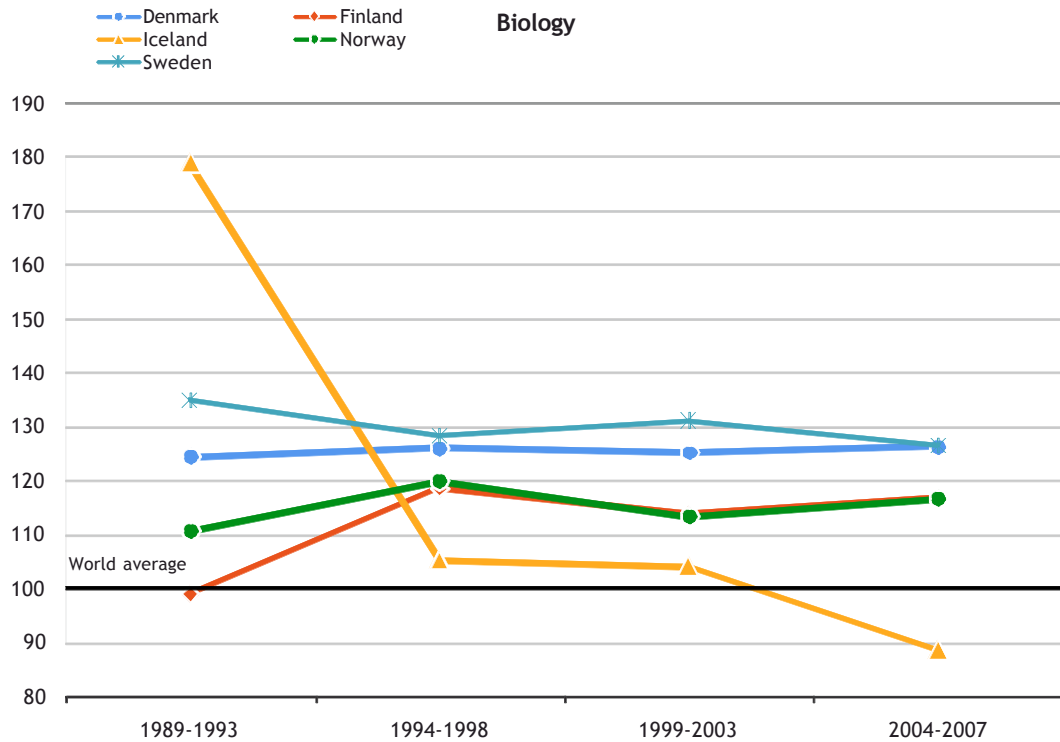


**Trends in field citation rates for the Nordic countries**

We present the trends in citation rates for 12 fields, excluding arts & humanities and other. We do not go into detailed descriptions for each field. The aim is to emphasize similarities and dissimilarities with the general patterns and identify salient cases. Consequently, we summarize the comments in the discussion section immediately after FIGURE 26.

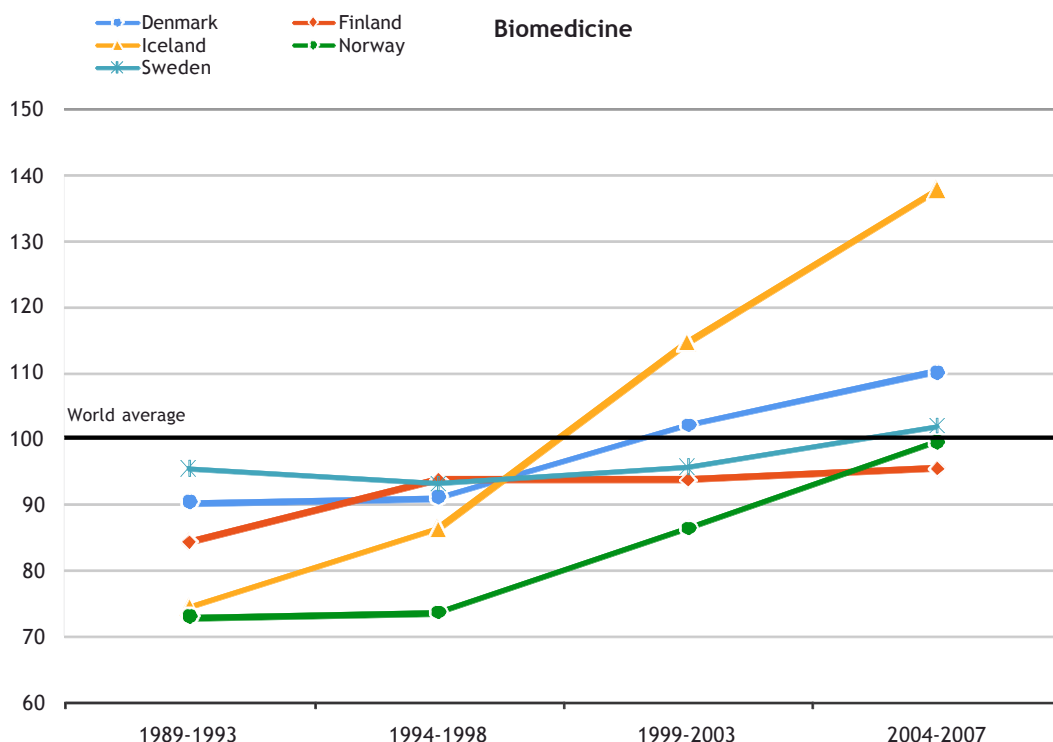
Despite fluctuations during the period, in the field of agriculture (FIGURE 15) all Nordic countries have relative citation rates well above the world average in the last period. All countries increased their citation rates between the second and third periods, but while Norway and Iceland continued their increase between the third and fourth periods, the other countries fell back.

**FIGURE 16: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF BIOLOGY; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



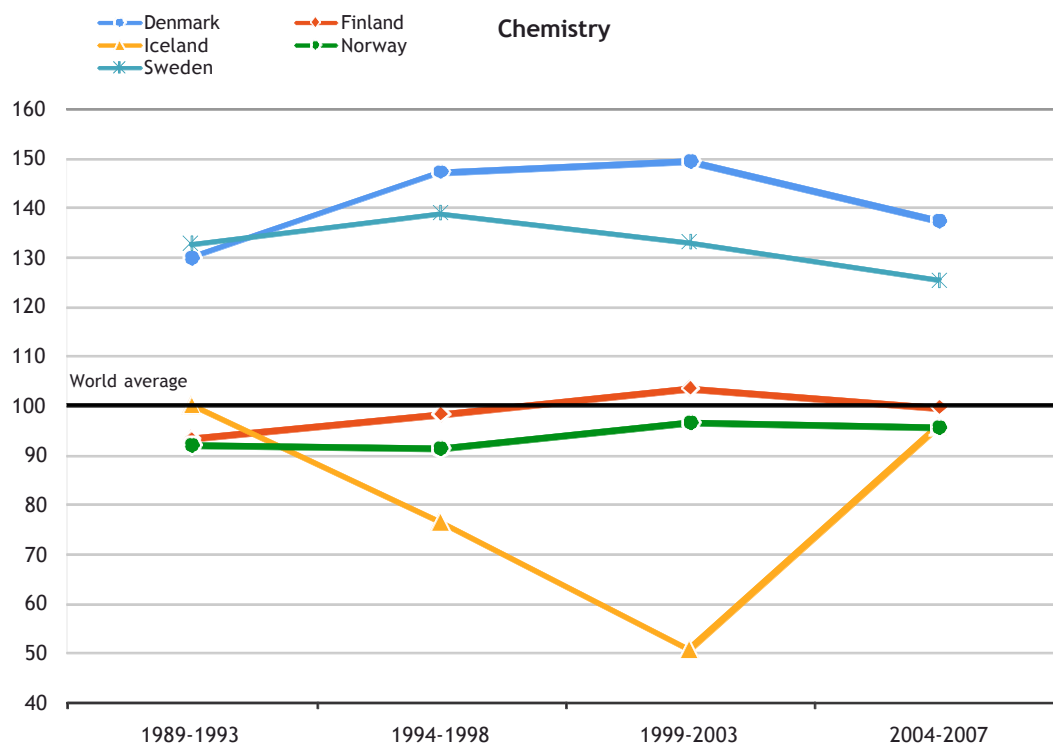
In the field of biology (FIGURE 16), all countries are rather stable, except for Iceland whose change is most likely an effect of its small size. Denmark and Sweden form a group above Finland and Norway, and although Sweden has had a somewhat higher citation rate than Denmark throughout the period studied, Denmark caught up with Sweden in the last period.

**FIGURE 17: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF BIOMEDICINE; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



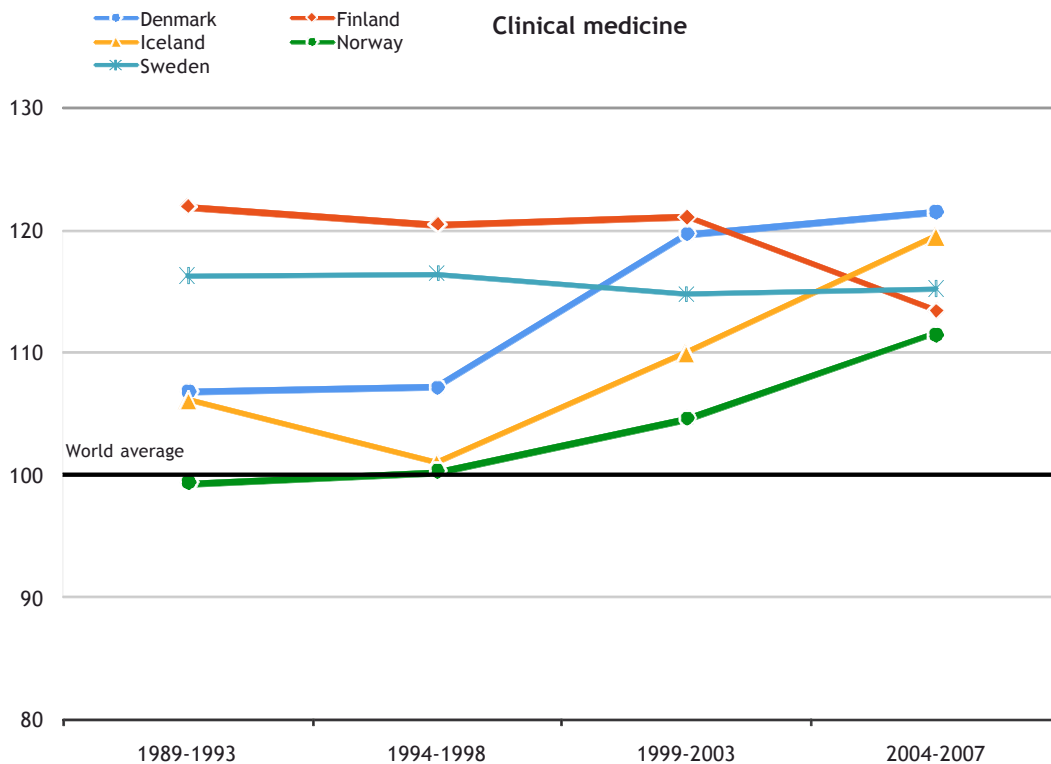
Denmark, Finland, and Sweden had similar citation rates for biomedicine (FIGURE 17) in the second period. Later, Denmark's citation rate increased substantially, while Sweden's increase was more modest and Finland's rate remained more or less on the same level. Norway made a major leap forward after the second period and surpassed Finland. For Iceland, the steep rise to high impact in the last period is attributed to genetics research by a private corporation, Decode Genetics, in collaboration with national and international research institutions. Still, the high citation rates in the latter two periods are also, to some degree, a size effect. The rather meager citation rates for the Nordic countries, although rising, are due to the fact that biomedical research is highly concentrated geographically and strongly related to industry. The United States, Switzerland, and the UK dominate the field<sup>9</sup>. If we exclude Iceland, however, then Denmark ranks in fourth place after the UK (not shown in FIGURE 17) even though Denmark's citation rates are not much above the world average. Citation patterns in biomedicine appear to be leveling out somewhat between the United States and the rest of the world.

