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NordForsk

# International Research Cooperation in the Nordic Countries

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

**Network members:**

Norwegian Institute for Studies in Innovation, Research and Education (NIFU STEP)  
Danish Agency for Science, Technology and Innovation  
The Icelandic Centre for Research (RANNIS)  
Swedish Research Council  
Academy of Finland  
Royal School of Library & Information Science

**Editor:** Magnus Gunnarsson, Swedish Research Council



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# Preface

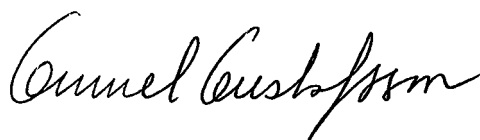
NordForsk is a platform for joint Nordic research and research policy development. The aim is to promote cooperation which adds value to what is going on nationally, and thereby contribute to the knowledge society through continuous efforts to improve the quality of Nordic research and innovation.

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 first 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

In this report, international research cooperation is studied using statistics based on the address details provided for scientific publications. The study is limited to items published between 1984 and 2008 where at least one of the authors is affiliated with a Nordic university. Accordingly, 'cooperation' means 'co-authorship' in this context. During the studied period, there has been a significant increase in the number of scientific publications per year in all Nordic countries. The proportion of articles resulting from international cooperation has also increased dramatically, showing a strong trend towards internationalization in all countries. About half of all scientific articles from Denmark, Finland, Norway and Sweden are published in international cooperation, and the same is true for two-thirds of the articles from Iceland. Almost the entire publication growth since the 1980s consists of international co-publications, the exception being Iceland, which has also seen considerable growth in national publications.

International comparison indicates that the proportion of articles with international cooperation partly depends on country size: the proportion of a country's publications that involve international cooperation increases as the overall size of the publication output decreases. All of the Nordic countries, especially Iceland, have a high propensity to cooperate internationally in publications. This corresponds well with the fact that they are small countries with open economies and political relations.

For all Nordic countries, cooperation with other EU countries has a high and increasing share within the total cooperation activity with all countries in the world. Cooperation with North America also has a high share, but in relative terms it has been decreasing. Internal Nordic cooperation remains important during the whole period.

A measurement of the cooperation activity between countries shows that some countries are more impor-

tant than others as cooperation partners, and that the selection of important cooperation partners varies from country to country. A general pattern is that cultural proximity seems to be a strong factor behind the choice of cooperation partners. The Nordic countries tend to cooperate with each other more often than might be expected given the international publication volume of these countries. Researchers from the rest of the Western world are chosen as cooperation partners by Nordic researchers approximately as often as expected, while researchers from other parts of the world are less frequent as cooperation partners.

There are some variations on this theme. In the case of Finland, we find the Baltic countries at the top of the list of preferred cooperation partners (cooperation with Estonia being the main reason for this). In the same list, Russia is found as high as in seventh place (by relative importance), and Turkey, Ukraine and Japan are all located above Australia, Israel and New Zealand. Further, the 'Eastern EU' group of countries is ranked as high as in tenth place.<sup>1</sup> In the case of Sweden, there is a similar, relative preference for Russia and Eastern EU. For Iceland, the Nordic and Baltic domination is greater than in the other Nordic countries.

Nordic cooperation with the Baltic countries increased dramatically during the 1990s, when the Baltic countries first appeared as research nations in their own right, but after that period the degree of cooperation levelled out. Cooperation with Eastern EU shows a similar pattern. In both cases, Iceland stands out somewhat by continuing the increase throughout the studied period.

Although the increase in intra-Nordic cooperation between 1982 and 2008 has not been as great as the increase in cooperation with other regions, it is clear that Nordic cooperation in research remains important within a framework of increasing international cooperation in all relations.

# 1. Introduction

International cooperation in research has received considerable attention during the last decades, and it is seen as both a sign of and a means to high-quality research (Luukkonen, Persson & Sivertsen 1992; Glänzel, Schubert & Czerwon 1999; Engels & Ruschenburg 2008; Aksnes, Frölich & Slipersæter 2008; Gornitzka & Langfeldt 2008). In this report, we have set out to use bibliometric methods to describe international cooperation in research in the Nordic countries. We describe trends and the current status of international cooperation for the Nordic countries, both on a regional and on a per-country basis.

The bibliometric source has been the Thomson Reuters database at the Swedish Research Council, which includes the *Science Citation Index Expanded*, the *Social Sciences Citation Index* and the *Arts & Humanities Citation Index*.<sup>2</sup> The study has been limited to articles, letters and reviews published between 1984 and 2008 that had at least one subject tag and one address, all in all 19 million publications. The 255 subject classes used by Thomson Reuters have been grouped into three main subject areas: Life Sciences, Natural Sciences, and Social Sciences & Humanities. Life Sciences comprise 50% of the publications in the database, Natural Sciences 44 %, while Social Sciences & Humanities only 6 %. The miniscule share of social science and humanities publications is mainly a result of the fact that the Thomson Reuters database typically covers only 5–15% of the research publications produced in

those fields (Sivertsen 2009). For that reason, the Thomson Reuters database generally cannot be used as a source for bibliometric analyses in those areas. However, there are a few exceptions to this rule, so we have included numbers for the social sciences and humanities in this report, where relevant. Further, total numbers include the social sciences and humanities, both in order to facilitate comparison with other reports and because these subjects have very little influence on the total numbers.

Cooperation can mean many different things, but in this report it has a very precise meaning: co-authorship. A publication with two author addresses denoting different countries is called an international co-publication and considered a result of international cooperation.

The USSR and Russia have been treated as the same country throughout this report, and the Baltic countries have been grouped into one unit. Throughout the report, publication numbers are reported as so-called whole counts; publication numbers for the world are the sum of the whole-count publication numbers of all countries.

More details on the methods used here are provided in the Appendix.

## **Bibliometric databases**

There are a number of available databases that contain information about scientific publications. However, only two of these are of sufficient quality and scope for our purposes: the Thomson Reuters citation database, often called *Web of Science*, and Elsevier's *Scopus*. Both of these databases are complex and expensive, but since the Swedish Research Council has access to the Thomson Reuters database, as well as several years' experience with it, this was chosen as our data source.

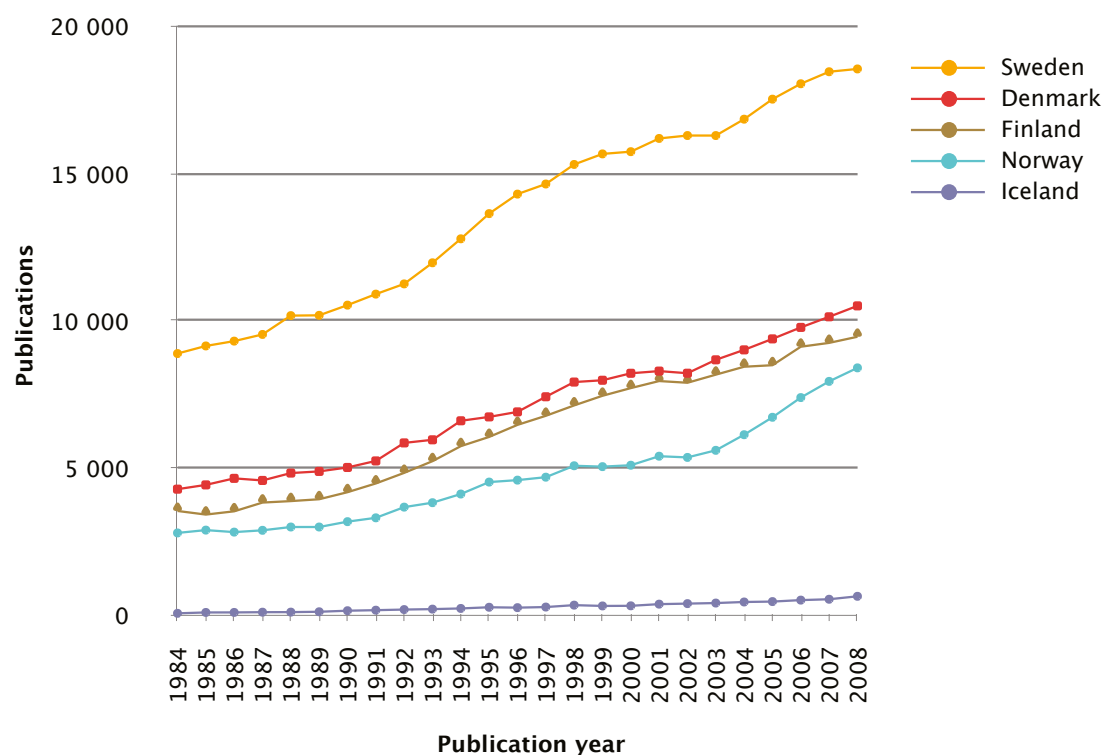
## 2. Total publication volume and number of international publications

The aim of this chapter is to give a broad overview of the development of the publication volumes of the Nordic countries and a selection of other countries. It also describes the development of the degree of international cooperation behind the scientific publications from the respective countries. We shall see, among other things, that almost the entire publica-

tion growth in the Nordic countries since the 1980s consists of international co-publications, the exception being Iceland, which has also seen considerable growth in national publications.

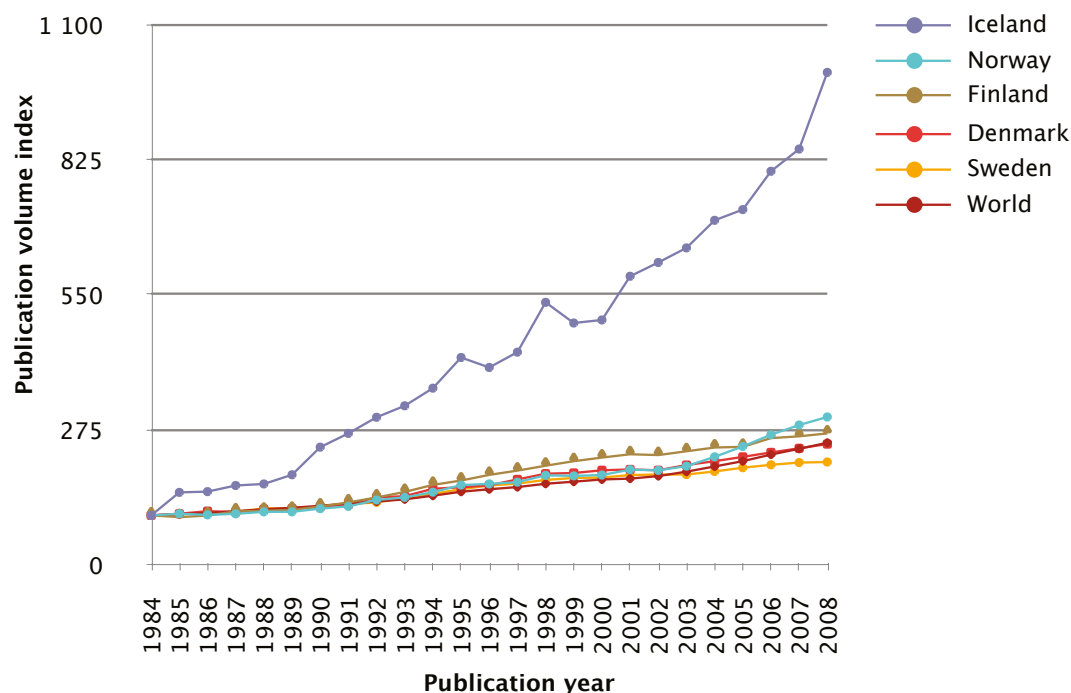
Figure 2.1 shows the number of publications produced by the Nordic countries each year since 1984.<sup>3</sup>

FIGURE 2.1. TOTAL NUMBER OF PUBLICATIONS, 1984–2008





**FIGURE 2.2. PUBLICATION INCREASE 1984–2008 (1984=100)**



Among the Nordic countries, Sweden is by far the largest nation at the present time, with 18,500 publications in 2008, while Denmark produced 10,500, Finland 9,500 and Norway 8,400 publications in the same year. Iceland's production was just above 600 publications in 2008.

In relative terms, the volume increase looks somewhat different, as Figure 2.2 shows.

Iceland has shown the largest increase (900%) since the early 1980s. The relative growth of the other countries has been considerably lower: 110% for Sweden, 140% for Denmark, 170% for Finland

and 200% for Norway. Norway has shown a marked increase over the last six years.

We also analysed the extent to which the Nordic countries differ in their scientific specialization. This can be analysed bibliometrically by calculating the relative distribution of publications on different subject areas.

Table 2.1 shows that the Nordic countries all have very similar profiles in the database, with a relatively high proportion of life sciences.