**FIGURE 18: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF CHEMISTRY; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD**



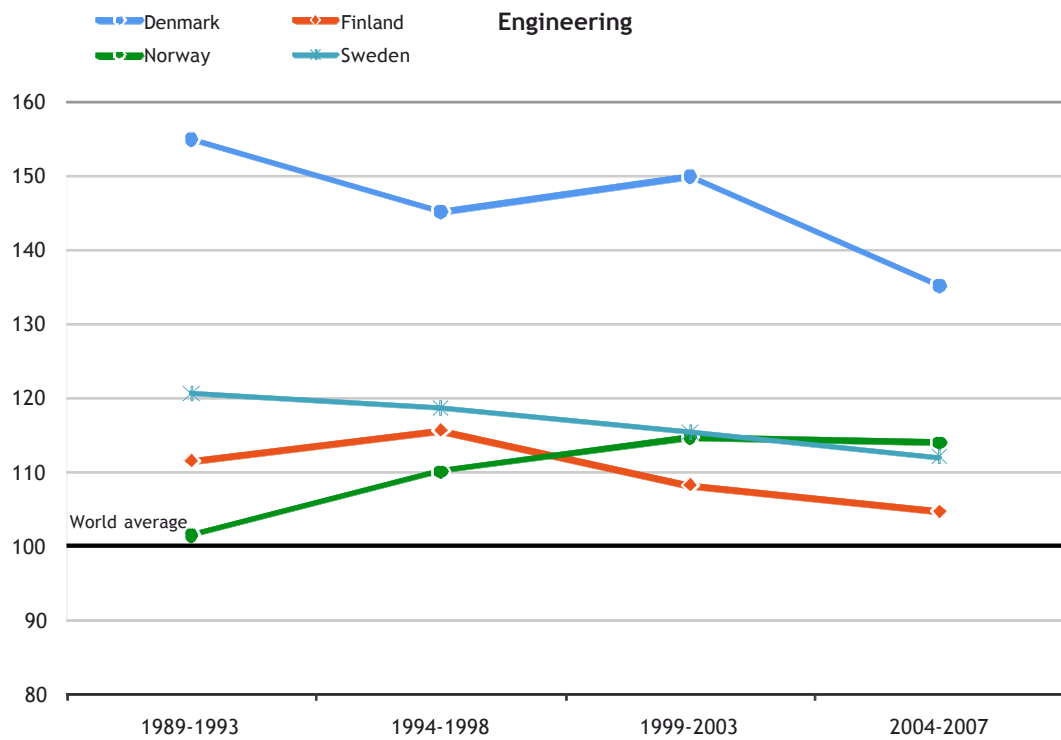
In chemistry (FIGURE 18), citation rates for Sweden and Denmark are much higher than for Finland and Norway. Denmark and Sweden were at the same level in the first period, but in the second period Denmark made a leap that was considerably higher than Sweden's increase. In the third period, Denmark continued to increase, while Sweden fell back to the level of 1989-1993. In the last period, the Danish decrease has been more marked than the Swedish one, thereby narrowing the gap between the two countries. Finland and Norway have shown a small but steadily increasing trend during the period studied.

**FIGURE 19: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF CLINICAL MEDICINE; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



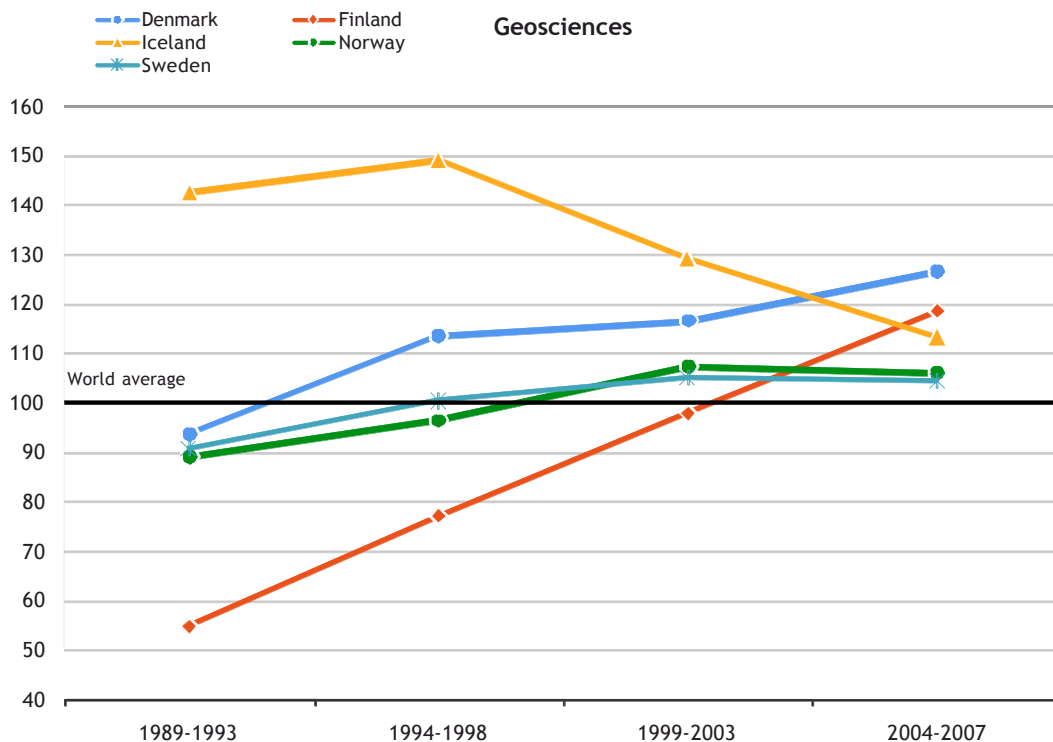
Clinical medicine (FIGURE 19) is by far the largest research field in all countries, which of course has the greatest influence on overall citation rates. Sweden experienced a small decrease, but remained close to stable. Citation rates for Norway, Iceland, and Denmark increased, but the rate for Finland fell abruptly. For a detailed analysis and evaluation of research in clinical medicine in Sweden and Finland, see their joint evaluation report from 2009 . The Danish rise between the second and third periods is spectacular, especially considering the size of the field.

**FIGURE 20: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF ENGINEERING; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD (ICELAND EXCLUDED, SEE APPENDIX 2 FOR DATA).**



In the field of engineering (FIGURE 20), the Danish citation rate is well above the rates of other countries, but shows the same declining trend as observed in Finland and Sweden. Norway's citation rate rose somewhat until the third period.

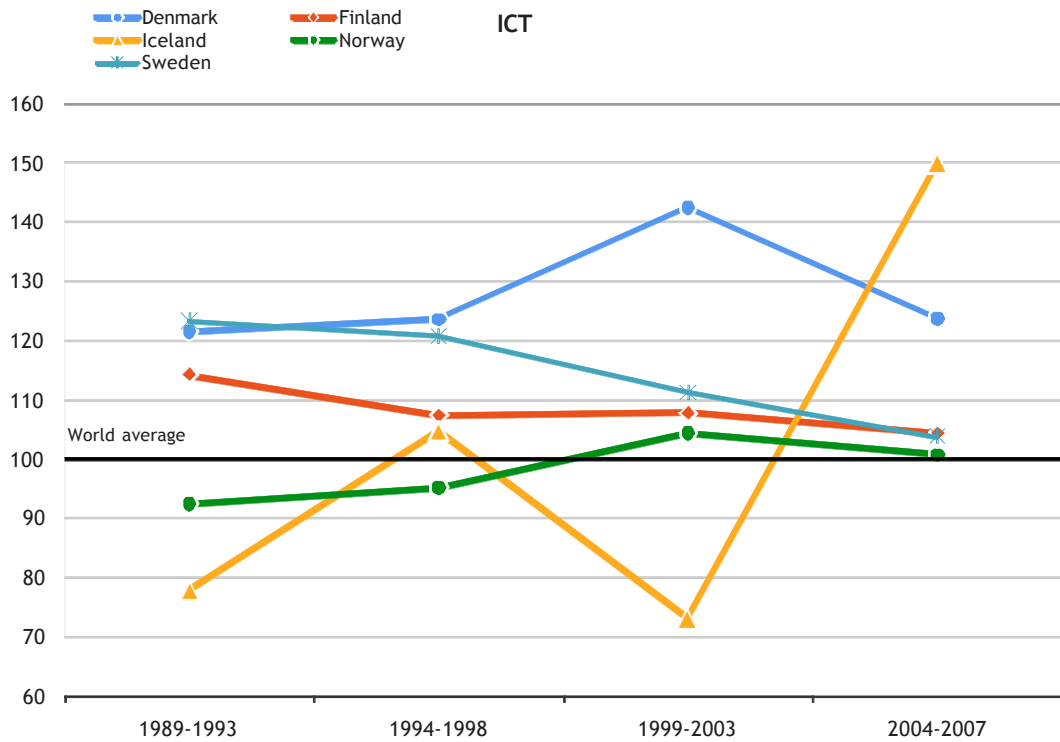
**FIGURE 21: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF GEOSCIENCES; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



In geosciences (FIGURE 21), Finland demonstrates a strong and almost linear growth in citation rates during the period, perhaps due to more highly cited papers. Starting from a low level, Finland surpassed Sweden and Norway. Denmark was at approximately the same level as Sweden and Norway in the first period, but managed to increase its citation rate (between the first and second periods the increase was as steep as Finland's, but started from a much higher level). Denmark remains well above Finland, although the gap between the two countries has narrowed.