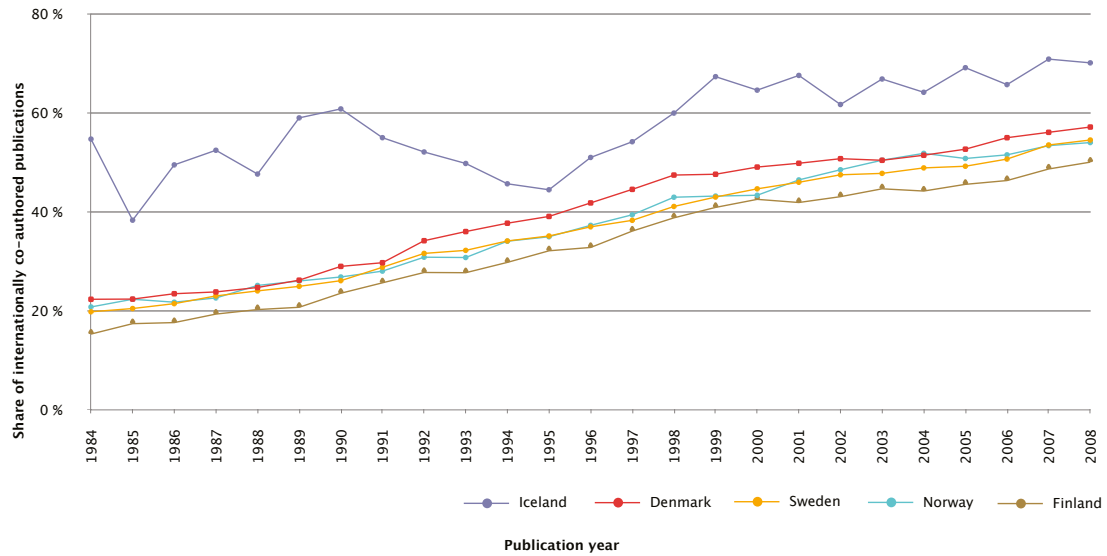
During recent decades, cooperation with international colleagues has become a very common

**TABLE 2.1. PROPORTION OF PUBLICATIONS PER SUBJECT AREA, 2004–2008**

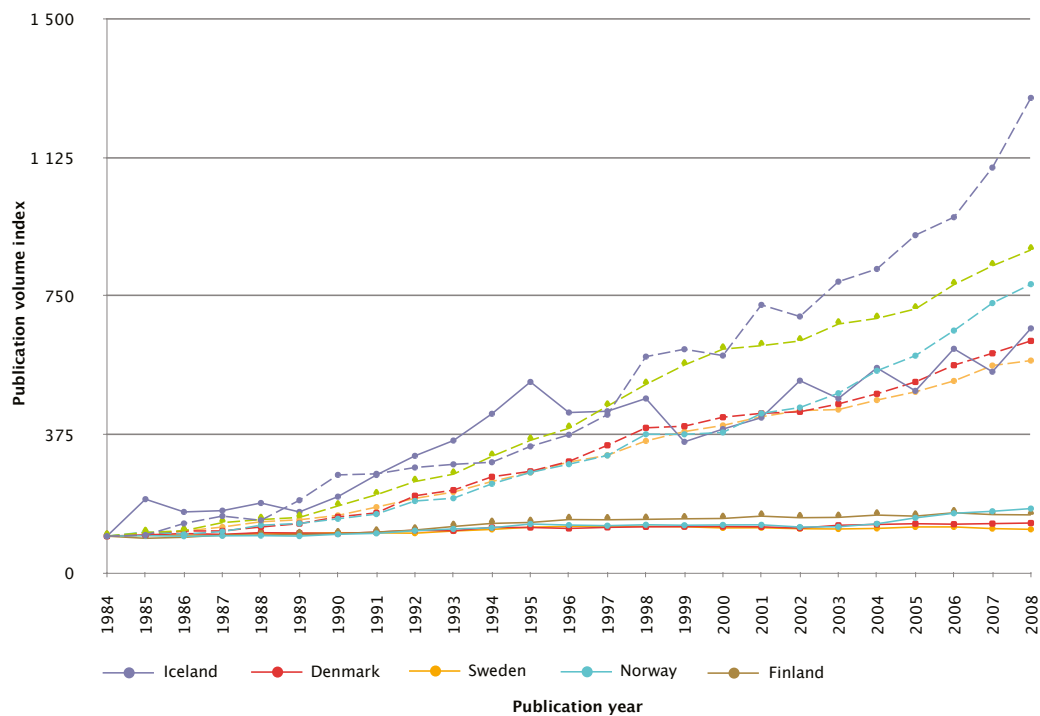
| Country                | Life Sciences | Natural Sciences | Social Sciences & Humanities | Total       |
|------------------------|---------------|------------------|------------------------------|-------------|
| Denmark                | 63%           | 32%              | 5%                           | 100%        |
| Finland                | 59%           | 37%              | 4%                           | 100%        |
| Iceland                | 58%           | 36%              | 7%                           | 100%*       |
| Norway                 | 59%           | 33%              | 8%                           | 100%        |
| Sweden                 | 60%           | 35%              | 5%                           | 100%        |
| <b>Entire database</b> | <b>50%</b>    | <b>44%</b>       | <b>6%</b>                    | <b>100%</b> |

\* The Icelandic numbers sum to 101% owing to rounding issues.

**FIGURE 2.3. THE SHARE OF INTERNATIONAL CO-PUBLICATIONS AMONG ALL PUBLICATIONS, FOR EACH NORDIC COUNTRY**



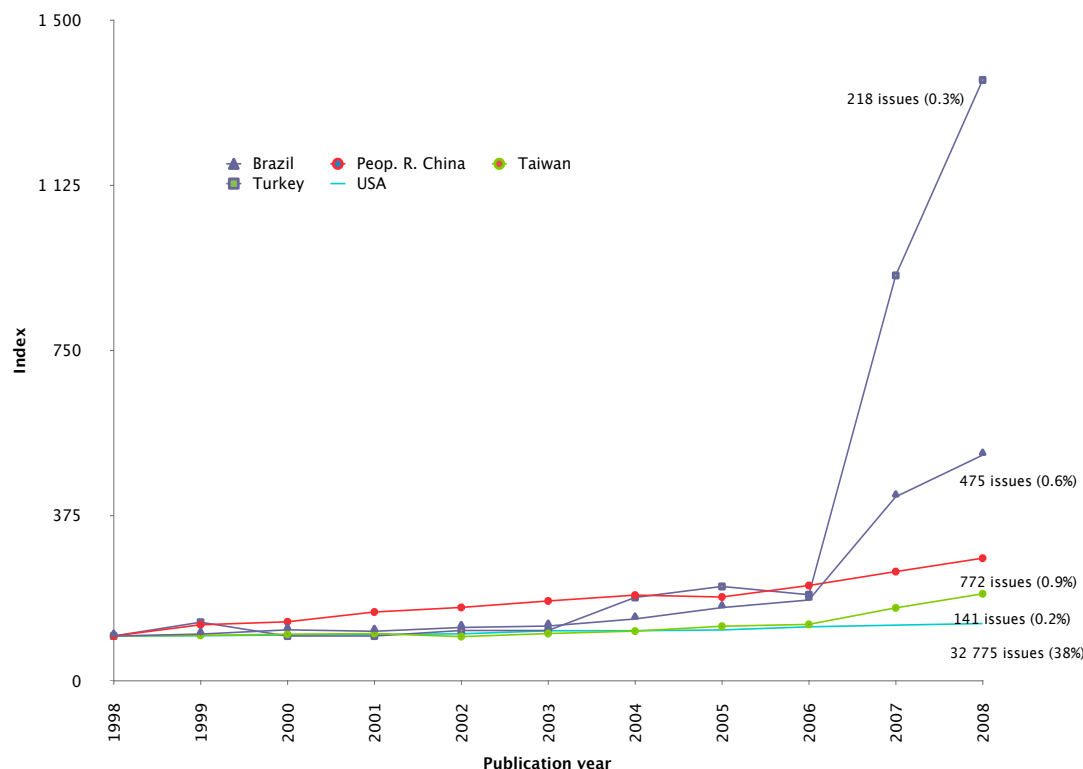
**FIGURE 2.4. INTERNATIONAL CO-PUBLICATION GROWTH COMPARED TO NATIONAL PUBLICATION GROWTH (1984=100)**



practice in research communities in all fields (Luukkonen, Persson & Sivertsen 1992; Wuchty, Jones & Uzzi 2007; Aksnes, Frölich & Slipersæter 2008). This is reflected bibliometrically through increasing proportions of articles involving international co-authorship. This is a general phenomenon that can be seen in all countries, but small nations are gener-

ally more exposed to this trend than larger ones (this is discussed further below). That small countries tend to cooperate more than large countries is clearly visible also in the results presented here (see Figure 2.3). For all the Nordic countries, we find a marked increase in international co-authorship during the period 1984–2008, and the proportion of the pub-

**FIGURE 2.5. RELATIVE GROWTH IN NUMBER OF JOURNAL ISSUES WITH PUBLISHER ADDRESS IN FIVE SELECTED COUNTRIES (1998=100). FOR 2008, ABSOLUTE NUMBERS AND THE SHARES OF ALL JOURNAL ISSUES ARE ALSO SHOWN.**



lications involving such cooperation has doubled or tripled since the mid-1980s. In 2008, approximately every second paper published by Norwegian, Swedish, Danish or Finnish researchers had co-authors from another country. Iceland stands out as even more internationalized than the other Nordic countries, with a proportion above 70% in 2008.

A general pattern found across most figures in this report is that the numbers for small countries tend to vary considerably from year to year. This is nothing new, but rather a fundamental and well-known property of statistical studies. However, since the volume of Iceland's publication output is so much smaller than those of the other Nordic countries, it is worth pointing out this property. The numbers for Iceland reported here in all cases vary much more between the studied periods than the corresponding numbers for the other countries.

When the relative growth of the international co-publications is compared to that of national publications, the increased importance of international cooperation becomes clearer, as shown in Figure 2.4.

Figure 2.4 shows that almost all of the growth in publications since the 1980s consists of interna-

tional co-publications, the exception being Iceland, which has also seen considerable growth in terms of national publications.

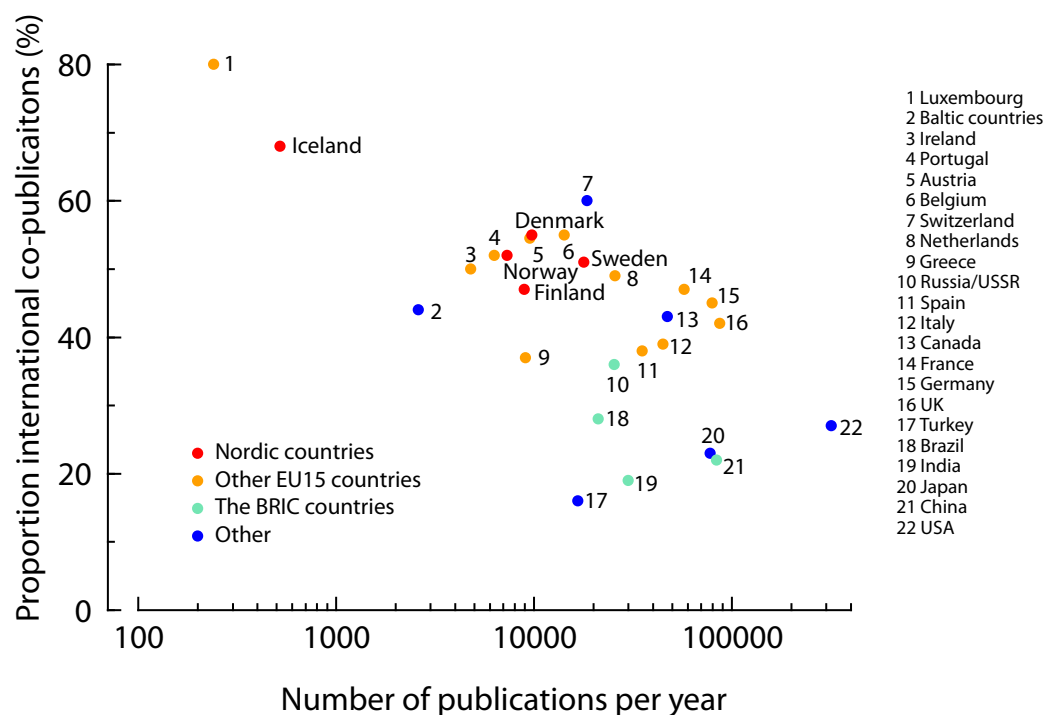
In Table 2.2, the data from Figure 2.3 are transformed into three five-year periods and compared both with the other EU15 nations and with some additional countries and regions (the selection of countries and regions is explained in the Appendix). A general pattern is that the smaller the size of the national publication output, the higher the proportion of international co-publications. The total publication volume is therefore also included in Table 2.2 for comparison.

The general trend in Table 2.2 is that both publication volumes and the shares of international co-publications have increased considerably since the 1980s. China, the Republic of Korea and Turkey deviate from this pattern by having exceptional growth in the volume of their publications, but where the share of international co-publications has remained fairly constant or even decreased somewhat. Brazil more or less follows the same pattern as China, Korea and Turkey, but the increase in the total volume of its publications is more moderate. Along with changes

**TABLE 2.2. THE PROPORTION OF INTERNATIONAL CO-PUBLICATIONS BY COUNTRY DURING THREE FIVE-YEAR PERIODS. THE TOTAL PRODUCTION VOLUME IS ALSO PRESENTED FOR COMPARISON.**