The most dramatic change, however, is the Icelandic decline between the second and fourth periods, moving Iceland from an impressive 150 to a much more modest 114. This is alarming, since geosciences is one of Iceland's specialties (around 13% of publications in the period from 2004-2008, i.e. approximately 140 fractionalized publications).

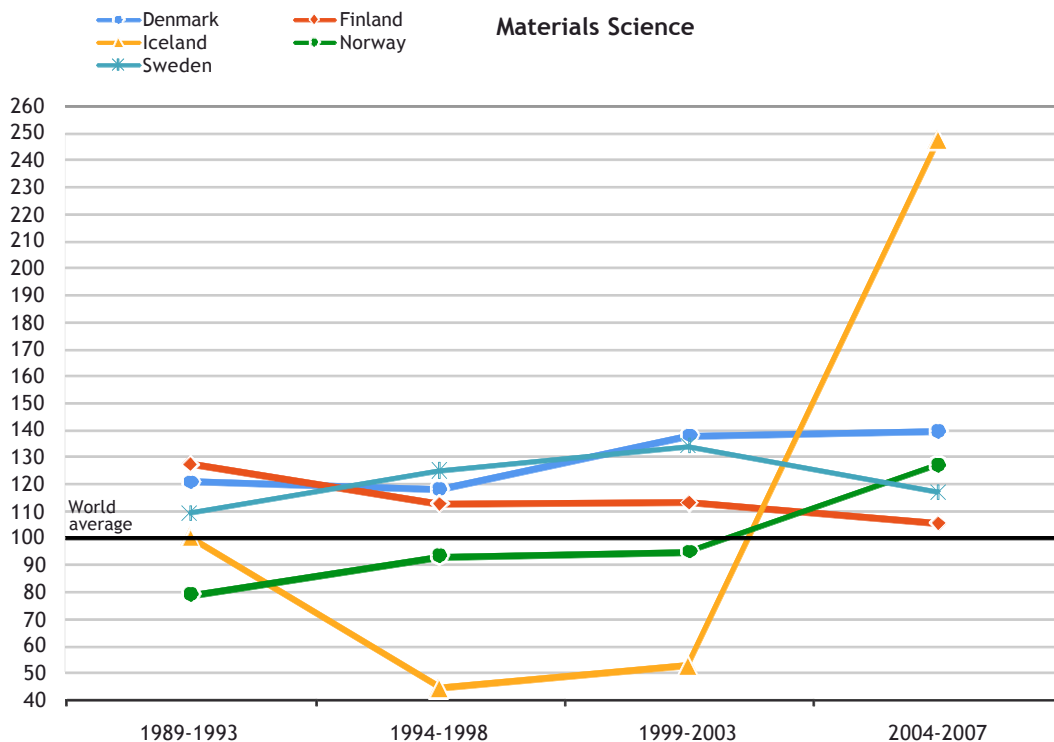
**FIGURE 22: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF INFORMATION, COMMUNICATION & TECHNOLOGY (ICT); INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



In the ICT field (FIGURE 22), the rates for Iceland vary due to low numbers. Interestingly, Sweden and Finland also declined during the period. Denmark peaked in the third period, but seems to have fallen back to its citation rates at the outset. Nevertheless, Denmark remains considerably above the world average. Norway rose during the first period, but fell back between the third and the fourth periods, similar to its trend in engineering.

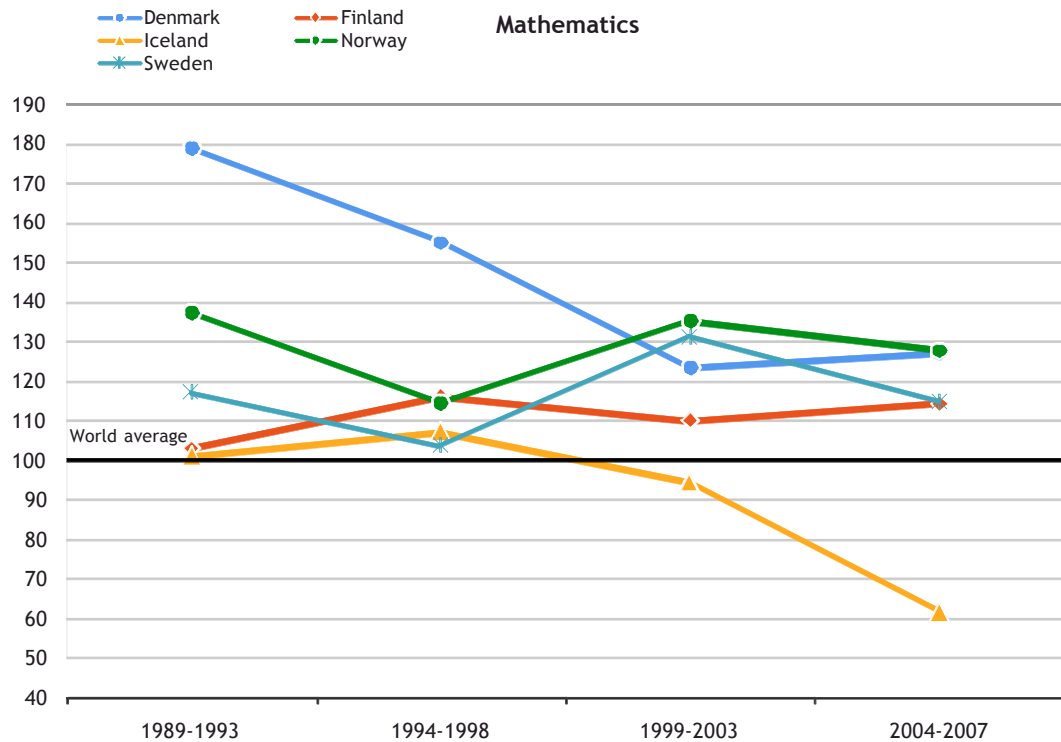


**FIGURE 23: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF MATERIALS SCIENCE; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



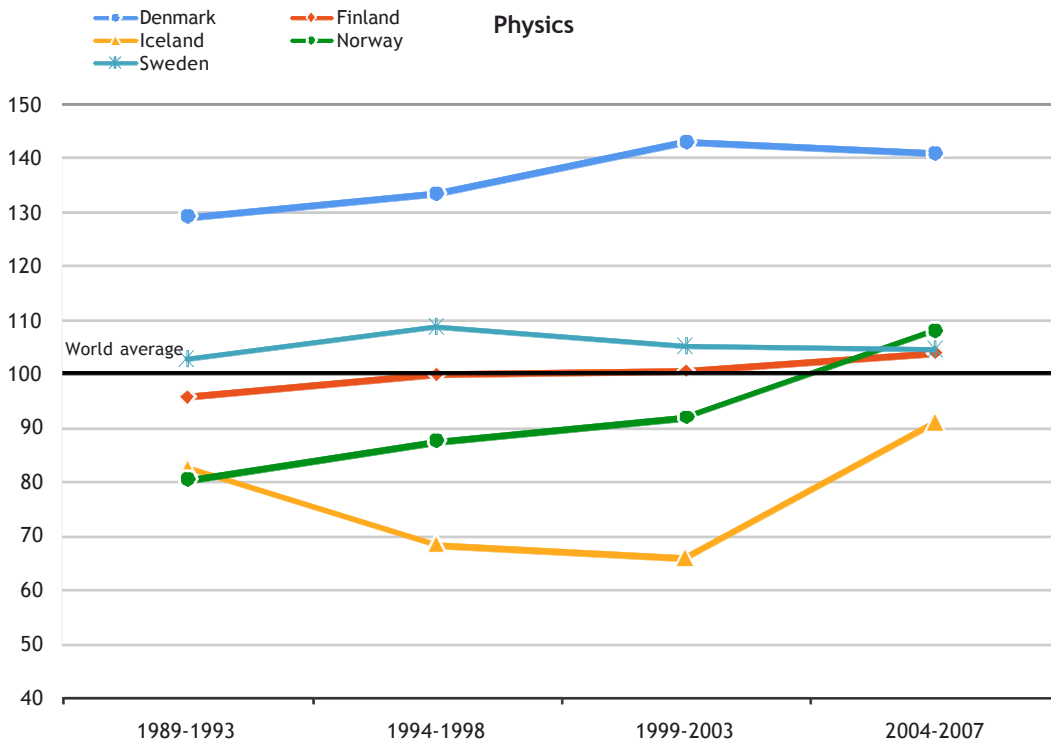
In the field of materials science (FIGURE 23), the steep increase for Iceland between the third and fourth periods is attributed to two highly cited papers published in 2006. Denmark again made a major leap between the second and third periods (note the scale of the y axis) and has remained at the high level. Sweden kept pace with Denmark up until the 1999-2003 period, but fell back in the last period. Norway has shown a steady increase.

**FIGURE 24: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF MATHEMATICS; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



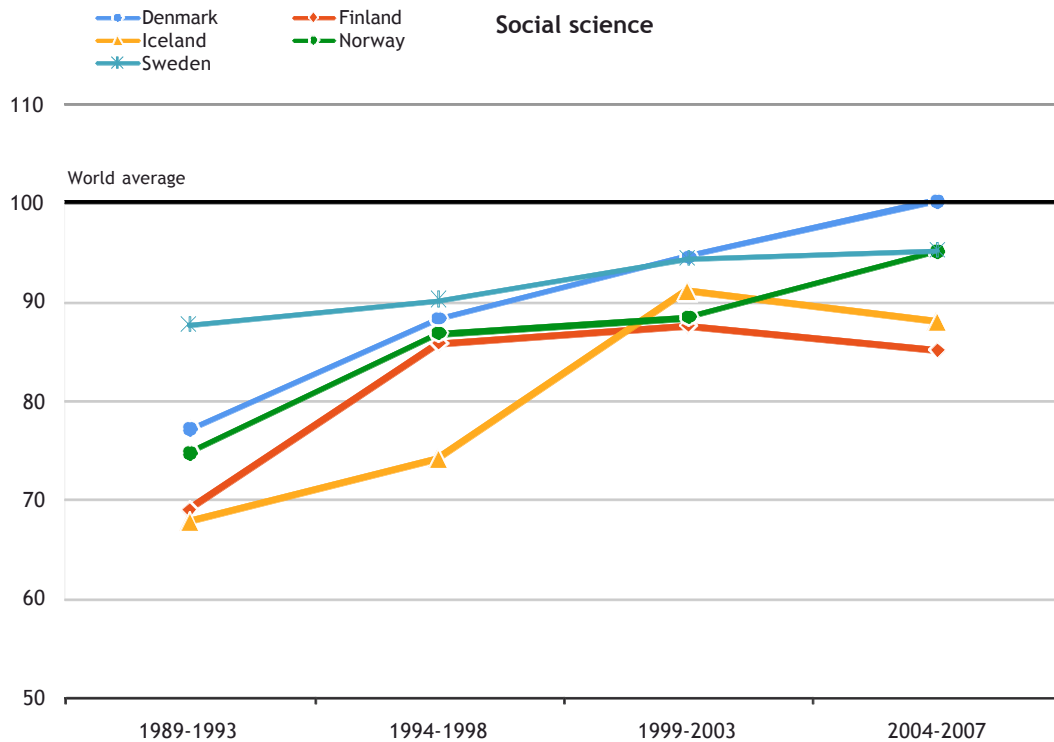
Variations in the field of mathematics (FIGURE 24) are probably due to small numbers, and citation rates appear to level out in the last period, except for Iceland (the publication activity for Iceland is very low, ranging between 11 and 25). Notice also that research papers in mathematics are often single-authored. Denmark's extremely high citation rates in the first and second periods are due to some extremely highly cited statistics papers. Norway and Sweden show similar trends, with Norway constantly about 10 units above Sweden. Finland has remained fairly stable.

**FIGURE 25: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF PHYSICS; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



In the field of physics (FIGURE 25), citation rates for Denmark are very high. Sweden has remained stable, slightly above the world average. Both Finland and Norway have risen from levels below the world average to levels above, but this trend is more marked for Norway, which surpassed both Finland and Sweden in the last period. Iceland shows a sharp increase in the last period.

**FIGURE 26: DEVELOPMENT OF RELATIVE CITATION IMPACT FOR THE FIELD OF SOCIAL SCIENCE; INDEX 100 IS THE WORLD AVERAGE FOR THE FIELD IN THE GIVEN PERIOD.**



In the field of social sciences (FIGURE 26), database coverage is poor and heavily dominated by economics and psychology. Further, it is biased towards the United States; i.e. the USA accounts for almost 60% of publications in the field. Hence, we would expect most European countries to be below the world average. All Nordic countries have risen from low levels, with Denmark surpassing Sweden and reaching the world average. Iceland and Finland fell during the last period.

**General trends in field citation rates for the Nordic countries**

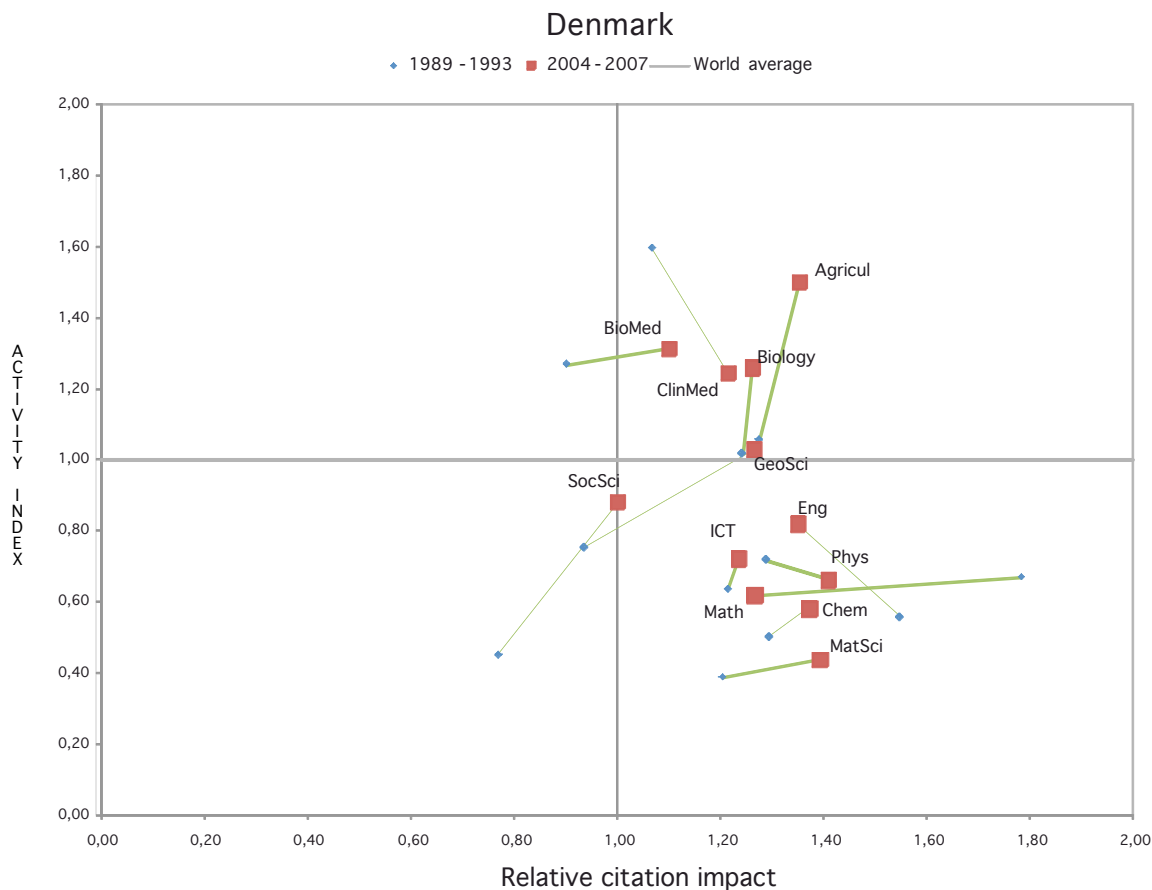
What are the general trends when we consider these 12 research fields? In most fields, the relative citation rates for Sweden are declining, not dramatically, but continuously. The opposite is true for Norway. In several fields, the citation rates for Norway appear to be increasing continuously. Citation rates for Finland appear to be rather stable in most fields, with some increases and decreases during the period (perhaps slightly more decreases), whereas Denmark generally has high citation rates in most fields. Finally, Iceland fluctuates considerably, but has high, reliable citation rates in biomedicine and geosciences.

Next we discuss the citation impact for the Nordic countries, addressing their publication activity in the respective fields and monitoring the changes between the first and last periods.

**Publication activity and citation impact by country**

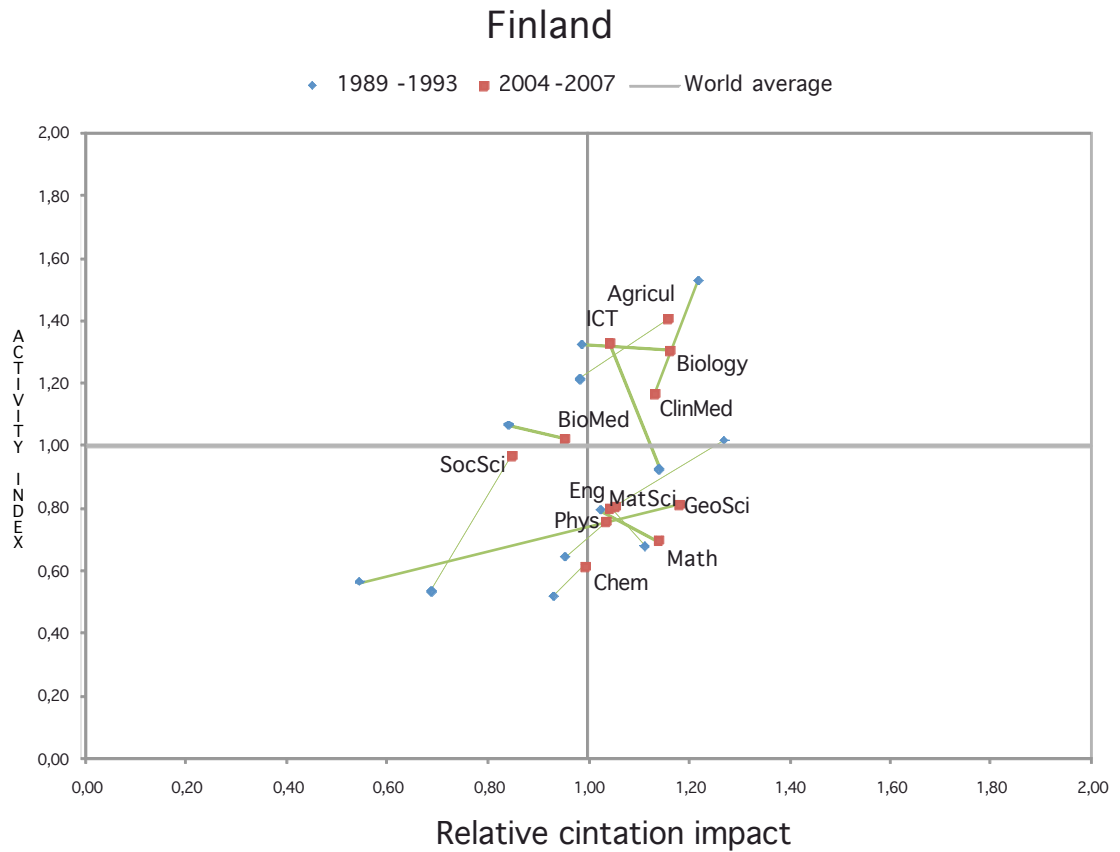
In FIGURES 27 through 31 we relate citation impact to publication activity for each Nordic country. For each field, we illustrate the changes between the first and last periods. The analyses are represented in a matrix with four quadrants; the first in the upper-left corner, the second in the upper-right corner, the third in the lower-right corner, and finally the fourth in lower-left corner. The y-axis indicates the activity index, which is the country's relative share of publications in the field in relation to the world's relative share of publications in the same field (i.e. the activity index is presented on page 14), and the x-axis indicates the relative citation impact. The four quadrants can be interpreted as follows: the first quadrant shows high publication activity and low citation impact; the second quadrant shows high publication activity and high citation impact; the third quadrant shows low publication activity and high citation impact; and the fourth quadrant shows low publication activity and low citation impact. Note that *low publication activity* is relative to world output for the given field. The smaller blue diamonds show the research field's position in the first period (1989-1993), and the larger red squares show the position in last period (2004-2007). The green lines indicate changing positions. (Note: the straight line is arbitrary.)