| Country/region     | The proportion of international co-publications |            |            | Total number of publications |               |               |
|--------------------|-------------------------------------------------|------------|------------|------------------------------|---------------|---------------|
|                    | 1984–88                                         | 1994–98    | 2004–08    | 1984–88                      | 1994–98       | 2004–08       |
| Argentina          | 13%                                             | 31%        | 44%        | 8 646                        | 16 473        | 28 423        |
| Australia          | 14%                                             | 26%        | 41%        | 65 709                       | 101 700       | 155 130       |
| Austria            | 22%                                             | 39%        | 55%        | 16 647                       | 30 774        | 48 743        |
| Baltics            | 0%                                              | 49%        | 44%        | 1                            | 5 619         | 13 015        |
| Belgium            | 25%                                             | 42%        | 55%        | 27 141                       | 46 323        | 71 311        |
| Brazil             | 22%                                             | 35%        | 28%        | 13 843                       | 34 644        | 105 591       |
| Canada             | 17%                                             | 29%        | 43%        | 137 722                      | 178 654       | 236 857       |
| China              | 19%                                             | 25%        | 22%        | 22 463                       | 74 885        | 420 400       |
| <b>Denmark</b>     | <b>23%</b>                                      | <b>42%</b> | <b>55%</b> | <b>22 755</b>                | <b>35 575</b> | <b>48 803</b> |
| <b>Finland</b>     | <b>18%</b>                                      | <b>34%</b> | <b>47%</b> | <b>18 185</b>                | <b>32 153</b> | <b>44 745</b> |
| France             | 18%                                             | 32%        | 47%        | 148 488                      | 233 686       | 287 471       |
| Germany            | 16%                                             | 31%        | 45%        | 207 216                      | 304 320       | 398 856       |
| Greece             | 24%                                             | 34%        | 37%        | 8 114                        | 19 357        | 45 297        |
| <b>Iceland</b>     | <b>48%</b>                                      | <b>52%</b> | <b>68%</b> | <b>461</b>                   | <b>1 376</b>  | <b>2 609</b>  |
| India              | 7%                                              | 13%        | 19%        | 69 379                       | 81 810        | 149 728       |
| Ireland            | 20%                                             | 36%        | 50%        | 6 535                        | 11 773        | 24 014        |
| Israel             | 25%                                             | 35%        | 41%        | 33 792                       | 46 035        | 57 446        |
| Italy              | 20%                                             | 31%        | 39%        | 71 853                       | 143 683       | 225 391       |
| Japan              | 7%                                              | 14%        | 23%        | 185 835                      | 325 156       | 390 362       |
| Korea, Republic of | 27%                                             | 25%        | 26%        | 3 964                        | 37 130        | 144 018       |
| Luxembourg         | 38%                                             | 66%        | 80%        | 117                          | 365           | 1 202         |
| Mexico             | 26%                                             | 38%        | 43%        | 6 377                        | 17 536        | 38 694        |
| Netherlands        | 19%                                             | 34%        | 49%        | 53 226                       | 92 732        | 128 788       |
| New Zealand        | 15%                                             | 30%        | 49%        | 14 445                       | 20 438        | 29 635        |
| <b>Norway</b>      | <b>23%</b>                                      | <b>38%</b> | <b>52%</b> | <b>14 384</b>                | <b>22 985</b> | <b>36 579</b> |
| Portugal           | 35%                                             | 46%        | 52%        | 2 581                        | 10 009        | 31 610        |
| Rest of the EU     | 19%                                             | 41%        | 44%        | 74 803                       | 107 801       | 191 335       |
| Rest of the World  | 28%                                             | 42%        | 51%        | 72 132                       | 138 200       | 266 822       |
| Russia/USSR        | 3%                                              | 24%        | 36%        | 185 054                      | 136 679       | 127 225       |
| Singapore          | 20%                                             | 28%        | 44%        | 2 765                        | 10 995        | 34 302        |
| South Africa       | 11%                                             | 25%        | 46%        | 17 863                       | 19 540        | 27 824        |
| Spain              | 13%                                             | 28%        | 38%        | 37 357                       | 95 164        | 176 421       |
| <b>Sweden</b>      | <b>22%</b>                                      | <b>37%</b> | <b>51%</b> | <b>47 042</b>                | <b>70 665</b> | <b>89 415</b> |
| Switzerland        | 30%                                             | 45%        | 60%        | 38 330                       | 63 468        | 92 940        |
| Taiwan             | 19%                                             | 17%        | 20%        | 6 748                        | 38 320        | 91 475        |
| Turkey             | 22%                                             | 19%        | 16%        | 3 075                        | 17 688        | 83 423        |
| Ukraine            | 11%                                             | 30%        | 48%        | 9                            | 20 283        | 20 757        |
| United Kingdom     | 13%                                             | 25%        | 42%        | 262 157                      | 363 029       | 435 448       |
| United States      | 8%                                              | 16%        | 27%        | 1 111 345                    | 1 361 534     | 1 592 338     |

**FIGURE 2.6. RELATIONSHIP BETWEEN THE PROPORTION OF INTERNATIONAL CO-PUBLICATIONS AND THE ANNUAL AVERAGE PUBLICATION VOLUME 2004–2008 (DATA FROM TABLE 2.2).**



in real-world production, the pattern for these four countries is also an effect of changes in database coverage, as shown by Figure 2.5.<sup>4</sup>

Figure 2.5 shows that while the number of US-based journal issues has remained fairly constant during the last decade, the corresponding figures for the other four countries have increased significantly. This can be explained by the fact that Thomson Reuters has been rapidly expanding its coverage of journals recently, especially journals from countries that traditionally have not been well covered in the database. It should be noted that, in absolute numbers, the United States stands for the vast majority of the journal issues in the database, while the other countries in Figure 2.5 stand for a small fraction.

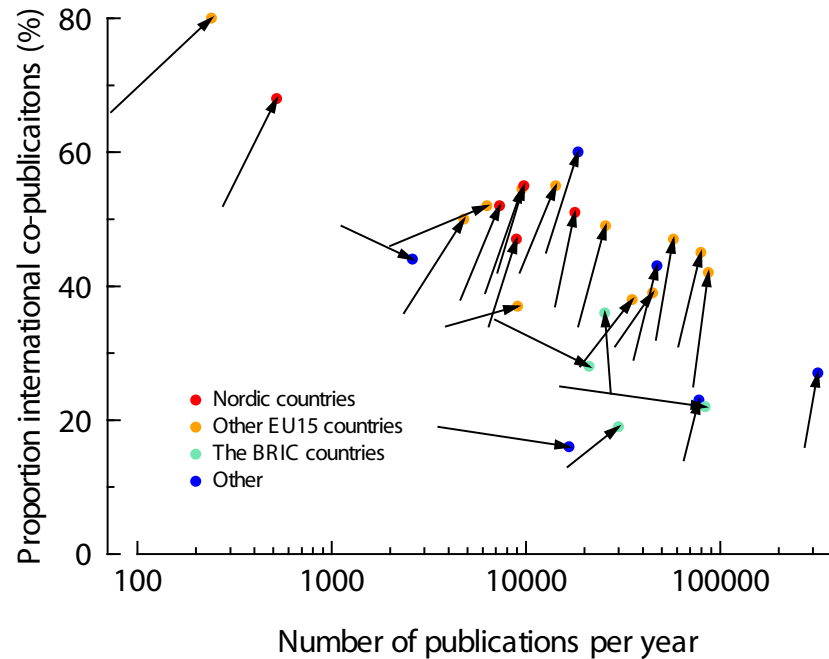
Luxembourg, Portugal, Singapore and Taiwan have all experienced dramatic increases in their publication volumes, but from very low levels. The disintegration of the USSR at the end of 1980s explains the extreme changes in Table 2.2 between the two first periods for the Baltic countries, Ukraine and Russia/USSR.

Another general trend visible in Table 2.2 is that countries with a low production of scientific publications (i.e. small countries) tend to have a large

share of international co-publications. The relationship between size and internationalization measured through international co-publications is shown in Figure 2.6. From this figure, it is also apparent that Turkey, Taiwan, China, India and Japan have relatively low proportions of international co-publications relative to their size. Furthermore, Switzerland has a high proportion in relation to its size. Among the EU15 countries, Greece, Italy and Spain show relatively low degrees of international cooperation considering their size.

Luukkonen, Persson & Sivertsen(1992) found the same general pattern, with the highest relative frequency of international collaboration being associated with the smallest countries. They explained this in terms of the greater need in small countries to share the costs of research infrastructure and to combine scarce competences in highly specialized research. According to the same study, deviances from the general pattern can either be explained as an artifact of the database – for example, an unusually low or high database coverage of journals from a certain country – or in terms of geopolitical and cultural factors that stimulate or inhibit research collaboration in certain relations. Both of these expla-

**FIGURE 2.7. CHANGE\* IN THE RELATIONSHIP BETWEEN THE PROPORTION OF INTERNATIONAL CO-PUBLICATIONS AND THE ANNUAL AVERAGE PUBLICATION VOLUME BETWEEN 1994–1998 AND 2004–2008 (DATA FROM TABLE 2.2. TO IDENTIFY INDIVIDUAL COUNTRIES, SEE FIGURE 2.6).**



\* The starting point of the arrow defines mean publication volume and the degree of internationalization during 1994–1998; the arrow point/coloured symbol defines the mean state 2004–2008.

nations are relevant in the present study, as seen in our discussion above. The four mainland Nordic countries are all fairly closely located in Figure 2.6, having publication volumes of similar magnitude. Iceland stands out here, having a smaller publication volume and accordingly a higher share of international co-publications.

Analysing how the relationship between volume and international cooperation changes over time reveals a pattern that holds for most countries. Interestingly, the pattern is thus robust over a wide range of nations. This conclusion also holds when expanding the analysis and including the 1980s (not shown).

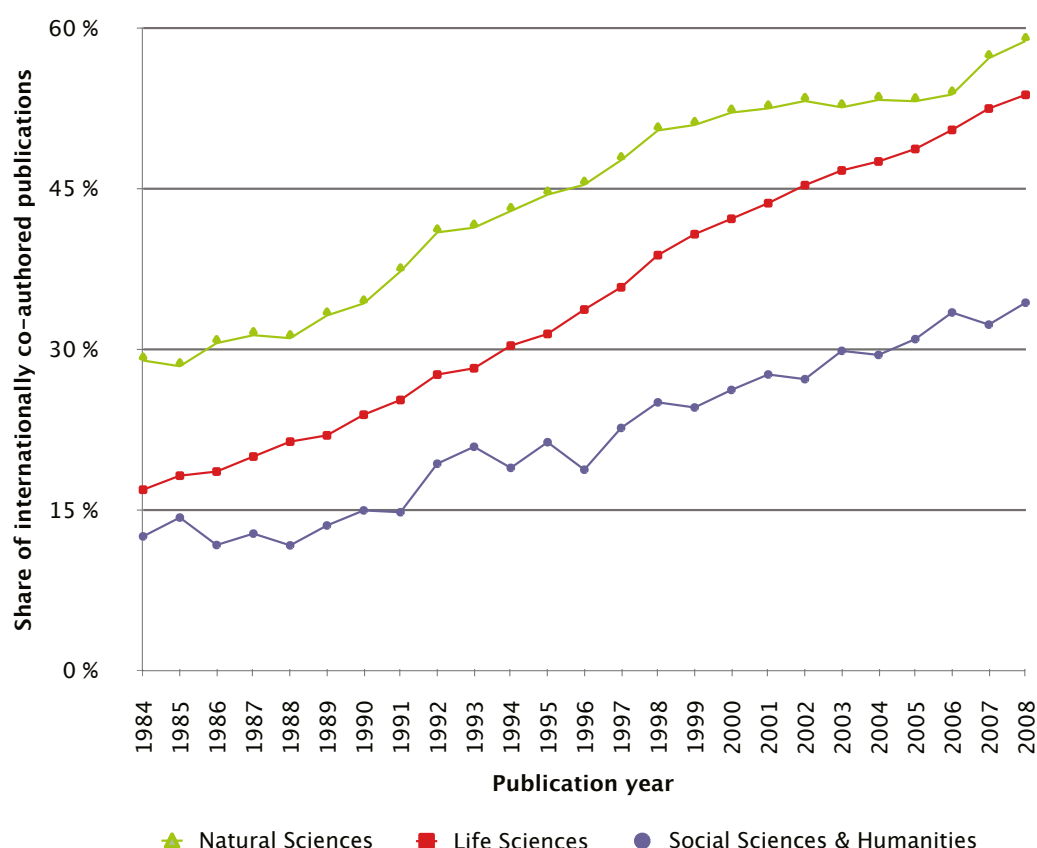
Mainly five countries deviate from the general pattern (marked in green in Figure 2.6 and Figure 2.7): Brazil, China, Taiwan, Korea and Turkey. As mentioned above, this can at least partly be explained by changes in database coverage. These countries have a strong increase in publication volume, but in combination with a small increase or even a decrease in the proportion of international co-publications. Russia has a decreasing publication output, while its degree of international cooperation has increased. The Baltic countries and Greece have increased their

publication volumes, while the proportion of international co-publications for these countries shows a modest increase.

The overall trend towards increasing international cooperation shown in Figure 2.3 is present in all areas. However, there are also area-specific patterns: The social sciences and humanities show the lowest proportion of international co-publications, reaching 34% in 2008. This low share is not immediately explained by the low database coverage for those fields. A possible explanation for this is that co-publication in general is less common in the social sciences and humanities: Single-author papers constitute 65% of all publications in the social sciences and humanities between 2004 and 2008; for life sciences and natural sciences, the shares are 9% and 13%, respectively.<sup>5</sup>

The life sciences currently have 54% international co-publications, while the natural sciences have a slightly higher share, 59 %.

**FIGURE 2.8. THE PROPORTION OF INTERNATIONAL CO-PUBLICATIONS IN THE THREE MAIN SUBJECT AREAS (ALL COUNTRIES)**



## SUMMARY OF CHAPTER 2

This chapter has given a broad overview of the development of publication volumes of the Nordic countries and a selection of other countries. Measured in terms of publication volume (whole counts), Sweden is the largest country (18,500 publications in 2008), with Denmark, Finland and Norway following (with 10,500, 9,500 and 8,400 publications in 2008, respectively). Iceland is considerably smaller (600 publications in 2008).

The relative increase in publication volumes since the early 1980s is inversely related to the size of the volumes themselves: Sweden's volume has increased 110%, while Iceland's has increased 900%.

Following the general international trend of increased international cooperation in research, all of the Nordic countries show a marked increase in the number of

international co-publications during the period 1984–2008, and the proportion of publications involving such cooperation has doubled or tripled since the mid-1980s. In 2008, approximately every second paper published by Norwegian, Swedish, Danish or Finnish researchers had co-authors from another country. Iceland stands out as even more internationalized than the other Nordic countries, with a proportion above 70% in 2008. This is consistent with the general pattern that the proportion of international co-publications increases with decreasing size of national publication output.

Almost all of the growth in publication volumes since the 1980s consists of international co-publications, the exception being Iceland, which has also experienced considerable growth in the volume of its national publication output.