**FIGURE 27: MATRIX RELATING DENMARK'S *RELATIVE CITATION IMPACT* TO ITS *PUBLICATION ACTIVITY INDEX* FOR TWO PERIODS; (I) 1989-1993, INDICATED WITH BLUE DIAMONDS, AND (II) 2004-2007, INDICATED WITH RED SQUARES. THE GREEN LINES INDICATE CHANGING POSITIONS OF A RESEARCH AREA BETWEEN THE TIME PERIODS.**



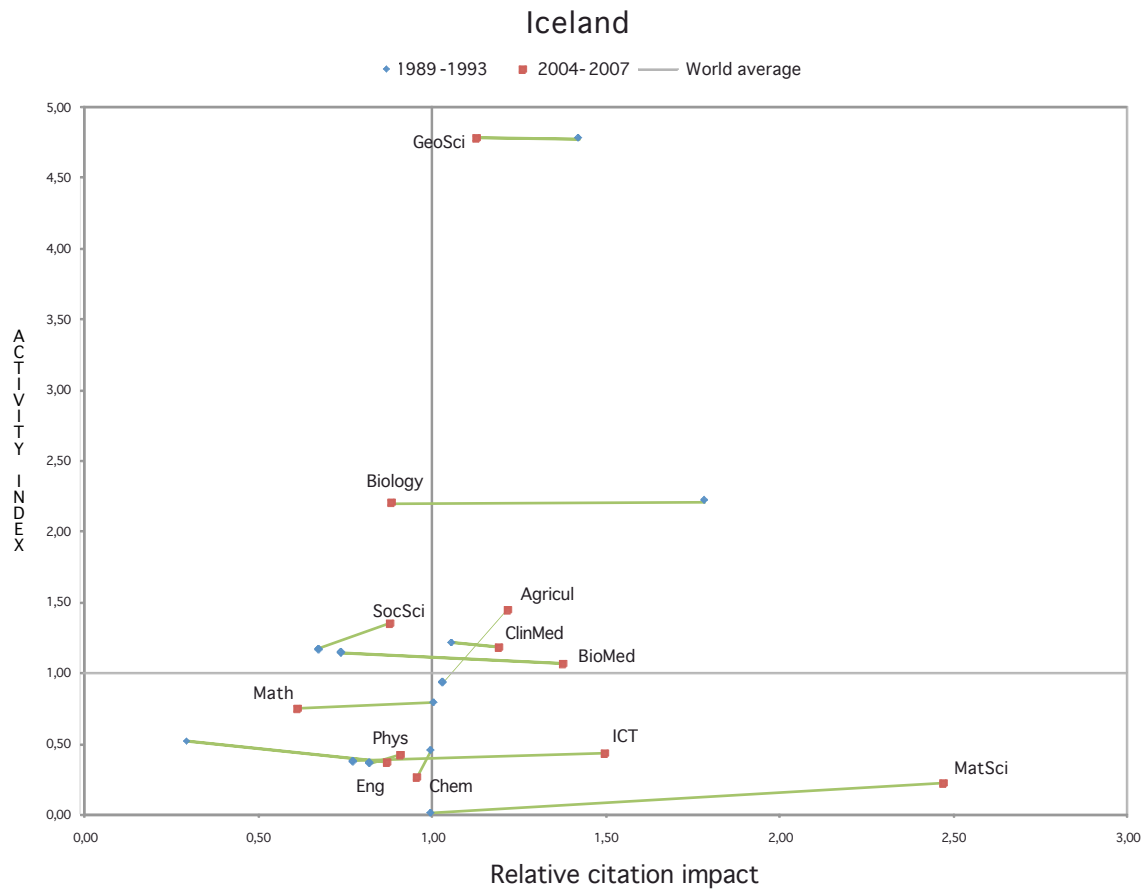
Denmark (FIGURE 27) has managed to move all research fields in the last period up to or above the world average in citation impact. The research fields are distributed almost equally between the second and third quadrants in the last period with most high-impact fields in the third quadrant – high impact and relatively low publication activity. Note that while publication activity in clinical medicine has decreased, the relative citation impact has increased. It should also be noted that the decrease in clinical medicine is relative to other fields and not necessarily an absolute decline in publication activity. The general trend appears to be upward, except for clinical medicine in publication activity, and mathematics and engineering in relative citation impact (although engineering actually reflects an increase in activity).

**FIGURE 28: MATRIX RELATING FINLAND'S *RELATIVE CITATION IMPACT* TO ITS *PUBLICATION ACTIVITY INDEX* FOR TWO PERIODS; (I) 1989-1993, INDICATED WITH BLUE DIAMONDS, AND (II) 2004-2007, INDICATED WITH RED SQUARES. THE GREEN LINES INDICATE CHANGING POSITIONS OF A RESEARCH AREA BETWEEN THE TIME PERIODS.**



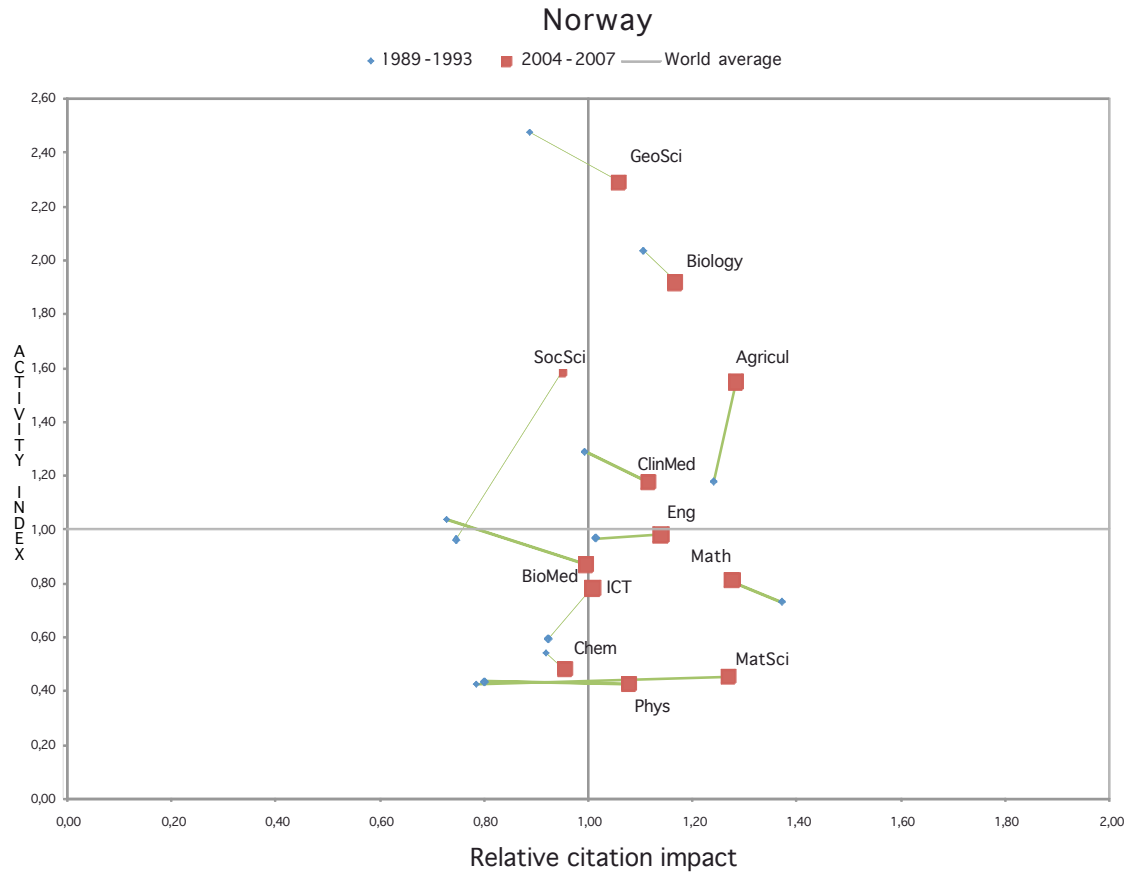
In the case of Finland (FIGURE 28), the research fields seem to cluster more or less around the centre of the matrix for the last period. Noticeable is the strong development for geosciences, moving from the fourth to the third quadrant, but also the increase in ICT publication activity, while concurrently this field experiences an overall decrease in relative citation impact. It should be noted that high activity could also mean broad activity and not necessarily a high citation impact. ICT is a relatively small research area that is not concentrated in large journals and therefore most likely have lower citation activity. Materials science decreased in relative volume, while concurrently experiencing a loss in citation impact.

**FIGURE 29: MATRIX RELATING ICELAND'S *RELATIVE CITATION IMPACT* TO ITS *PUBLICATION ACTIVITY INDEX* FOR TWO PERIODS; (I) 1989-1993, INDICATED WITH BLUE DIAMONDS, AND (II) 2004-2007, INDICATED WITH RED SQUARES. THE GREEN LINES INDICATE CHANGING POSITIONS OF A RESEARCH AREA BETWEEN THE TIME PERIODS.**



Although in the fractionalized publication count, clinical medicine accounts for almost 30% of Iceland's (FIGURE 29) research output indexed in Thompson Reuters, and even though materials science has a very high impact, what stands out for Iceland are the geosciences. This field has extremely high relative publication activity compared to the world. The geosciences also have a high citation impact. As always, statistics for Iceland should be interpreted with caution, which the different sizes of the quadrants illustrate (see Appendix 2 for the actual fractionalized publication counts).

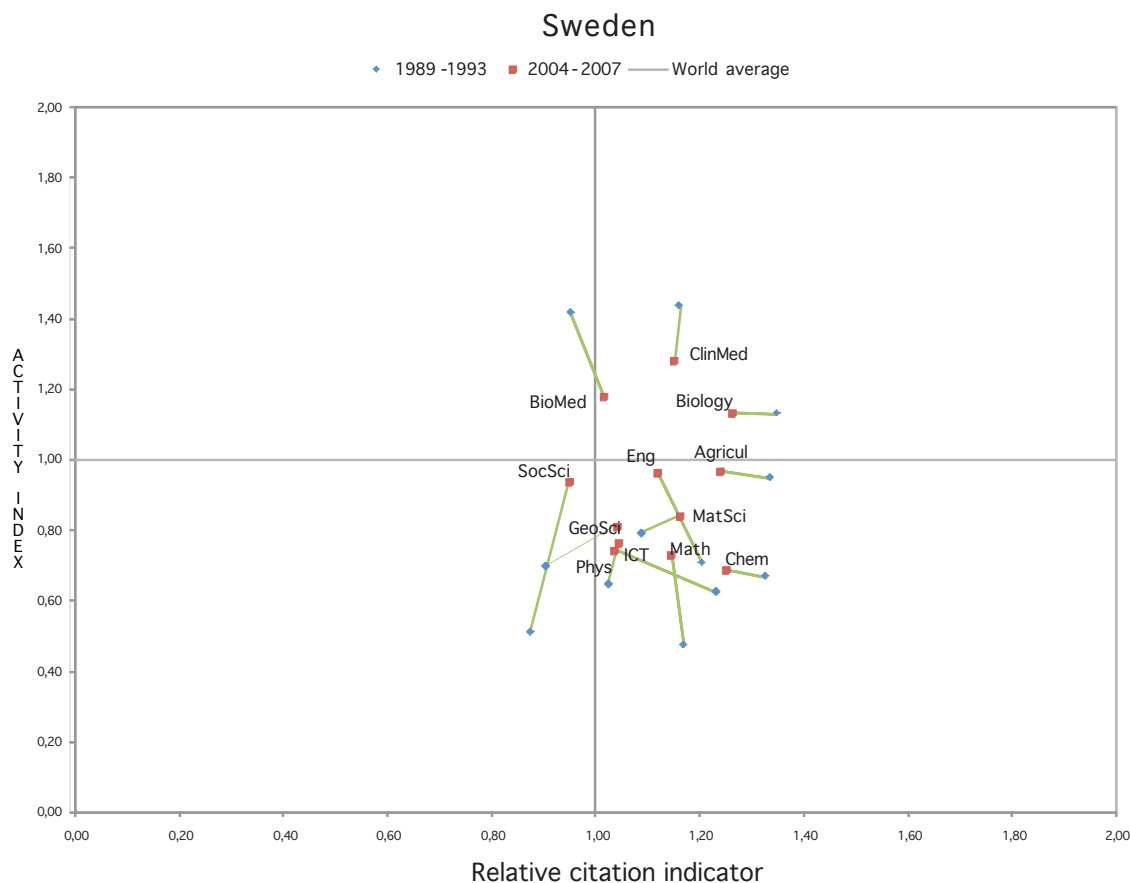
**FIGURE 30: MATRIX RELATING NORWAY'S RELATIVE CITATION IMPACT TO ITS PUBLICATION ACTIVITY INDEX FOR TWO PERIODS; (I) 1989-1993, INDICATED WITH BLUE DIAMONDS, AND (II) 2004-2007, INDICATED WITH RED SQUARES. THE GREEN LINES INDICATE CHANGING POSITIONS OF A RESEARCH AREA BETWEEN THE TIME PERIODS.**



Noticeably, and in support of the trend in field citation rates identified in the previous section, Norway (FIGURE 30) has increased its citation impact in all fields but mathematics, moving close to or above the world average. It is also noticeable that Norway is strong in fields involving *natural resources*, e.g. geosciences, agriculture, and biology. But Norway also has relatively high publication activity in social sciences. The research fields are stretched out along the centre of the matrix.



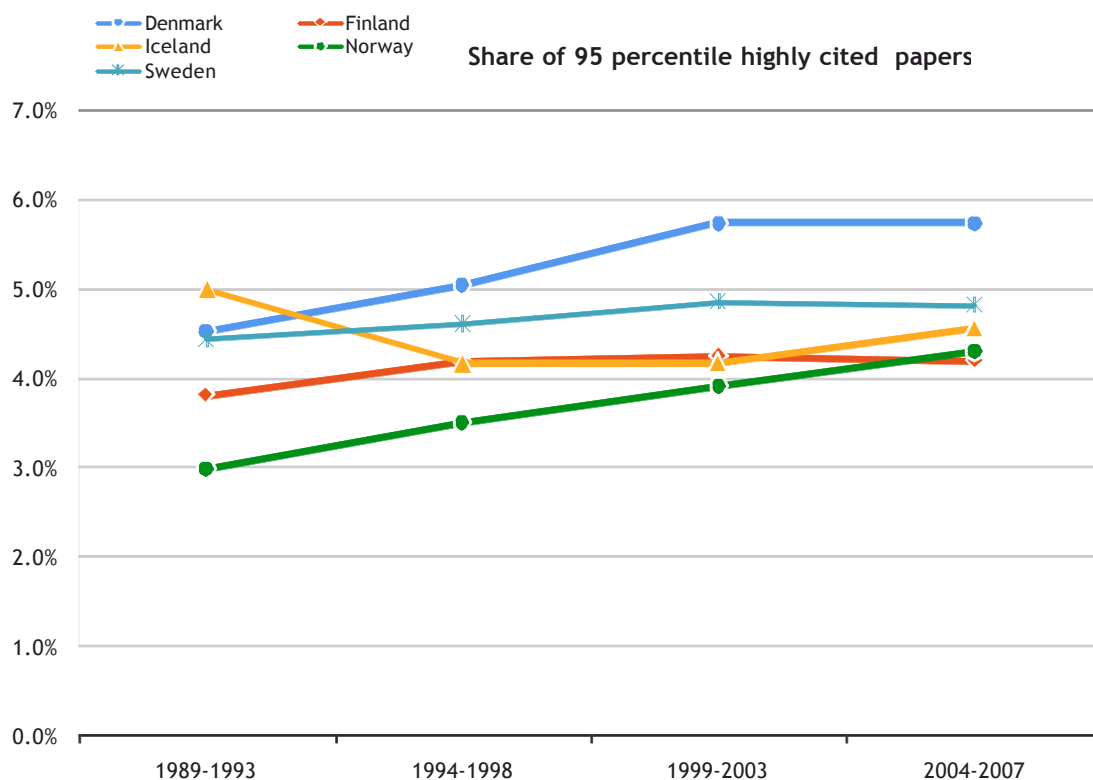
**FIGURE 31: MATRIX RELATING SWEDEN'S *RELATIVE CITATION IMPACT* TO ITS *PUBLICATION ACTIVITY INDEX* FOR TWO PERIODS; (I) 1989-1993, INDICATED WITH BLUE DIAMONDS, AND (II) 2004-2007, INDICATED WITH RED SQUARES. THE GREEN LINES INDICATE CHANGING POSITIONS OF A RESEARCH AREA BETWEEN THE TIME PERIODS.**



The Swedish research fields (FIGURE 31) are moving towards the centre of the matrix. This applies to both dimensions, i.e. relative publication activity and relative citation impact. Higher impact fields in the first period lose impact in the last period. Social sciences, engineering, and mathematics have increased in relative size, while biomedicine and clinical medicine have decreased. Further, there have been considerable citation decreases in biology, agriculture, chemistry, and ICT. This is true also for engineering, but concurrently this field has grown.

Generally, FIGURE 27 through FIGURE 31 confirm the previous findings and trends in publication activity and citation impact for the Nordic countries.

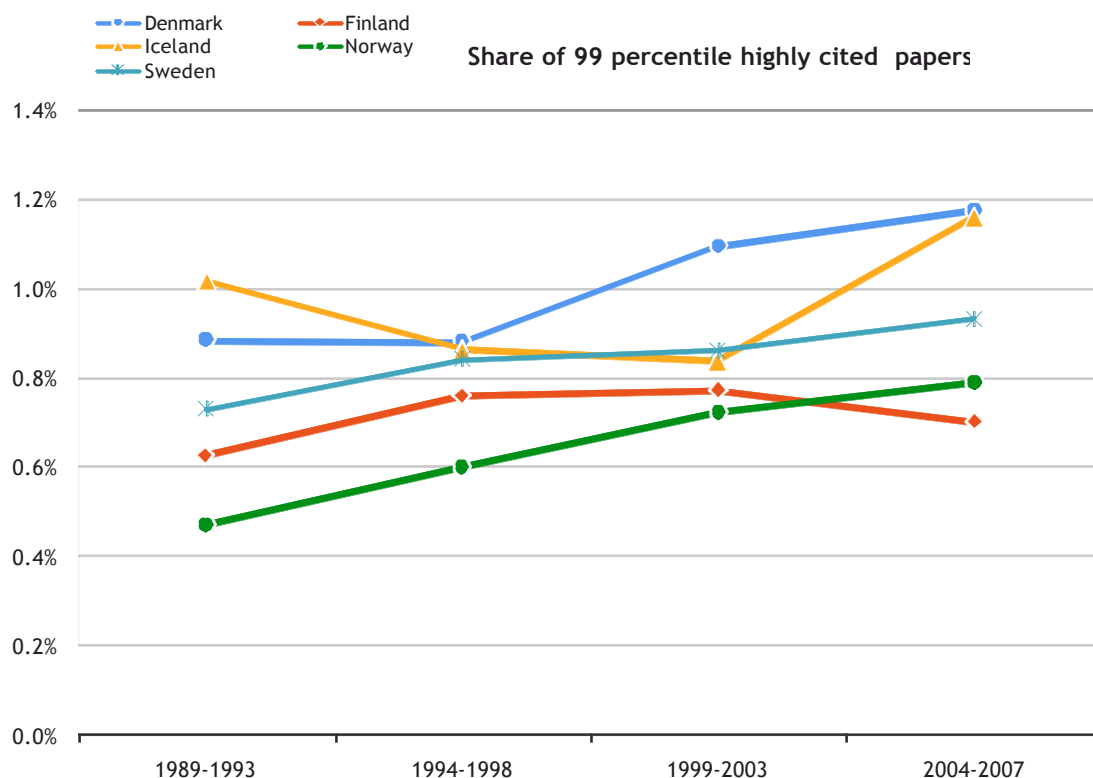
**FIGURE 32: SHARE OF HIGHLY PAPERS ABOVE THE 95TH PERCENTILE OF HIGHLY CITED PAPERS.**



**The Nordic countries' share of highly cited papers**

Finally, we investigate trends in the number of publications each Nordic country has among the 5% and 1% most highly cited papers relative to all fields, publication years, and document types. Notice that the publications are identified by percentiles, and the top 5% actually means papers that are cited above the 95th percentile. FIGURES 32 and 33 illustrate the share of the top 5% and top 1% most highly cited papers respectively. These figures can be compared to FIGURE 14, which shows the trend in relative citation impact for all fields combined.

**FIGURE 33: SHARE OF HIGHLY PAPERS ABOVE THE 99TH PERCENTILE OF HIGHLY CITED PAPERS.**



The overall trend is similar to FIGURE 14. Denmark has high overall citation rates and also the largest share of highly cited papers among the Nordic countries. Norway is increasing its share of highly cited papers. Finland's share increases between the first two periods but decreases between the two last, whereas Iceland seems to have a few very highly cited papers in last period. These papers most likely account for some of the very high citation rates identified in a few fields for Iceland. Finally, contrary to the trend in overall citation rates, Sweden appears to be experiencing a small increase in highly cited papers. This indicates that the cause behind the overall decrease in citation impact should be looked for elsewhere.

### Conclusions from chapter 3

In the last period studied, i.e. 2004 through 2007, the Nordic countries were amongst the world's most-cited countries, ranging from Denmark in fourth place to Finland in eleventh place.

In the first period studied, 1989 through 1993, Sweden and Denmark were at approximately the same level (just over 10% above the world average). While Sweden has remained basically at the same level since then, Denmark has taken a major leap, primarily between 1994-1998 and 1999-2003. Finland started at about 5% above the world average

(a level lower than Sweden and Denmark in the 1989-1993 period), but rose to almost 10% above world average during the 1990s and early 2000s. In the 2004-2007 period, however, Finland returned to nearly the same level as in 1989-1993.