# 3. Interregional cooperation

This chapter deals with international cooperation between the Nordic region and other large geographic regions. International co-publications involving at least one Nordic address were placed in one or more categories based on the other countries represented in the list of author addresses (see the Appendix for details on which countries are included in the regions). The categories were as follows:

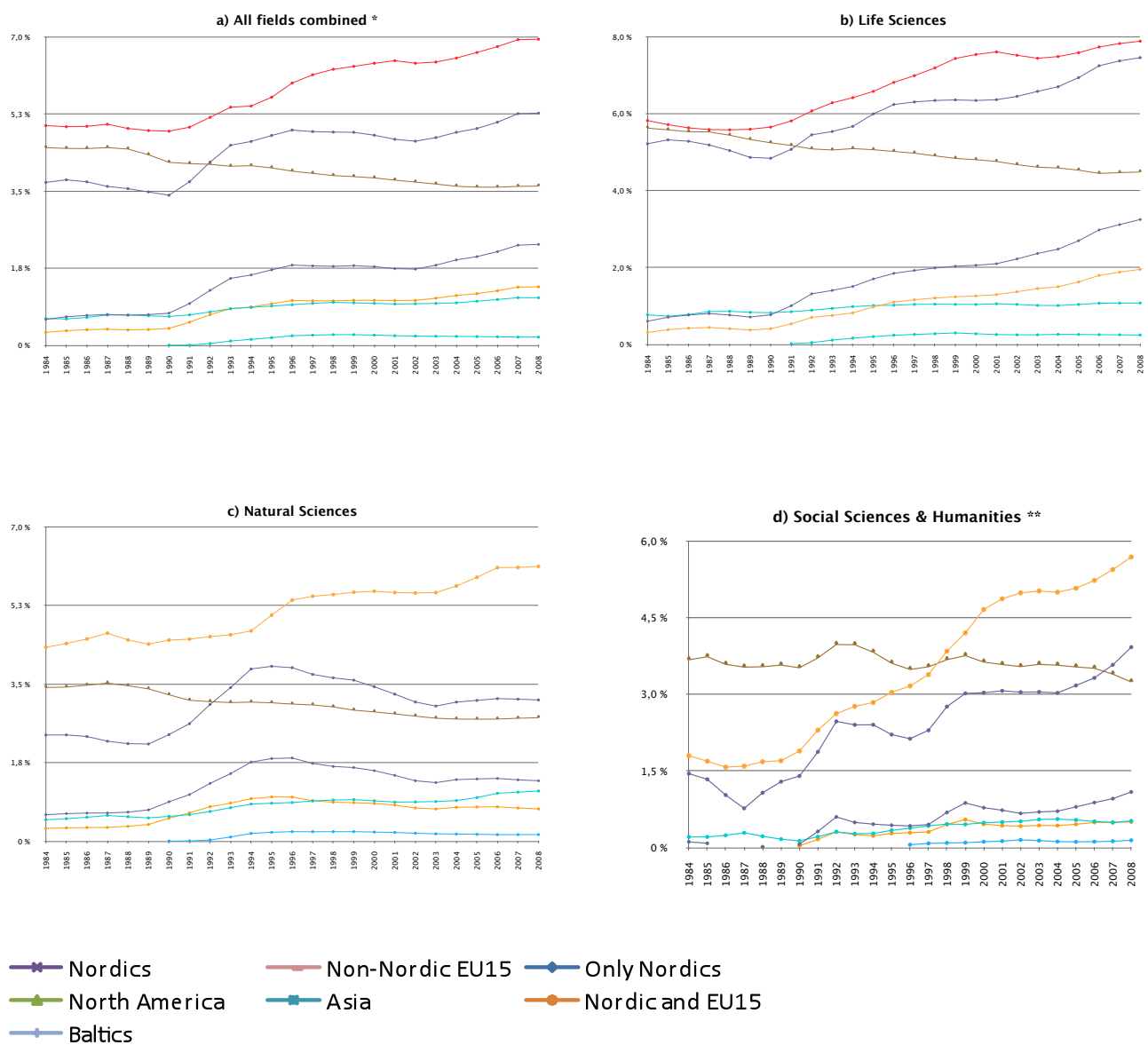
- *Only Nordics*: publications with more than one Nordic country and without any non-Nordic countries represented in the address list.
- *Nordics*: publications with more than one Nordic country represented in the address list (and possibly other countries).
- *Non-Nordic EU15*: publications with exactly one Nordic and at least one non-Nordic EU15 country represented in the address list.
- *Nordic and EU15*: publications with at least two Nordic countries and one non-Nordic EU15 country represented in the address list.
- *Baltics*: publications with at least one Nordic and one Baltic country represented in the address list.
- *Asia*: publications with at least one Nordic and one Asian country represented in the address list.
- *North America*: publications with at least one Nordic and one North American country represented in the address list.

The charts in Figure 3.1 show that cooperation with all listed regions increased during the period under study. They also show that the most common types of international cooperation for researchers in the Nordic countries have been cooperation with other Nordic, North American and EU15 countries. However, relative to other types of cooperation, cooperation with North American countries has decreased during the period studied. These general trends hold for all fields.

It should be noted that strictly Nordic cooperation – that is, cooperation with at least two Nordic countries and no other countries – remains an important type of cooperation. In the natural sciences, it has diminished during the last decade, while it has increased in the life sciences during the same period.



**FIGURE 3.1. INTERNATIONAL CO-PUBLICATIONS INVOLVING NORDIC COUNTRIES, AS SHARE OF ALL INTERNATIONAL CO-PUBLICATIONS. THREE-YEAR AVERAGES ARE USED.**



\* Note that Social Sciences & Humanities is a very small subject area compared to Natural Sciences and Life Sciences and has virtually no impact at all on diagram (a).

\*\* The absolute numbers in diagram (d) are very small; even for the largest category, Nordic cooperation, the number of publications in 2008 was only 5,899. In 1990, it was a mere 293.

## 4. Patterns for international cooperation

In this chapter, we take a closer look at which countries and regions the Nordic countries cooperate with. Among other things, we shall see that cultural proximity seems to be a strong factor behind the choice of cooperation partner.

To report data from all countries in the world would have made the report impossible to read. Accordingly, a selection of relevant countries was made. One criterion used in this selection was to include all countries with at least 25,000 publications between 1984 and 2008.

Table 4.1 shows the shares that a number of countries have in the international production of the Nordic countries. When the table is read horizontally, each row compares the country/region of that row as co-publication partner for each of the Nordic countries. For example, Russia stands for 3.7% of Finland's international co-publications, but only 0.9% of Iceland's international co-publications. The rightmost column is not a row sum, but the share that the country in question has of all international publications.

Reading the table vertically shows the importance of the listed countries/regions as co-publication partners for a given Nordic country. For example, for Denmark we see that the United States, the United Kingdom, Germany and Sweden are the most common co-publication partners.

To enable better understanding of the relative numbers in Table 4.1, we will now investigate the data in greater detail. First, we will focus on one Nordic country at a time and examine which countries are chosen as cooperation partners most often. Then, we will look at which regions or parts of the world each of the Nordic countries cooperates most often with. Finally, we will look at the Nordic region as a whole and its pattern of cooperation with other regions.

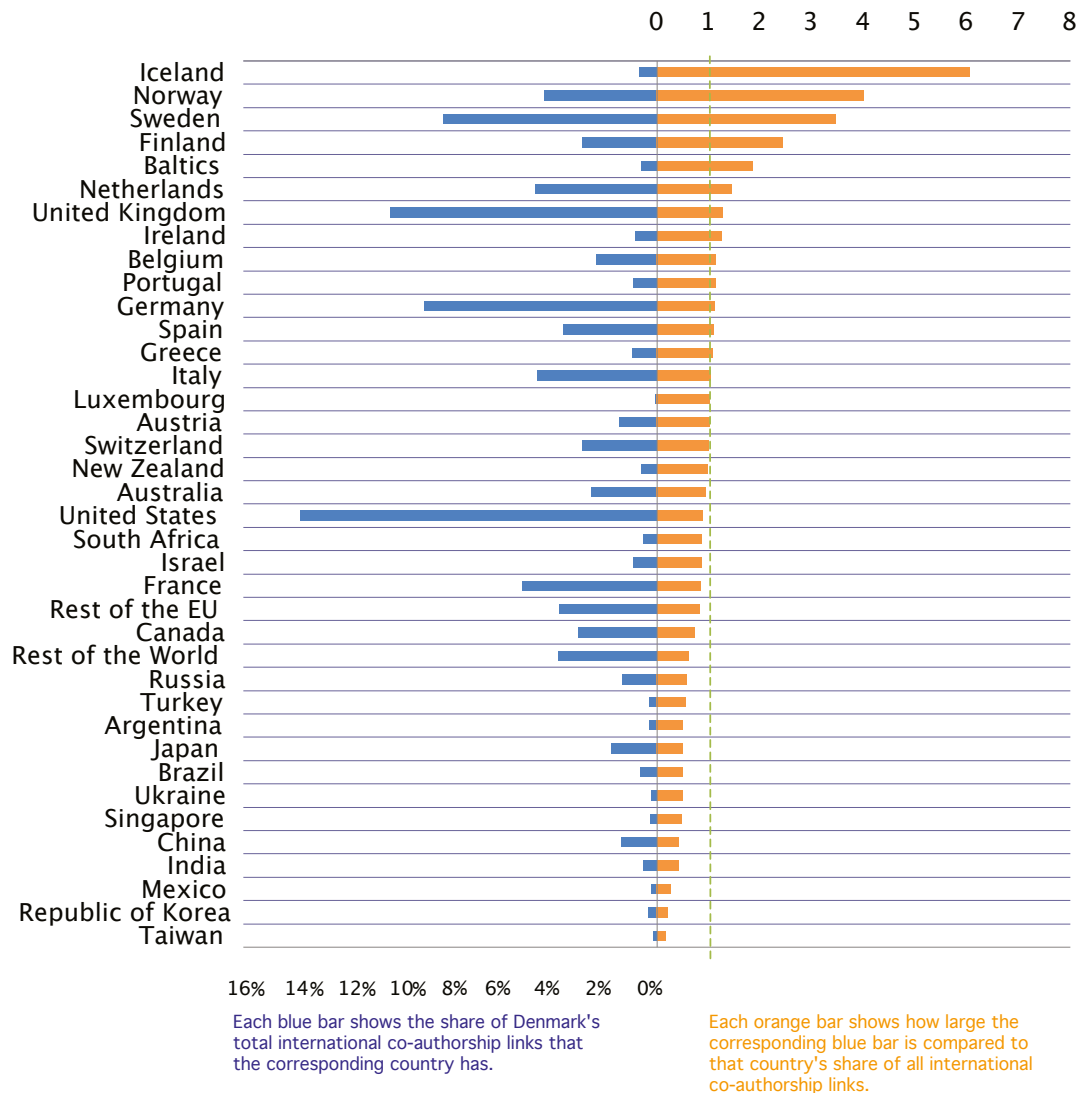
### Cooperation patterns per country

In Figures 4.1–4.5, it can be seen that the United States is the most common country for Nordic cooperation, usually followed by the United Kingdom, Germany and Sweden. However, since the United States, the United Kingdom and Germany are also the largest international research nations overall, it is not surprising that they come out on top. To see the cooperation patterns for individual countries more clearly, we will use diagrams that include the measure observed/expected share. This measure was introduced in Luukkonen, Persson & Sivertsen (1992) and expresses how large the cooperation with a given country is in relation to that country's size. In the case of Denmark (see Figure 4.1), the co-authorship links with Iceland constitute 0.66% of Denmark's total international co-authorship links. However, since the Icelandic share in the total pool of international co-authorship links is only 0.11%, a share of 0.66% is quite a lot. The share in the total pool of international co-authorship links can be considered the expected share, and so the ratio observed/expected share is 6 for Denmark in relation to Iceland. This is explained in greater detail in the Appendix.

**TABLE 4.1. INTERNATIONAL CO-PUBLICATIONS 2004–2008  
FOR A NUMBER OF COUNTRIES/REGIONS, AS PERCENTAGES  
OF INTERNATIONAL CO-PUBLICATIONS IN NORDIC COUNTRIES  
AND IN THE WORLD. HIGH NUMBERS ARE MARKED WITH RED,  
AND LOW NUMBERS WITH YELLOW.**

| Country/region     | Denmark (%) | Finland (%) | Iceland (%) | Norway (%) | Sweden (%) | World (%) |
|--------------------|-------------|-------------|-------------|------------|------------|-----------|
| Argentina          | 0.30        | 0.20        | 0.20        | 0.20       | 0.40       | 0.60      |
| Australia          | 2.50        | 1.70        | 1.60        | 1.90       | 2.20       | 2.60      |
| Austria            | 1.50        | 1.50        | 1.30        | 1.50       | 1.50       | 1.40      |
| Baltics            | 0.60        | 1.80        | 1.10        | 0.60       | 1.10       | 0.30      |
| Belgium            | 2.30        | 2.00        | 1.50        | 1.70       | 2.10       | 2.00      |
| Brazil             | 0.60        | 0.60        | 0.40        | 0.60       | 0.90       | 1.30      |
| Canada             | 3.00        | 3.20        | 3.30        | 4.00       | 3.00       | 4.10      |
| China              | 1.40        | 1.30        | 1.10        | 1.60       | 2.50       | 3.30      |
| Denmark            | –           | 3.50        | 8.60        | 5.70       | 4.90       | 1.40      |
| Finland            | 2.90        | –           | 4.70        | 3.40       | 4.30       | 1.20      |
| France             | 5.20        | 4.70        | 4.50        | 5.70       | 5.30       | 6.10      |
| Germany            | 9.00        | 8.50        | 4.50        | 7.30       | 8.70       | 8.00      |
| Greece             | 0.90        | 1.00        | 0.60        | 1.00       | 0.90       | 0.90      |
| Iceland            | 0.70        | 0.40        | –           | 0.80       | 0.50       | 0.10      |
| India              | 0.50        | 0.50        | 0.20        | 0.40       | 0.70       | 1.20      |
| Ireland            | 0.80        | 0.90        | 1.10        | 0.70       | 0.80       | 0.60      |
| Israel             | 0.90        | 0.60        | 0.50        | 0.70       | 0.60       | 1.00      |
| Italy              | 4.60        | 4.60        | 2.80        | 4.40       | 4.50       | 4.40      |
| Japan              | 1.80        | 2.50        | 1.30        | 1.30       | 2.30       | 3.50      |
| Korea, Republic of | 0.30        | 0.70        | 0.30        | 0.30       | 0.60       | 1.50      |
| Luxembourg         | 0.10        | 0.10        | 0.20        | 0.10       | 0.10       | 0.10      |
| Mexico             | 0.20        | 0.20        | 0.30        | 0.20       | 0.40       | 0.70      |
| Netherlands        | 4.70        | 4.10        | 2.80        | 4.90       | 3.90       | 3.20      |
| New Zealand        | 0.60        | 0.40        | 0.60        | 0.60       | 0.40       | 0.60      |
| Norway             | 4.40        | 3.10        | 8.40        | –          | 3.90       | 1.10      |
| Portugal           | 0.90        | 1.10        | 1.10        | 0.80       | 0.90       | 0.80      |
| Rest of the EU     | 3.80        | 5.90        | 2.60        | 3.90       | 4.90       | 4.60      |
| Rest of the World  | 3.80        | 2.40        | 2.30        | 3.20       | 4.10       | 6.10      |
| Russia             | 1.30        | 3.70        | 0.90        | 2.80       | 2.50       | 2.30      |
| Singapore          | 0.30        | 0.30        | 0.60        | 0.20       | 0.30       | 0.60      |
| South Africa       | 0.50        | 0.30        | 0.20        | 0.70       | 0.50       | 0.60      |
| Spain              | 3.60        | 3.40        | 2.90        | 3.40       | 3.10       | 3.30      |
| Sweden             | 8.30        | 8.70        | 11.00       | 8.70       | –          | 2.40      |
| Switzerland        | 2.90        | 3.00        | 2.10        | 2.20       | 2.70       | 2.90      |
| Taiwan             | 0.10        | 0.50        | 0.40        | 0.20       | 0.20       | 0.80      |
| Turkey             | 0.30        | 0.50        | 0.30        | 0.40       | 0.30       | 0.50      |
| Ukraine            | 0.20        | 0.30        | 0.10        | 0.20       | 0.40       | 0.40      |
| United Kingdom     | 10.30       | 9.30        | 10.80       | 10.20      | 9.50       | 8.00      |
| United States      | 13.80       | 12.50       | 12.70       | 13.60      | 14.20      | 15.50     |
| Total              | 100%        | 100%        | 100%        | 100%       | 100%       | 100%      |

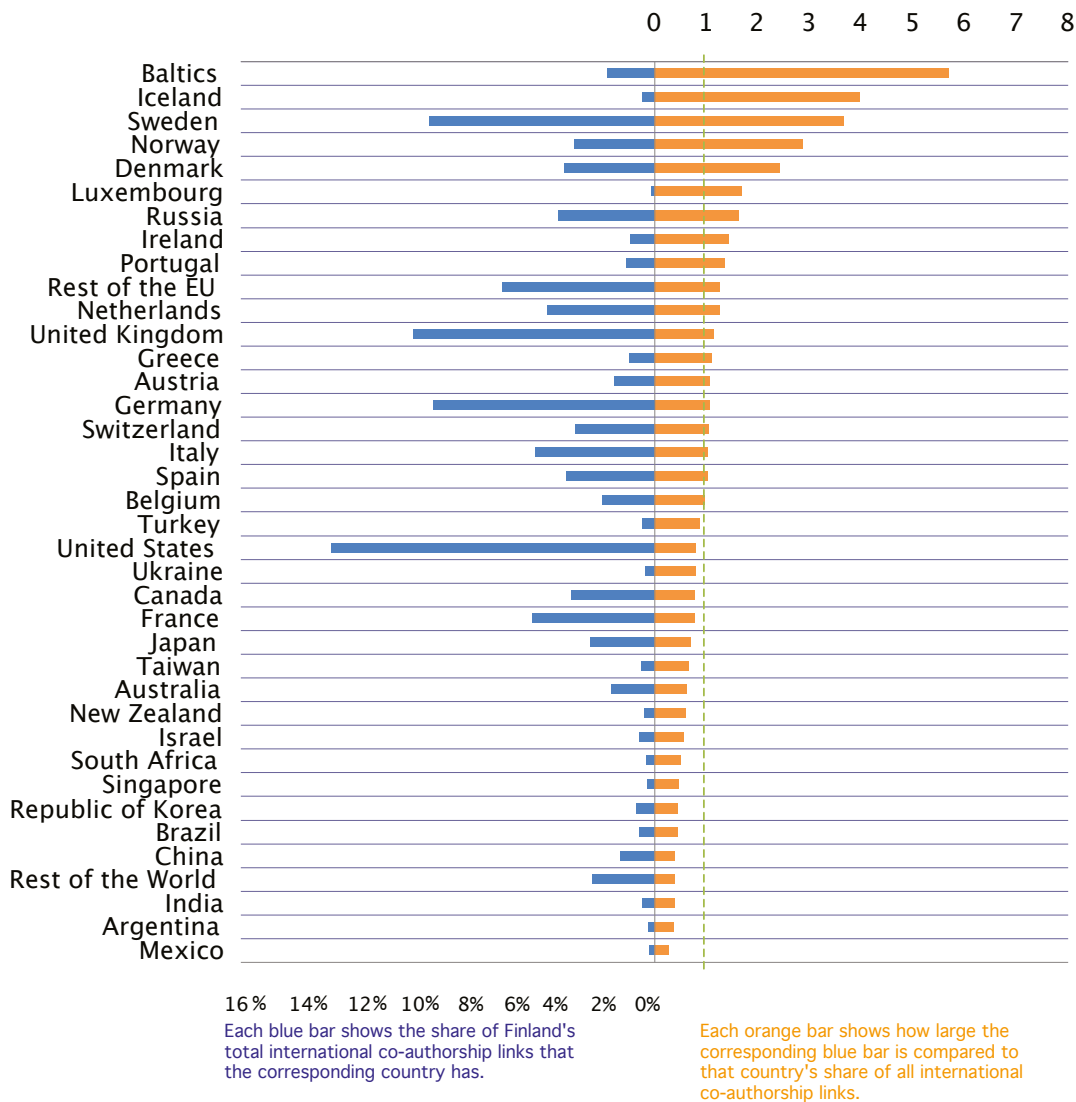
**FIGURE 4.1. DENMARK'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.**



According to Figure 4.1, cultural proximity seems to be a strong factor behind the choice of cooperation partners for Denmark. When the size of the partner country (in terms of international co-publications) is considered, the other Nordic and Baltic states are found at the top the list. The next 19 countries/regions – approximately the rest of the Western world – are chosen as cooperation partners by Danish researchers approximately as often as expected considering their size. The exception to this is South Africa, which is above both Canada and France in the Danish list. This is most likely an effect of directed development programmes.

The large Asian and Latin American research nations are found at the bottom of the list. Since the observed/expected measure is a zero-sum game, this means that some other countries cooperate more with these countries.

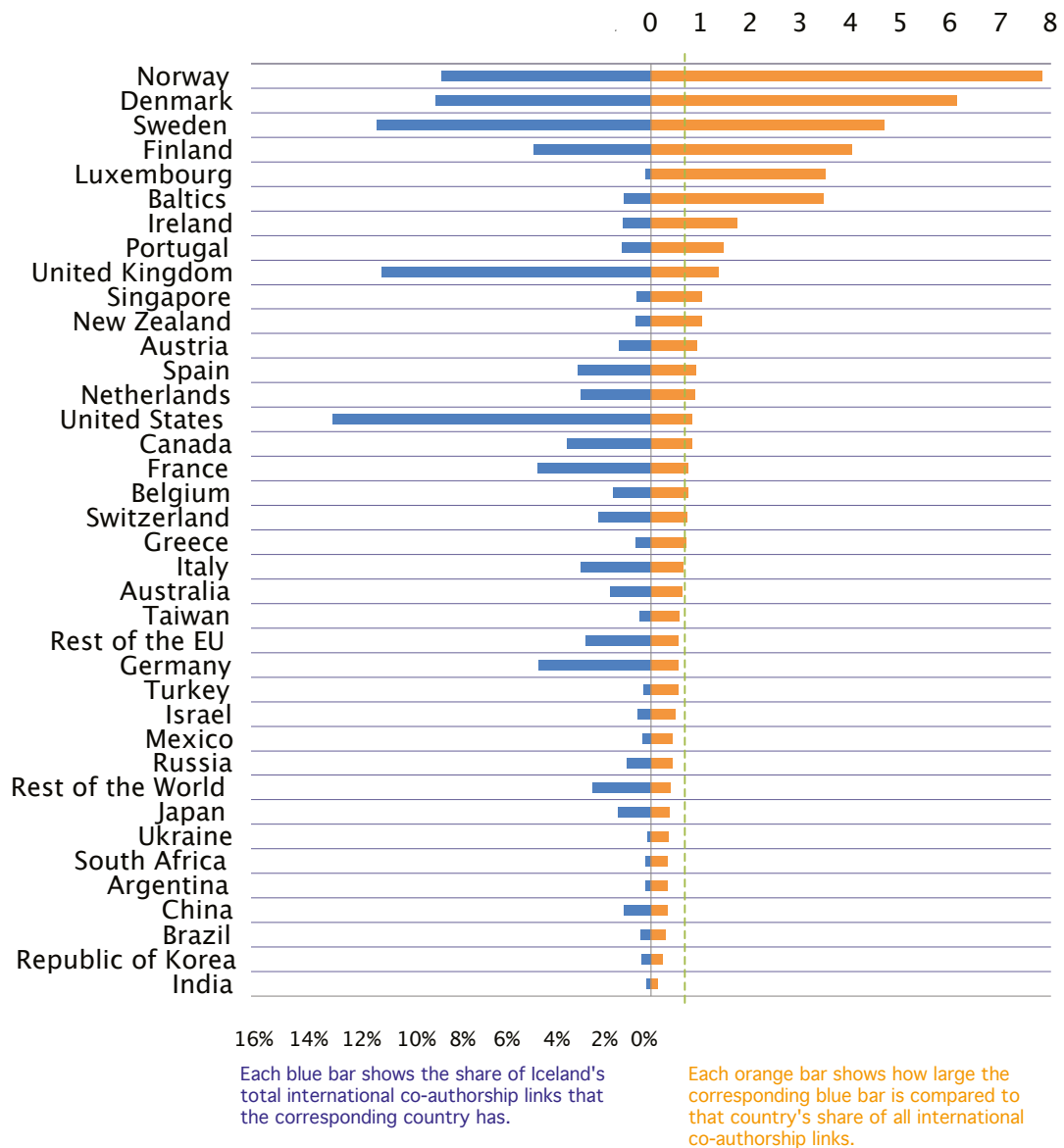
**FIGURE 4.2. FINLAND'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.**



As with Denmark, the other Nordic and Baltic countries are at the top of the list for Finland (see Figure 4.2). If Finland, culturally speaking, is closer than Denmark to the Baltic states, especially Estonia, it is not surprising that the Baltic states have a higher rank in the Finnish list than in the Danish one.<sup>6</sup>

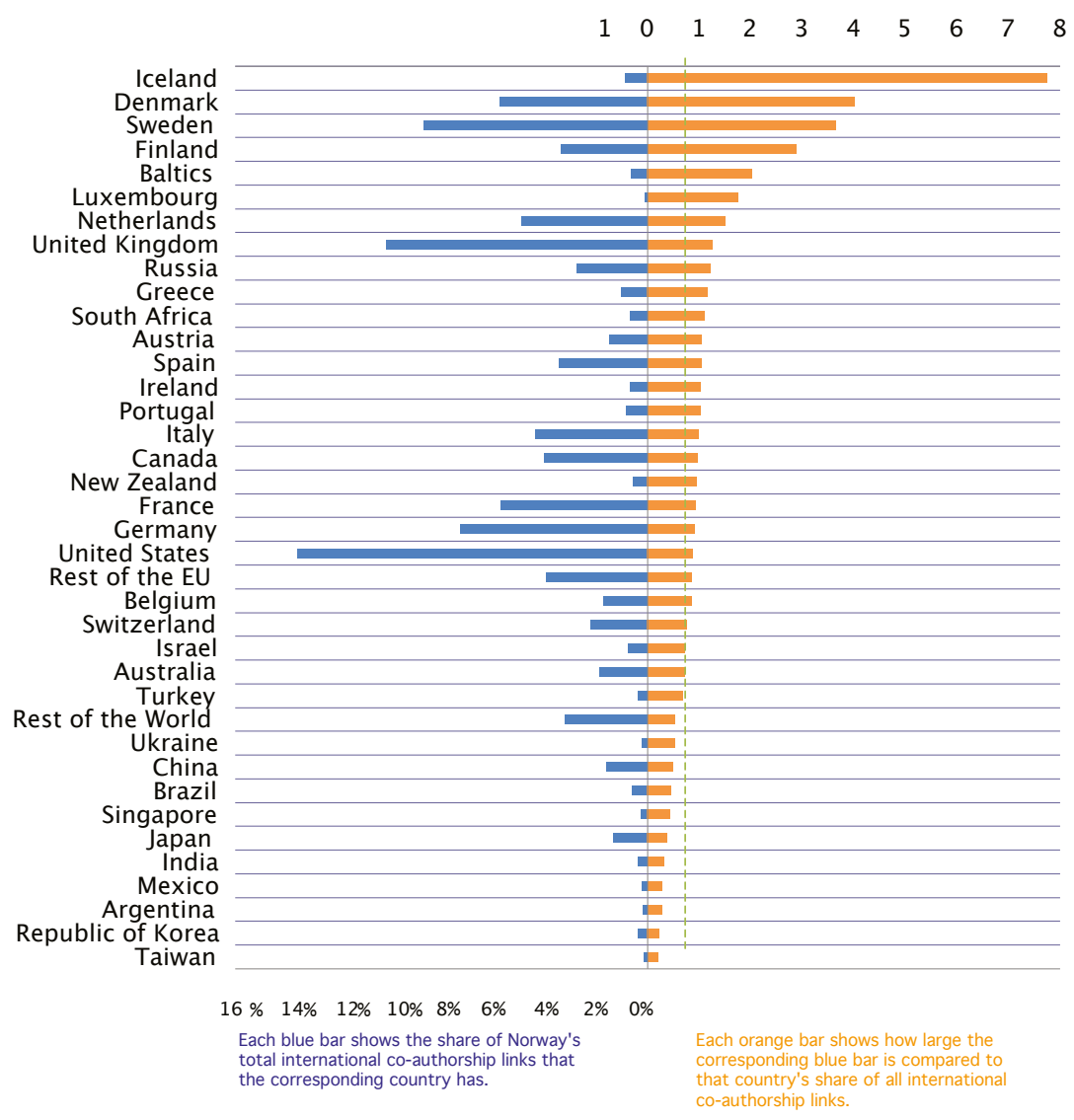
Looking at the bloc of countries below the Nordic and Baltic ones, we see that Finnish researchers are somewhat less focused on the Western world than their Danish counterparts (compare Figure 4.1). Russia is found in seventh place, and Turkey, Ukraine and Japan are all located above Australia, Israel and New Zealand. Further, the rest of the EU – that is, the Eastern European members – are ranked as high as tenth place.