In 1989-1993 Norway started at the lowest citation level of all the Nordic countries (about 5% below the world average), but has since shown a steady increase, surpassing Finland in 2004-2007. Iceland advanced rapidly during the last two periods and in 2004-2007 held second place in the Nordic group, around 15% above the world average. It should be remembered that statistics for Iceland, due to its small size, are strongly affected by individual, highly cited publications.

Splitting the data into national publications (where all authors represent the same country) and international publications (where more than one country is represented among the authors) we find that much of the increase in citation rates for Denmark and Norway can be attributed to increased citation rates of national publications. For Iceland the increase is due to increased citation rates of international publications, while Finland and Sweden experienced decreasing citation rates regarding their international publications and constant rates regarding the national ones.

When splitting the data into broad subject categories, we find the overall pattern repeated for many categories. At times the pattern is repeated on higher citation levels (*agriculture, biology, materials sciences*) and at times on lower levels (*biomedicine, social sciences*). However, for some subject categories the overall pattern is not repeated. In *chemistry*, Sweden and Denmark form a group with considerably higher citation rates (25-50% above the world average) than Finland and Norway (on or slightly below the world average); the statistics for Iceland are unstable due to small publication numbers. In *clinical medicine*, Finland started at the highest Nordic level (more than 20% above the world average), but recently has fallen back about 10 percentage points. In *geosciences*, Denmark, Finland, Norway, and Sweden started at levels below the world average and have now reached levels well above. Iceland started at a very high level (40%-50% above world average), but has fallen back to a more characteristic Nordic level of 12% above the world average. In *engineering and physics*, Denmark stands out at a stable level 30% to 40% above the world average (more stable for *physics* than for *engineering*), while the other Nordic countries group together around the world average (where the Norwegian trend is clearly increasing). In *mathematics*, the pattern is quite different, probably due to the small underlying publication volumes, although all Nordic countries except Iceland remain on very high citation levels (15%-30% above world average). Generally, Iceland shows unstable values for several fields, since the number of underlying publications in many cases is very small (< 100).

Looking at the different fields country-by-country, we see that in the last period Denmark has managed to push all research fields up to or above the world average in citation impact. For Finland, the field of *geosciences* stands out with a strong trend in both size and citation rate, while ICT has increased in volume but decreased in citation rate. For Iceland, the *geosciences* stand out with a very large volume compared to other countries and also a high citation rate. Norway has increased its citation rates in all fields except

mathematics, and stands strong in fields involving natural resources (*geosciences, agriculture, and biology*). For Sweden, we see a trend where all fields are moving towards the world average – fields that used to be strong are weakening, while fields that used to be weak are strengthening.

Since citations are unevenly distributed across publications (some papers receive many citations while most papers receive few) it is worth studying the highly cited papers. In fact, the trends for these papers and the trends for average citation rates are much the same for the Nordic countries, except that Sweden's trend shows a small increase in the share of highly cited papers. Consequently, the explanation for the general decline in Swedish citations is likely to be hidden amongst the papers with medium or low citation rates.

It should be noted that the methodology used here sets different conditions for the countries depending on the size of publication output. Large countries change their citation rates less easily than small countries, and in this respect Sweden is 2.0 to 2.5 times larger than Denmark, Finland, and Norway, and more than 40 times larger than Iceland. Hence, it is not surprising that Sweden generally shows the most stable trend, and Iceland shows the most unstable trend. The trend in Denmark is, however, exceptional. Contrary to what could have been expected in the late 1980s, Denmark has increased her citation rates dramatically, and now seems to have stabilized amongst the world elite, with an average citation rate 20% or more above the world average. Norway and Iceland have also experienced strong increases, but from lower levels than Denmark. Sweden and Finland, on the other hand, have remained at the same citation levels, or even declined.

This chapter has focused on the differences between the Nordic countries, but we must remember that on a higher level all Nordic countries are similar, with high citation rates in all fields. In *agriculture, biology, materials sciences*, and perhaps *mathematics* the Nordic countries are especially strong.

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# Appendix 1: Main Subject Areas

The 255 subject classes used by Thomson Reuters have been grouped into 14 main groupings. The classification is a slight modification of the scheme developed by Katz & Hicks (1995).

Category	ISI Subject
AGRICULTURE	Agricultural Economics & Policy
AGRICULTURE	Agricultural Engineering
AGRICULTURE	AGRICULTURAL EXPERIMENT STATION REPORTS
AGRICULTURE	Agriculture, Dairy & Animal Science
AGRICULTURE	Agriculture, Multidisciplinary
AGRICULTURE	Agronomy
AGRICULTURE	Environmental Sciences
AGRICULTURE	Fisheries
AGRICULTURE	Food Science & Technology
AGRICULTURE	Forestry
AGRICULTURE	Horticulture
AGRICULTURE	Plant Sciences
AGRICULTURE	Soil Science
AGRICULTURE	Water Resources
AGRICULTURE	Veterinary Sciences
ART	Archaeology
ART	Architecture
ART	Art
ART	Asian Studies
ART	Classics
ART	Communication
ART	Dance
ART	Ethics
ART	Film, Radio, Television
ART	Folklore
ART	History
ART	History & Philosophy of Science
ART	History of Social Sciences
ART	Humanities, Multidisciplinary
ART	Language & Linguistics
ART	Linguistics
ART	Literary Reviews
ART	Literary Theory & Criticism
ART	Literature
ART	Literature, African, Australian, Canadian
ART	Literature, American
ART	Literature, British Isles
ART	Literature, German, Dutch, Scandinavian
ART	Literature, Romance
ART	Literature, Slavic
ART	Medieval & Renaissance Studies
ART	Music

ART	ORIENTAL STUDIES
ART	PHILOSOPHY
ART	Poetry
ART	Religion
ART	Theater
BIOLOGY	Biodiversity Conservation
BIOLOGY	Biology
BIOLOGY	BIOLOGY, MISCELLANEOUS
BIOLOGY	Developmental Biology
BIOLOGY	Ecology
BIOLOGY	Entomology
BIOLOGY	Evolutionary Biology
BIOLOGY	Limnology
BIOLOGY	Marine & Freshwater Biology
BIOLOGY	Mycology
BIOLOGY	Ornithology
BIOLOGY	Reproductive Biology
BIOLOGY	Zoology
BIOMEDICINE	Anatomy & Morphology
BIOMEDICINE	Biochemical Research Methods
BIOMEDICINE	Biochemistry & Molecular Biology
BIOMEDICINE	Biophysics
BIOMEDICINE	Biotechnology & Applied Microbiology
BIOMEDICINE	Cell Biology
BIOMEDICINE	Chemistry, Medicinal
BIOMEDICINE	COMPUTER CRITICAL REVIEWS
BIOMEDICINE	CYTOLOGY & HISTOLOGY
BIOMEDICINE	Genetics & Heredity
BIOMEDICINE	Immunology
BIOMEDICINE	Mathematical & Computational Biology
BIOMEDICINE	Microbiology
BIOMEDICINE	Microscopy
BIOMEDICINE	Neurosciences
BIOMEDICINE	Parasitology
BIOMEDICINE	Pharmacology & Pharmacy
BIOMEDICINE	Physiology
BIOMEDICINE	Sport Sciences
CHEMISTRY	Chemistry, Analytical
CHEMISTRY	Chemistry, Applied
CHEMISTRY	Chemistry, Inorganic & Nuclear
CHEMISTRY	Chemistry, Multidisciplinary
CHEMISTRY	Chemistry, Organic
CHEMISTRY	Chemistry, Physical
CHEMISTRY	Crystallography
CHEMISTRY	Electrochemistry
CHEMISTRY	Polymer Science
CHEMISTRY	Spectroscopy
CLINICAL MEDICINE	Allergy
CLINICAL MEDICINE	Andrology
CLINICAL MEDICINE	Anesthesiology
CLINICAL MEDICINE	Cardiac & Cardiovascular System
CLINICAL MEDICINE	Clinical Neurology
CLINICAL MEDICINE	Critical Care Medicine

CLINICAL MEDICINE	Dentistry, Oral Surgery & Medicine
CLINICAL MEDICINE	Dermatology
CLINICAL MEDICINE	Emergency Medicine
CLINICAL MEDICINE	Endocrinology & Metabolism
CLINICAL MEDICINE	Gastroenterology & Hepatology
CLINICAL MEDICINE	Geriatrics & Gerontology
CLINICAL MEDICINE	Gerontology
CLINICAL MEDICINE	Health Care Sciences & Services
CLINICAL MEDICINE	Hematology
CLINICAL MEDICINE	Infectious Diseases
CLINICAL MEDICINE	Integrative & Complementary Medicine
CLINICAL MEDICINE	Medical Ethics
CLINICAL MEDICINE	Medical Informatics
CLINICAL MEDICINE	Medical Laboratory Technology
CLINICAL MEDICINE	Medicine, General & Internal
CLINICAL MEDICINE	MEDICINE, LEGAL
CLINICAL MEDICINE	MEDICINE, MISCELLANEOUS
CLINICAL MEDICINE	Medicine, Research & Experimental
CLINICAL MEDICINE	Neuroimaging
CLINICAL MEDICINE	Nursing
CLINICAL MEDICINE	Nutrition & Dietetics
CLINICAL MEDICINE	Obstetrics & Gynecology
CLINICAL MEDICINE	Oncology
CLINICAL MEDICINE	Ophthalmology
CLINICAL MEDICINE	Orthopedics
CLINICAL MEDICINE	Otorhinolaryngology
CLINICAL MEDICINE	Pathology
CLINICAL MEDICINE	Pediatrics
CLINICAL MEDICINE	Peripheral Vascular Disease
CLINICAL MEDICINE	Psychiatry
CLINICAL MEDICINE	Psychology, Clinical
CLINICAL MEDICINE	Public, Environmental & Occupational Health
CLINICAL MEDICINE	Radiology, Nuclear Medicine & Medical Imaging
CLINICAL MEDICINE	Rehabilitation
CLINICAL MEDICINE	Respiratory System
CLINICAL MEDICINE	Rheumatology
CLINICAL MEDICINE	Substance Abuse
CLINICAL MEDICINE	Surgery
CLINICAL MEDICINE	Toxicology
CLINICAL MEDICINE	Transplantation
CLINICAL MEDICINE	Tropical Medicine
CLINICAL MEDICINE	Urology & Nephrology
CLINICAL MEDICINE	Virology
ENG	Construction & Building Technology
ENG	Energy & Fuels
ENG	Engineering, Aerospace
ENG	Engineering, Biomedical
ENG	Engineering, Chemical
ENG	Engineering, Civil
ENG	Engineering, Environmental
ENG	Engineering, Geological
ENG	Engineering, Industrial
ENG	Engineering, Manufacturing
ENG	Engineering, Marine



ENG	Engineering, Mechanical
ENG	Engineering, Multidisciplinary
ENG	Engineering, Ocean
ENG	Engineering, Petroleum
ENG	Ergonomics
ENG	Mechanics
ENG	Metallurgy & Metallurgical Engineering
ENG	METALLURGY & MINING
ENG	Mining & Mineral Processing
ENG	Operations Research & Management Science
ENG	TRANSPORTATION
ENG	Transportation Science & Technology
GEOSCIENCES	Geochemistry & Geophysics
GEOSCIENCES	Geography, Physical
GEOSCIENCES	Geology
GEOSCIENCES	Geosciences, Multidisciplinary
GEOSCIENCES	Meteorology & Atmospheric Sciences
GEOSCIENCES	Mineralogy
GEOSCIENCES	Oceanography
GEOSCIENCES	Paleontology
ICT	Automation & Control Systems
ICT	COMPUTER APPLICATIONS & CYBERNETICS
ICT	Computer Science, Artificial Intelligence
ICT	Computer Science, Cybernetics
ICT	Computer Science, Hardware & Architecture
ICT	Computer Science, Information Systems
ICT	Computer Science, Interdisciplinary Applications
ICT	Computer Science, Software Engineering
ICT	Computer Science, Theory & Methods
ICT	Engineering, Electrical & Electronic
ICT	Imaging Science & Photographic Technology
ICT	Instruments & Instrumentation
ICT	Remote Sensing
ICT	Robotics
ICT	Telecommunications
MATERIALS SCIENCE	Materials Science, Biomaterials
MATERIALS SCIENCE	Materials Science, Ceramics
MATERIALS SCIENCE	Materials Science, Characterization, Testing
MATERIALS SCIENCE	Materials Science, Coatings & Films
MATERIALS SCIENCE	Materials Science, Composites
MATERIALS SCIENCE	Materials Science, Multidisciplinary
MATERIALS SCIENCE	Materials Science, Paper & Wood
MATERIALS SCIENCE	Materials Science, Textiles
MATERIALS SCIENCE	Nanoscience & Nanotechnology
MATHEMATICS	Mathematics
MATHEMATICS	Mathematics, Applied
MATHEMATICS	Mathematics, General
MATHEMATICS	Mathematics, Interdisciplinary Applications
MATHEMATICS	Statistics & Probability
OTHER	Multidisciplinary Sciences
PHYSICS	Acoustics
PHYSICS	Astronomy & Astrophysics
PHYSICS	Nuclear Science & Technology
PHYSICS	Optics

PHYSICS	Physics, Applied
PHYSICS	Physics, Atomic, Molecular & Chemical
PHYSICS	Physics, Condensed Matter
PHYSICS	Physics, Fluids & Plasmas
PHYSICS	Physics, Mathematical
PHYSICS	Physics, Multidisciplinary
PHYSICS	Physics, Nuclear
PHYSICS	Physics, Particles & Fields
PHYSICS	Thermodynamics
SOC	Anthropology
SOC	Area Studies
SOC	Behavioral Sciences
SOC	Business
SOC	Business, Finance
SOC	Criminology & Penology
SOC	Demography
SOC	Economics
SOC	Education & Educational Research
SOC	Education, Scientific Disciplines
SOC	Education, Special
SOC	Environmental Studies
SOC	Ethnic Studies
SOC	Family Studies
SOC	Geography
SOC	Health Policy & Services
SOC	HOSPITALITY, LEISURE, SPORT & TOURISM
SOC	Industrial Relations & Labor
SOC	INFORMATION SCIENCE & LIBRARY SCIENCE
SOC	International Relations
SOC	Law
SOC	Management
SOC	Planning & Development
SOC	Political Science
SOC	Politics & Policy
SOC	Psychology
SOC	Psychology, Applied
SOC	Psychology, Biological
SOC	Psychology, Developmental
SOC	Psychology, Educational
SOC	Psychology, Experimental
SOC	Psychology, Mathematical
SOC	Psychology, Multidisciplinary
SOC	Psychology, Psychoanalysis
SOC	Psychology, Social
SOC	Public Administration
SOC	Social Issues
SOC	Social Sciences, Biomedical
SOC	Social Sciences, Interdisciplinary
SOC	Social Sciences, Mathematical Methods
SOC	Social Work
SOC	Sociology
SOC	Urban Studies
SOC	Women's Studies

# Appendix 2:

## Fractionalized publication counts for each field

<b>AGRICULTURE</b>	<b>1989-1993</b>	<b>1994-1998</b>	<b>1999-2003</b>	<b>2004-2008</b>
Denmark	1535.71	2464.18	2903.49	2434.19
Finland	1556.33	2119.25	2513.22	2298.20
Iceland	34.33	69.19	93.82	102.08
Norway	1098.47	1667.53	2005.94	1884.99
Sweden	2888.47	3536.02	3631.43	3069.16
<b>BIOLOGY</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	813.45	1174.00	1508.02	1186.43
Finland	935.79	1315.99	1494.03	1238.05
Iceland	45.09	57.03	75.58	90.08
Norway	1044.91	1236.44	1475.43	1355.17
Sweden	1897.19	2180.00	2515.94	2082.40
<b>ENG</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	555.88	961.42	1065.54	1144.51
Finland	598.33	885.91	1102.39	1126.35
Iceland	13.10	17.58	15.08	22.47
Norway	620.37	985.09	966.69	1027.60
Sweden	1483.57	2284.35	2684.86	2628.97
<b>GEOSCIENCES</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	404.54	681.24	995.40	733.55
Finland	268.39	414.58	593.55	585.82
Iceland	65.27	89.56	123.50	148.07
Norway	854.74	1010.62	1249.20	1224.50
Sweden	787.61	1169.26	1331.63	1128.66
<b>ICT</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	564.70	768.70	1110.15	1129.60
Finland	727.55	1128.70	1796.21	2096.50
Iceland	8.54	12.99	26.98	29.46
Norway	340.15	554.17	673.08	919.65
Sweden	1163.56	1728.06	2457.18	2275.98
<b>MATHEMATICS</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	372.75	506.75	577.51	466.46
Finland	391.79	436.53	575.57	530.34
Iceland	11.17	25.58	19.16	24.37
Norway	262.42	344.23	437.86	459.07
Sweden	554.98	907.22	1000.19	1074.13
<b>PHYSICS</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	1862.97	2592.47	2556.96	1940.94
Finland	1477.74	2045.74	2448.82	2242.53
Iceland	23.86	50.79	66.06	53.68
Norway	726.89	973.77	860.88	939.76
Sweden	3528.44	4916.02	5449.71	4361.84

<b>ART</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	284.05	319.71	385.16	356.98
Finland	256.48	270.72	365.16	355.45
Iceland	9.50	23.47	30.36	23.58
Norway	279.94	333.16	341.83	389.22
Sweden	402.95	427.63	591.79	460.07
<b>BIOMEDICINE</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	4606.48	5502.70	5874.37	5029.04
Finland	3419.14	4267.77	4754.03	3944.04
Iceland	105.13	158.69	170.12	177.21
Norway	2417.71	2648.18	2684.98	2501.23
Sweden	10783.84	11778.56	11317.35	8814.57
<b>CHEMISTRY</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	1212.30	1621.81	1876.72	1612.13
Finland	1105.79	1683.56	1948.56	1724.51
Iceland	27.91	34.70	41.43	30.77
Norway	840.69	1105.67	1013.64	1001.76
Sweden	3400.92	4117.07	4344.00	3729.26
<b>CLINICAL MEDICINE</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	9084.87	8915.71	8768.37	7966.47
Finland	7679.04	9692.91	9913.06	7532.18
Iceland	175.01	312.21	329.00	326.83
Norway	4706.94	5516.63	5713.52	5638.63
Sweden	17120.62	19544.26	19605.60	15989.75
<b>MATERIALS SCIENCE</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	176.99	338.16	352.24	403.17
Finland	412.35	681.67	890.43	746.76
Iceland	0.08	12.50	4.35	8.66
Norway	125.36	259.82	304.34	313.27
Sweden	761.11	1381.68	1823.46	1508.95
<b>OTHER</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	23.75	22.08	24.01	17.21
Finland	10.33	12.61	6.92	5.91
Iceland	3.00	1.83	2.33	1.00
Norway	18.92	19.50	11.67	9.68
Sweden	55.48	37.42	23.00	21.40
<b>SOC SCI</b>	1989-1993	1994-1998	1999-2003	2004-2008
Denmark	627.34	816.91	1122.31	1246.09
Finland	659.89	1019.75	1281.22	1384.04
Iceland	41.45	67.88	71.63	82.87
Norway	863.15	1265.54	1448.37	1684.04
Sweden	1499.14	2022.64	2457.82	2594.38

# Endnotes

- 1 The reports can be downloaded at: [http://www.vr.se/english/nordic\\_bibliometrics](http://www.vr.se/english/nordic_bibliometrics)
- 2 Certain data included herein are derived from the *Science Citation Index Expanded*, *Social Science Citation Index* and *Arts & Humanities Citation Index*, prepared by Thomson Reuters®, Philadelphia, Pennsylvania, USA, © Copyright Thomson Reuters® 2009. All rights reserved.
- 3 Agriculture includes the subject areas of fisheries and forestry.
- 4 See [http://nifu.pdc.no/index.php?seks\\_id=12474](http://nifu.pdc.no/index.php?seks_id=12474).
- 5 Information and Communications Technology.
- 6 This section includes only 12 fields since two, “Arts & Humanities” and “Other”, have been left out, see below.
- 7 Note: the last period is reduced to 4 years due to a lack of citation data for publications in 2008.
- 8 In the crown indicator, normalization is done on an aggregated level – the citation average for a given country is divided by the weighted citation average for the relevant fields (Moed et al 1995, p. 399). In our calculations, normalization is done on a item level – the citation for each paper from a given country is divided by the average citations for the field of that paper. These differences are described in detail in: (Lundberg, 2007, p. 146-147).
- 9 cf. Appendix D in *Clinical Research in Finland and Sweden. Evaluation Report* (2009): [http://www.aka.fi/Tiedostot/Tiedostot/Julkaisut/05\\_09%20Clinical%20Research.pdf](http://www.aka.fi/Tiedostot/Tiedostot/Julkaisut/05_09%20Clinical%20Research.pdf).
- 10 [http://www.aka.fi/Tiedostot/Tiedostot/Julkaisut/05\\_09%20Clinical%20Research.pdf](http://www.aka.fi/Tiedostot/Tiedostot/Julkaisut/05_09%20Clinical%20Research.pdf)
- 11 See the section on *Methodological considerations*







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