**FIGURE 4.3. ICELAND'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.**



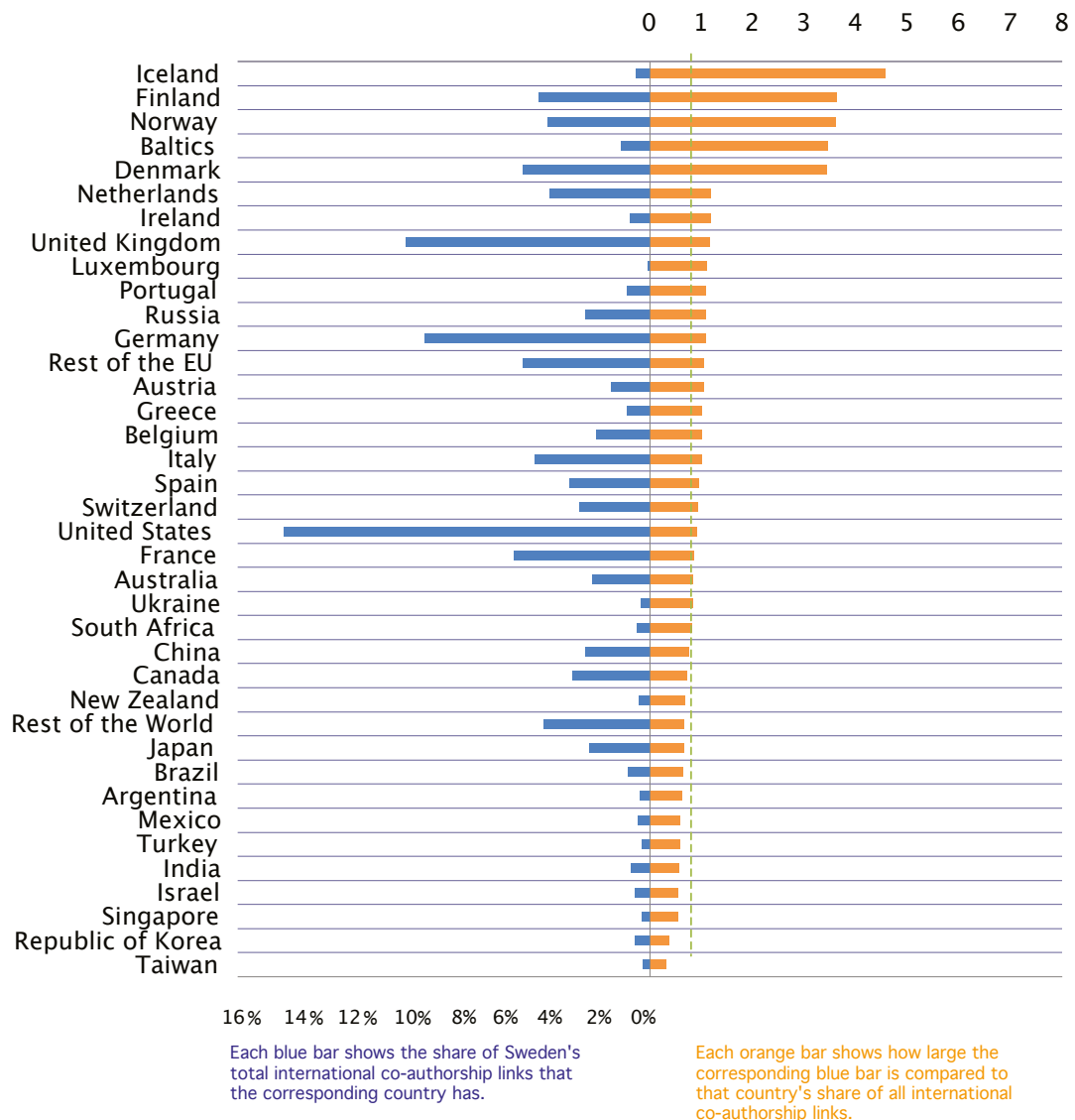
For Iceland, the Nordic and Baltic domination is greater than it is for the other Nordic countries (see Figure 4.3). Outside the Nordic and Baltic countries, the other Western countries dominate the list, very much in the same way as in the case of Denmark. The somewhat unexpected rankings of Singapore and Luxembourg are most likely coincidences: the total number of publications co-authored between Iceland and Singapore during this period is 23; between Iceland and Luxembourg, the number is 8.

**FIGURE 4.4. NORWAY'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.**



Norway's list is similar to Denmark's, but Russia and Luxembourg are more important partners for Norway (see Figure 4.4).

**FIGURE 4.5. SWEDEN'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.**

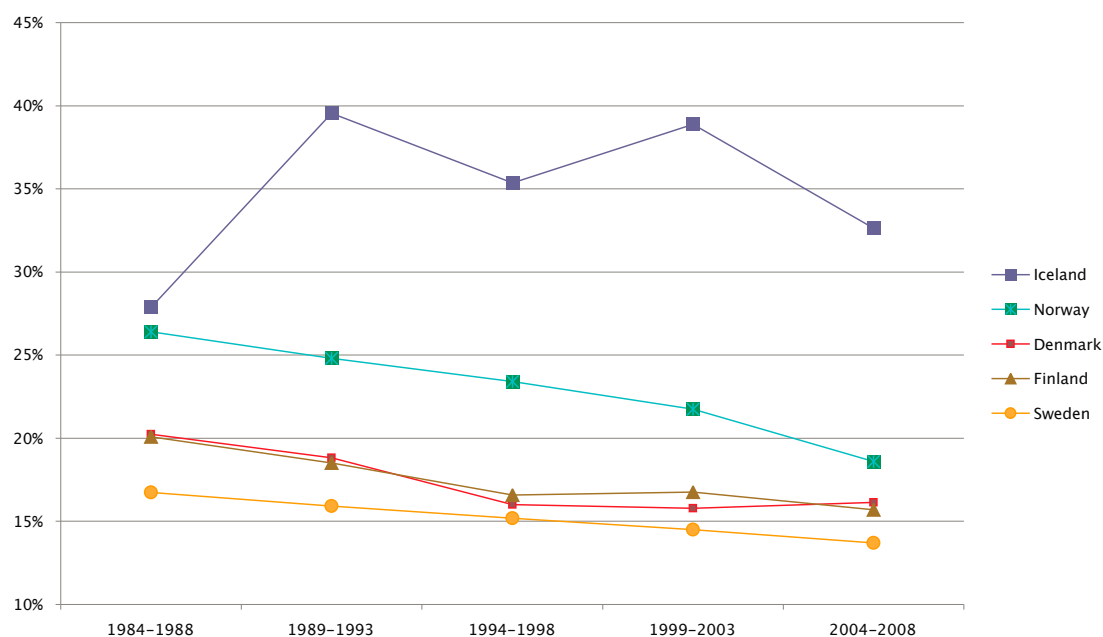


The Swedish list is the one with the clearest jump from the Nordic and Baltic countries to other countries and regions (see Figure 4.5).

As in the Finnish case, Russia is a fairly important cooperation partner, as well as the rest of the EU – that is, the Eastern European member-states.



**FIGURE 4.6. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH OTHER NORDIC COUNTRIES, AS SHARE OF EACH COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS. NOTE THE SCALE OF THE Y-AXIS.**

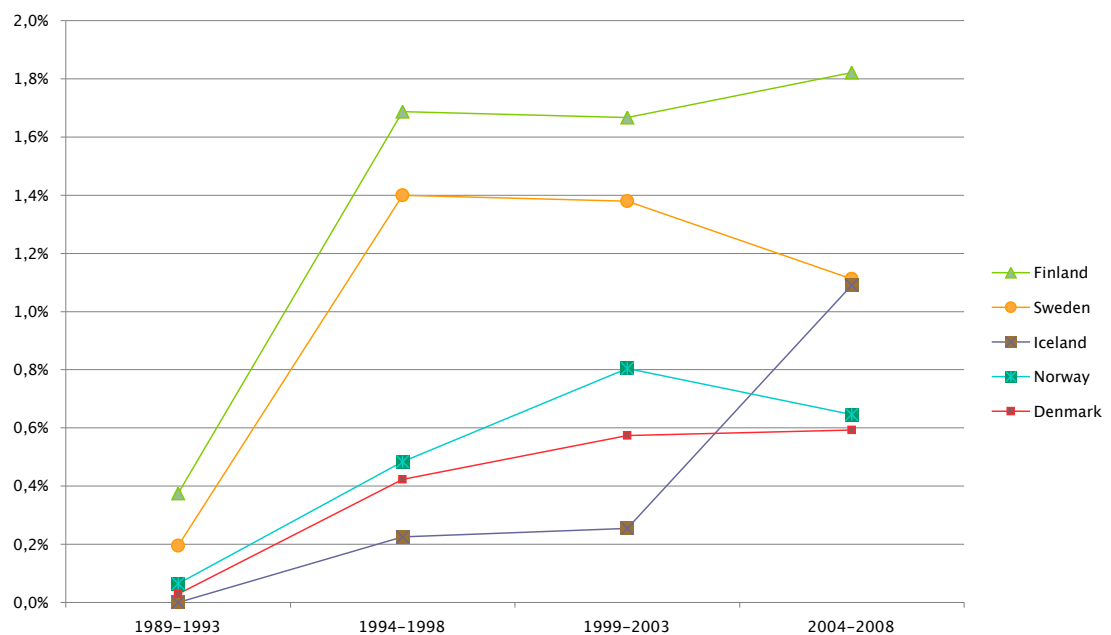


#### **Changes in Nordic international cooperation**

Having scrutinized the cooperation patterns at the country level, we will now adopt a regional perspective. We shall see how the international cooperation between the Nordic countries and some major regions has changed during recent decades.

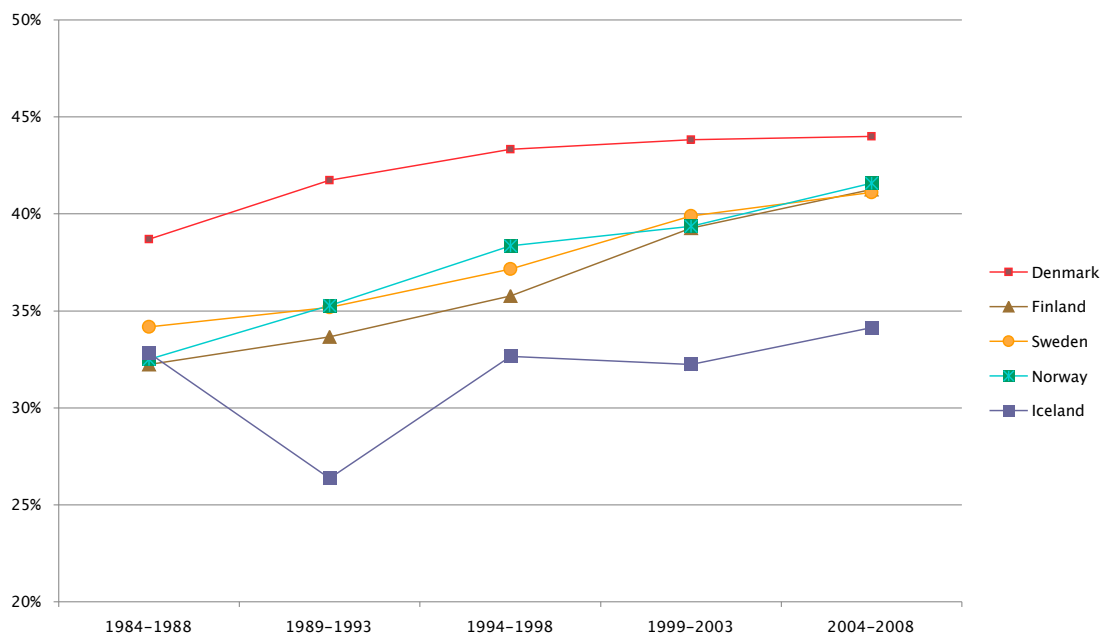
Figure 4.6 shows that cooperation with other Nordic countries has decreased somewhat in importance since the 1980s for Denmark, Finland, Norway and Sweden, compared to cooperation with other countries. Figure 3.1 showed that the number of intra-Nordic co-publications rose during the same period in relation to the total publication volume, and Figure 2.1 showed that the total publication volume also increased. Thus we learn from these diagrams that intra-Nordic cooperation has increased, although not quite as much as cooperation with other countries. For Iceland, this pattern is not clear.

**FIGURE 4.7. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH THE BALTIC COUNTRIES, AS SHARE OF EACH NORDIC COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS.**



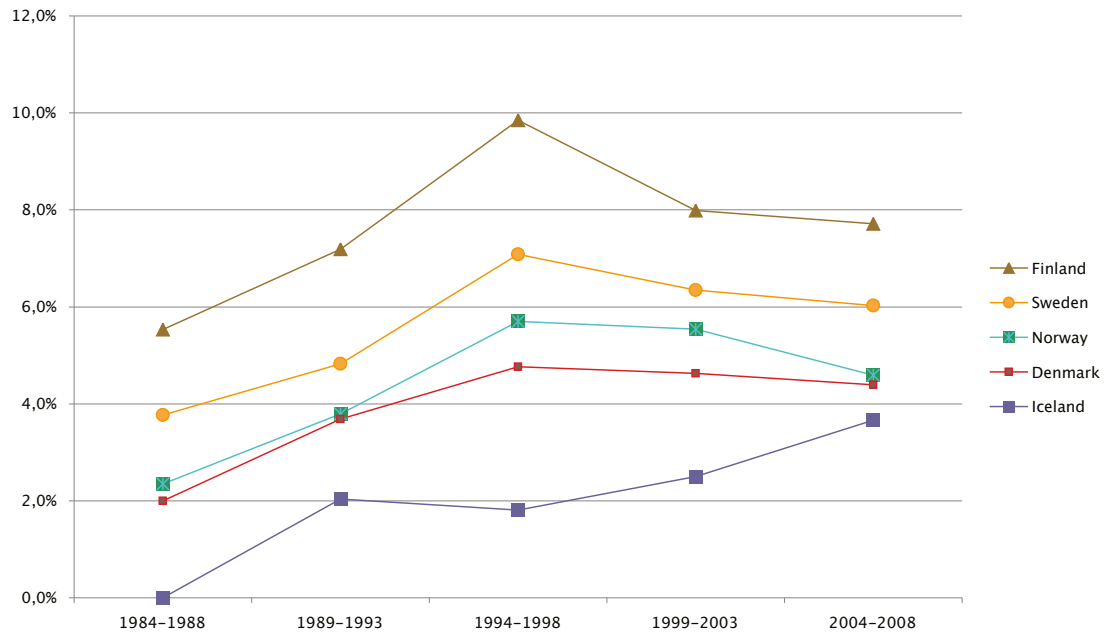
The Nordic cooperation with the Baltic countries increased dramatically during the 1990s, when the Baltic countries first appeared as research nations in their own right, but after that period the degree of cooperation levelled out. In the cases of Sweden and Norway, it even decreased somewhat during the last decade. For Iceland, on the other hand, the cooperation has taken a great leap during the last decade, but the absolute numbers are very low.

**FIGURE 4.8. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH NON-NORDIC EU15 COUNTRIES, AS SHARE OF EACH NORDIC COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS. NOTE THE SCALE OF THE Y-AXIS.**



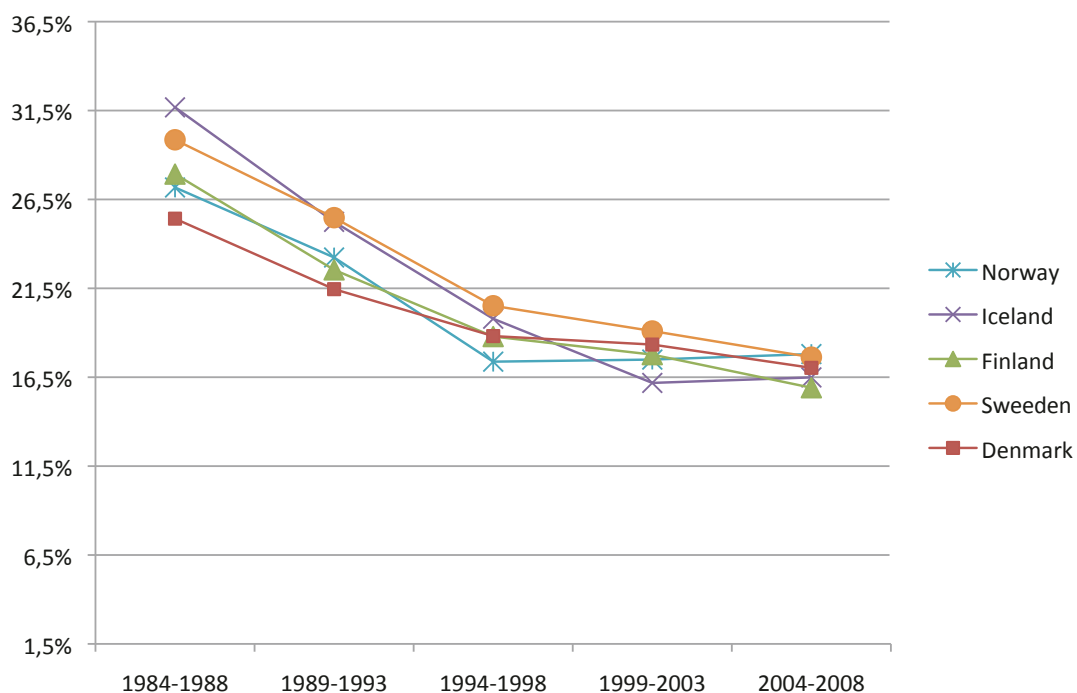
Non-Nordic EU15 countries, roughly corresponding to the rest of Western Europe, were important cooperation partners at the start of the period, and this importance increased somewhat during the period for all Nordic countries.

**FIGURE 4.9. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH THE REMAINING EU27 COUNTRIES (I.E. EU27 COUNTRIES THAT ARE NEITHER EU15 NOR NORDIC NOR BALTIC COUNTRIES), AS SHARE OF EACH NORDIC COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS, 1984–2008.**



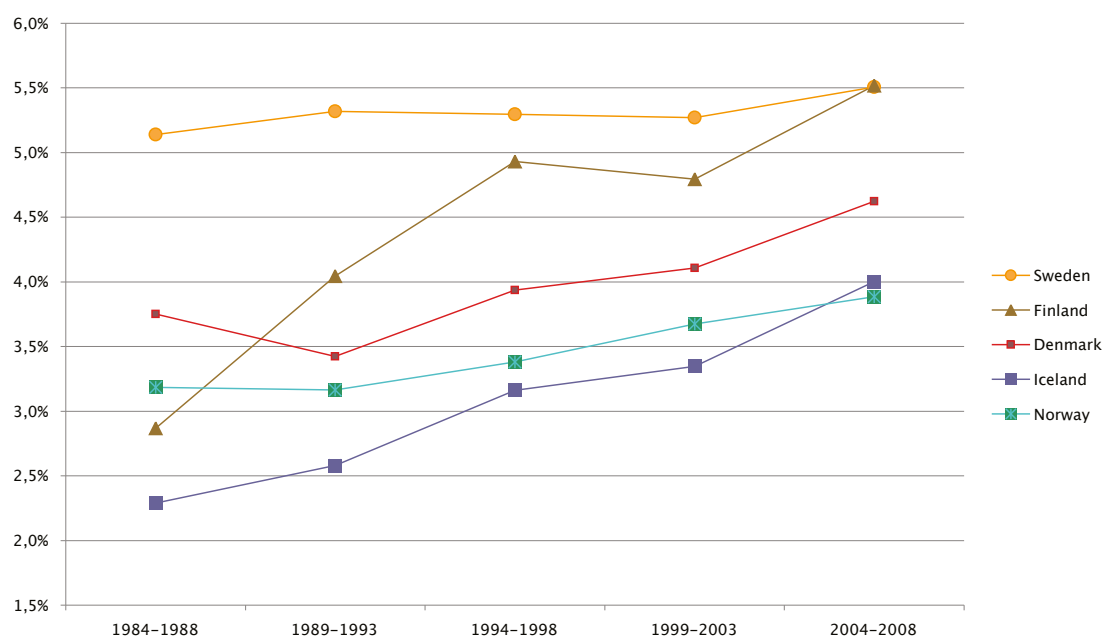
EU27 countries that are neither EU15, nor Nordic, nor Baltic are Bulgaria, Cyprus, the Czech Republic, Hungary, Malta, Poland, Romania, Slovakia and Slovenia. Danish, Finnish, Norwegian and Swedish cooperation with these countries increased rapidly (compared to cooperation with other countries) from the late 1980s until the late 1990s, during which period several of these countries let go of communist systems to adapt capitalistic ones. The following decade saw a moderate decrease in cooperation with these countries, compared to cooperation with other countries. For Iceland, the increase has continued throughout the period, but again, the absolute numbers are very small and difficult to generalize from.

**FIGURE 4.10. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH NORTH AMERICAN COUNTRIES, AS SHARE OF EACH NORDIC COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS. NOTE THE SCALE OF THE Y-AXIS.**



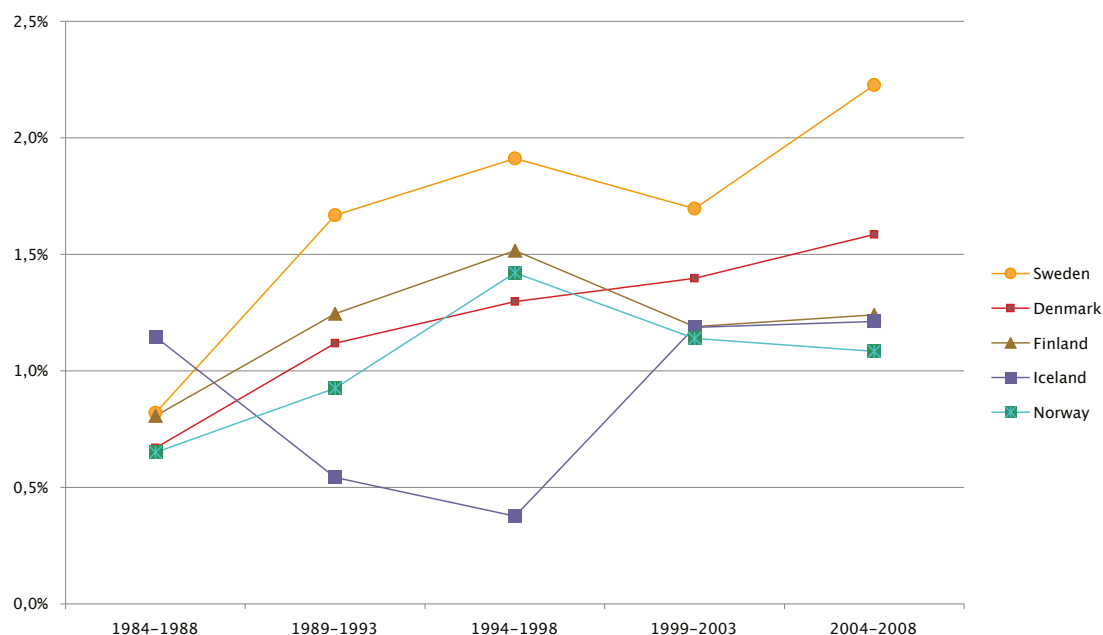
All Nordic countries follow the same patterns regarding cooperation with North American countries (where the USA dominates heavily). The relative importance of North American cooperation has fallen throughout the studied period.

**FIGURE 4.11. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH ASIAN COUNTRIES, AS SHARE OF EACH NORDIC COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS. NOTE THE SCALE OF THE Y-AXIS.**



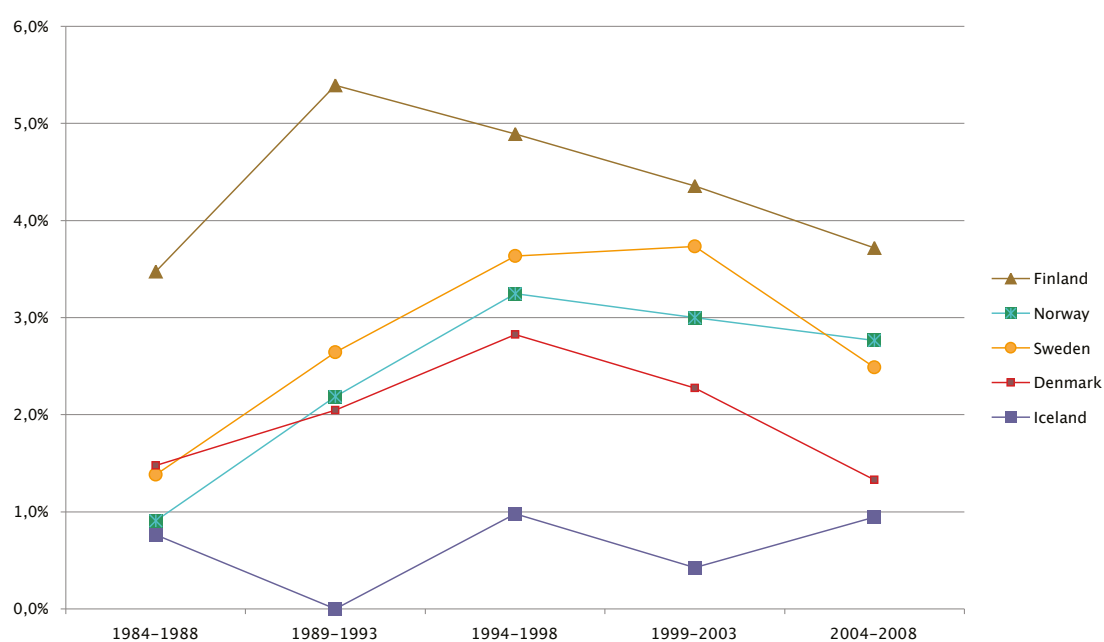
Cooperation with Asian countries has increased during the period for all Nordic countries, most so for Finland, which started at a low level, and least so for Sweden, which started at a high level.

**FIGURE 4.12. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH SOUTH AND CENTRAL AMERICAN COUNTRIES, AS SHARE OF EACH NORDIC COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS.**



Sweden's cooperation with South and Central American countries rose considerably during the period, compared to its cooperation with other countries, with a dip around the turn of the millennium. Norway and Finland followed the Swedish development until the most recent five-year period, when Swedish cooperation increased while Finnish and Norwegian cooperation remained at the same level. Denmark showed a steady increase during the entire period, while the Icelandic development was rather uneven; the absolute numbers for Iceland are very small.

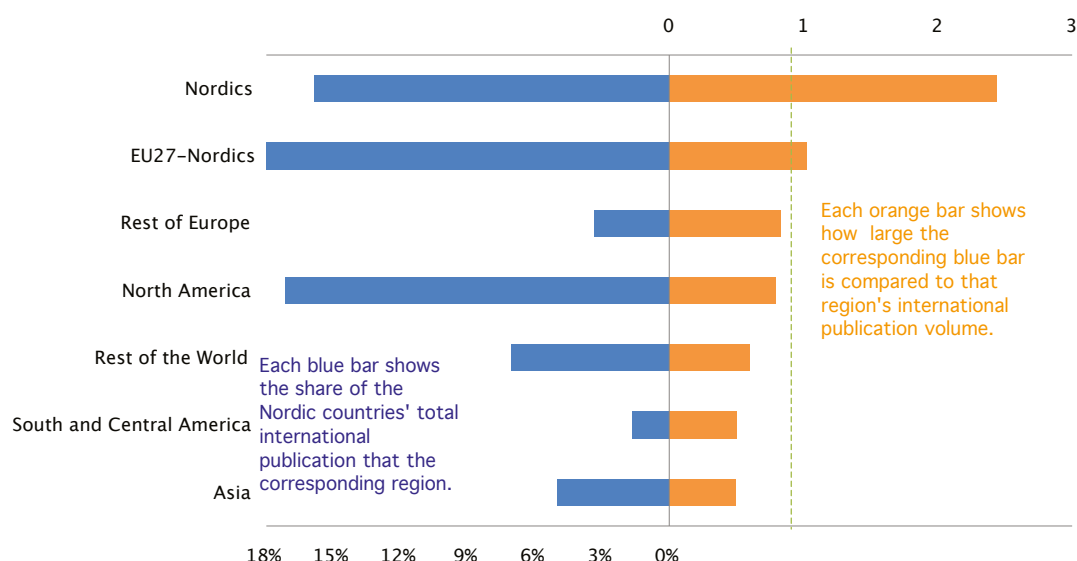
**FIGURE 4.13. THE NORDIC COUNTRIES' CO-AUTHORSHIP LINKS WITH RUSSIA/USSR, AS SHARE OF EACH NORDIC COUNTRY'S TOTAL INTERNATIONAL CO-AUTHORSHIP LINKS.**



Finnish cooperation with Russia/USSR rose significantly around 1990. After this, the Russian share has decreased steadily in the Finnish international co-authorship links. The pattern is similar for Sweden, Norway and Denmark, with delayed peaks. The Icelandic cooperation with Russia/USSR was very low during the entire period, even reaching zero during 1989–1993.



**FIGURE 4.14. COOPERATION BETWEEN THE NORDIC COUNTRIES AND OTHER REGIONS OF THE WORLD, 2004–2008. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.**



### Inter-regional cooperation

We have just seen the cooperation patterns for each of the Nordic countries, both for individual countries and for regions. We will now examine the Nordic region as a whole and its pattern of cooperation with other regions. Figure 4.14 shows some large regions' relative importance as cooperation partners for Nordic researchers.

Figure 4.14 shows the size of different regions in the pool of international co-authorship links for the Nordic countries. The international cooperation within the Nordic region is almost as large as the cooperation between Nordic countries and the EU or the cooperation between Nordic countries and North America.

#### Summary of Chapter 4

In this chapter, we examined which countries and regions the Nordic countries cooperate with. A selection of relevant countries was made, which included all countries with at least 25,000 publications between 1984 and 2008.

Cultural proximity seems to be a strong factor behind the choice of cooperation partners. When the size of the country (in terms of international co-publications) is taken into account, the other Nordic and Baltic states are at the top of the list of cooperation partners for all Nordic countries. Researchers from the rest of the Western world are chosen as cooperation partners by Nordic researchers approximately as often as expected, considering their sizes of these countries.

There are some variations on this theme. In the case of Finland, we find the Baltic countries at the top of the list of preferred cooperation partners, when country size is taken into consideration. (Closer inspection reveals that Estonia stands for 65% of this). Following the Nordic and Baltic countries, Russia is found as high as at seventh place in Finland's list, and Turkey, Ukraine and Japan are all located above Australia, Israel and New Zealand. Further, Eastern EU is ranked as high as at tenth place. Sweden shows a similar relative preference for Russia and Eastern EU.

For Iceland, the Nordic and Baltic domination is greater than in any of the other Nordic countries.

At the regional level, intra-Nordic cooperation has increased between 1982 and 2008, although not quite as much as cooperation with other countries.

Nordic cooperation with the Baltic countries increased dramatically during the 1990s, when those countries first appeared as research nations in their own right, but after that period the degree of cooperation levelled out. For Iceland, on the other hand, the cooperation has taken a great leap during the last decade, but the absolute numbers are very low and must be interpreted with caution.

Non-Nordic EU15 countries have been important cooperation partners since the early 1980s, and this importance has even increased somewhat during the period studied.

Nordic cooperation with the new, non-Baltic EU countries Bulgaria, Cyprus, the Czech Republic, Hungary, Malta, Poland, Romania, Slovakia and Slovenia increased rapidly. Danish, Finnish, Norwegian and Swedish cooperation with these countries increased rapidly from the late 1980s until the late 1990s, during which period several of these countries let go of communist systems to adapt capitalistic ones. The following decade saw a moderate decrease in cooperation with these countries, compared to cooperation with other

countries. For Iceland, the increase continued throughout the period.

Nordic cooperation with North American countries has fallen throughout the studied period. All the Nordic countries follow the same declining pattern regarding cooperation with North American countries (where the USA dominates heavily).

The cooperation with Asian countries has increased during the period for all Nordic countries, most so for Finland, which started at a low level, and least so for Sweden, which started at a high level.

Cooperation with South and Central America shows the greatest variation in patterns between the Nordic countries. Sweden's cooperation rose considerably during the period compared to its cooperation with other countries, with a dip around the turn of the millennium. Norway and Finland followed the Swedish development until the most recent five-year period, when Swedish cooperation increased while Finnish and Norwegian cooperation remained at the same level. Denmark showed a steady increase during the entire period, while the Icelandic development was rather uneven; again, the absolute numbers for Iceland are very small and must be interpreted with caution.

Finnish cooperation with Russia/USSR rose significantly around 1990. After this, the Russian share has decreased steadily in the Finnish international co-authorship links. The pattern is similar for Sweden, Norway and Denmark, with delayed peaks. The level of Icelandic cooperation with Russia/USSR was very low during the entire period, even reaching zero during 1989–1993.

# 5. A network analysis of Nordic cooperation

For this chapter, the scientific cooperation in the Nordic countries has been analysed in terms of a network, resulting in the diagram shown in Figure 5.1. This diagram is based on data for the production of scientific articles over a five-year period (original articles and reviews during 2003–2007), as covered by the Thomson Reuters database. All the included publications have been authored by researchers in one of the Nordic countries in cooperation with researchers in one other Nordic country, a Baltic state, a EU15 country, or a country in North America or Asia. Co-authoring occurring only within a single nation or region is not included in the dataset, while multiple addresses from the same country in a single article have been merged into one single country or region occurrence.

The thickness of the lines drawn between cooperating countries or regions in the figure is directly proportional to the number of articles produced by the two regions/countries in cooperation. The number of co-authorship links between the countries/regions within the five-year interval is also given next to each line connecting the countries/areas.

The area of the country/region circles in the graphs reflects the number of articles in the co-publication set produced by the country/region in question.<sup>7</sup>

The positions of the various country or region circles and the distance between them have no relation to any bibliometric data. Circles were positioned solely to maximize the visibility of cooperation lines and figures.

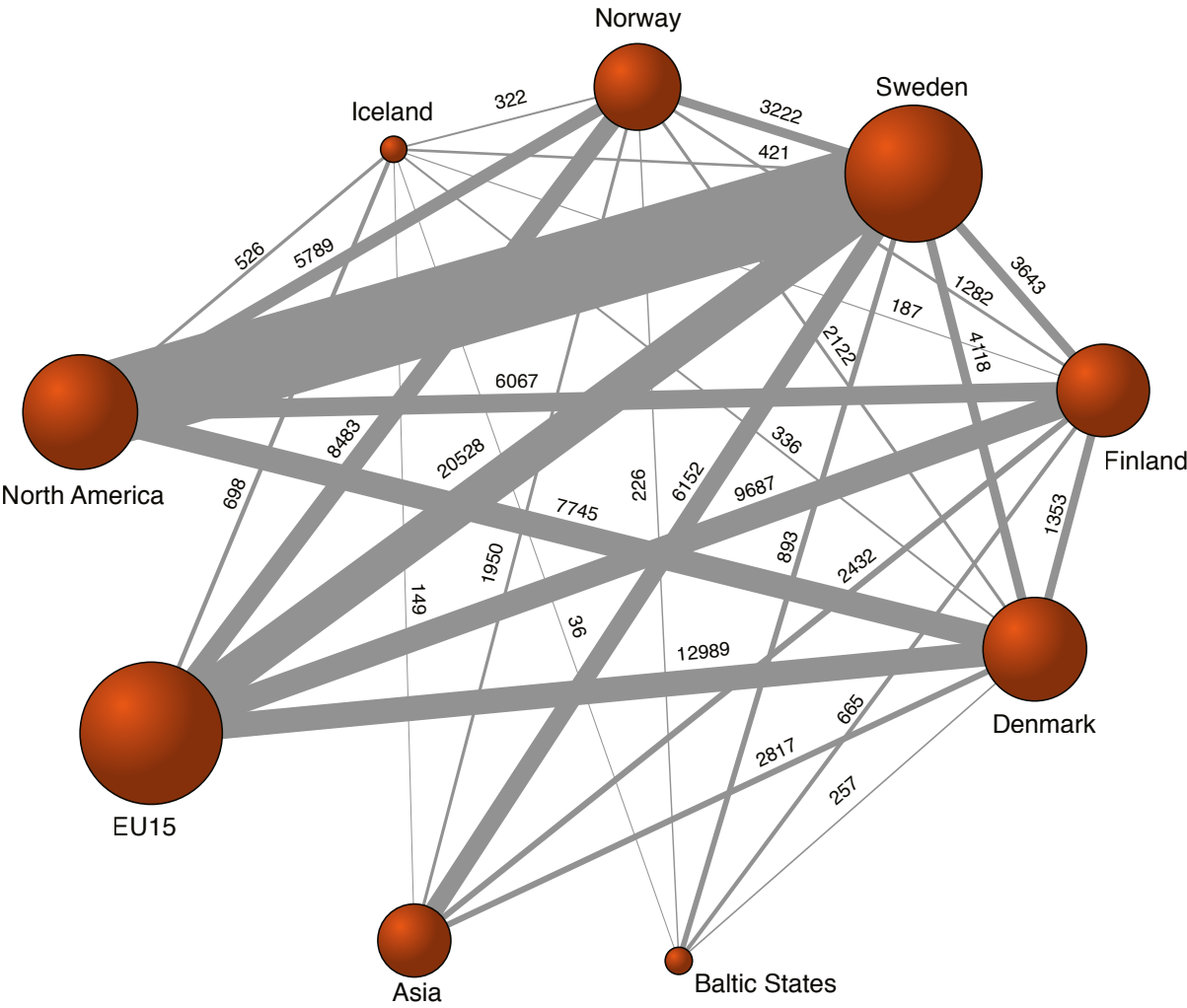
The visual presentation was done using the computer program Pajek.<sup>8</sup> The final figures were edited with the computer program Inkscape,<sup>9</sup> and some secondary cooperation patterns between non-Nordic regions were removed, since these did not form part of the focus of the present study.<sup>10</sup>

**TABLE 5.1. NUMBERS AND SHARES OF CO-AUTHORSHIP LINKS FOR THE COUNTRIES/REGIONS IN FIGURE 5.1**

| Country/region       | Co-authorship links | Share of all co-authorship links |
|----------------------|---------------------|----------------------------------|
| Denmark              | 24 850              | 12.5%                            |
| Finland              | 19 837              | 10.0%                            |
| Iceland              | 1 597               | 0.8%                             |
| Norway               | 17 361              | 8.7%                             |
| Sweden               | 43 393              | 21.9%                            |
| Asia                 | 12 371              | 6.2%                             |
| Baltic States        | 1 716               | 0.9%                             |
| EU15                 | 46 922              | 23.6%                            |
| North America        | 30 476              | 15.4%                            |
| <b>Sum 2003–2007</b> | <b>198 523</b>      | <b>100%</b>                      |

Figure 5.1 and Table 5.1 illustrate the patterns that have already been discussed in Chapter 4. The Nordic countries stand out as large; however, since the selection of co-authorship links was restricted to links involving at least one Nordic country, this is not surprising. EU15 and North America stand out as large cooperation patterns, but the intra-Nordic cooperation is clearly also important – Norway, for example, has almost as many links with Sweden and Denmark as with all of North America.

**FIGURE 5.1.** NORDIC COOPERATION PATTERNS 2003-2007, EXPRESSED AS A NETWORK.



## 6. References

- Aksnes, Dag W. (2003). 'Characteristics of highly cited papers', *Research Evaluation* 12(3): 159–170.
- Aksnes, Dag W.; Nicoline Frölich & Stig Slipersæter (2008). 'Science policy and driving forces behind the internationalisation of science: the case of Norway', *Science and Public Policy* 35(6): 445–457.
- Aksnes, Dag W. & Dag O. Hessen (2009). 'The structure and development of polar research (1981–2007)', *Arctic, Antarctic, and Alpine Research* 41(2): 155–163.
- Engels, Anita & Tina Ruschenburg (2008). 'The uneven spread of global science: patterns of international collaboration in global environment change research', *Science and Public Policy* 35(5): 347–360.
- Glänzel Wolfgang; András Schubert & Hans-Jürgen Czerwon (1999). 'A bibliometric analysis of international scientific cooperation of the European Union (1985–1995)', *Scientometrics* 45(2): 185–202.
- Gornitzka, Åse & Liv Langfeldt (2008). 'The internationalisation of national knowledge policies', in Åse Gornitzka & Liv Langfeldt (eds) *Borderless knowledge? Understanding the 'new' internationalisation of research and higher education in Norway*. Dordrecht: Springer.
- Kostoff, Ronald N. (2007). 'The difference between highly and poorly cited medical articles in the journal *Lancet*', *Scientometrics* 72(3): 513–520.
- Leimu, Roosa & Julia Korisheva (2005). 'Does scientific collaboration increase the impact of ecological articles?', *BioScience* 55(5): 438–443.
- Luukkonen, Terttu; Olle Persson & Gunnar Sivertsen (1992). 'Understanding patterns of international scientific collaboration', *Science, Technology, & Human Values* 17(1): 101–126.
- Sivertsen, Gunnar (2009). 'Publication patterns in all fields', in Fredrik Åström, Rickard Danell, Birger Larsen & Jesper Wiborg-Schneider (eds) *Celebrating scholarly communication studies: a festschrift for Olle Persson at his 60th Birthday*, special volume of the e-newsletter of the International Society for Scientometrics and Informetrics 5-S: 55–60.
- Wuchty, Stefan; Benjamin F. Jones & Brian Uzzi (2007). 'The increasing dominance of teams in production of knowledge', *Science* 316: 1036–1039.

# Appendix: Methods

The bibliometric source for this study has been the Thomson Reuters database at the Swedish Research Council, which includes the *Science Citation Index Expanded*, the *Social Sciences Citation Index* and the *Arts & Humanities Citation Index*. The study has been restricted to include only articles, letters and reviews published between 1984 and 2008 that had at least one subject tag and one address, but less than 100 addresses,<sup>11</sup> all in all 19 million publications.

## A1. PUBLICATION COUNTING AND CO-AUTHORSHIP LINKS

When publication volume numbers are given in this report, they are whole counts – that is, the number for a given country is calculated as the number of publications with at least one address from that country. A publication with one Danish and four Finnish addresses thus results in one Danish publication and one Finnish publication. Publication numbers for the world total have been calculated by summing the whole-count publication numbers for each country. Since the subject classification system allows for more than one subject tag per journal, the same procedure is used for subject classifications: a publication with one natural sciences subject tag and three life sciences subject tags result in one natural sciences publication and one life sciences publication.

For co-authorship links, a similar approach has been used. The addresses for each publication have been reduced to one address per represented country, and the co-authorship links have been extracted after that. Thus, a publication with one Danish address, two Finnish addresses and three Icelandic addresses results in one bi-directed co-authorship link between Denmark and Finland, one between Denmark and Iceland, and one between Iceland and Finland.

## A2. OBSERVED/EXPECTED

The observed/expected measure was introduced in Luukkonen, Persson & Sivertsen (1992: 114) and expresses how large the cooperation with a certain country is in relation to that country's size:

$$\frac{C_{x,y} \cdot (T - C_x)}{C_x \cdot C_y}$$

where

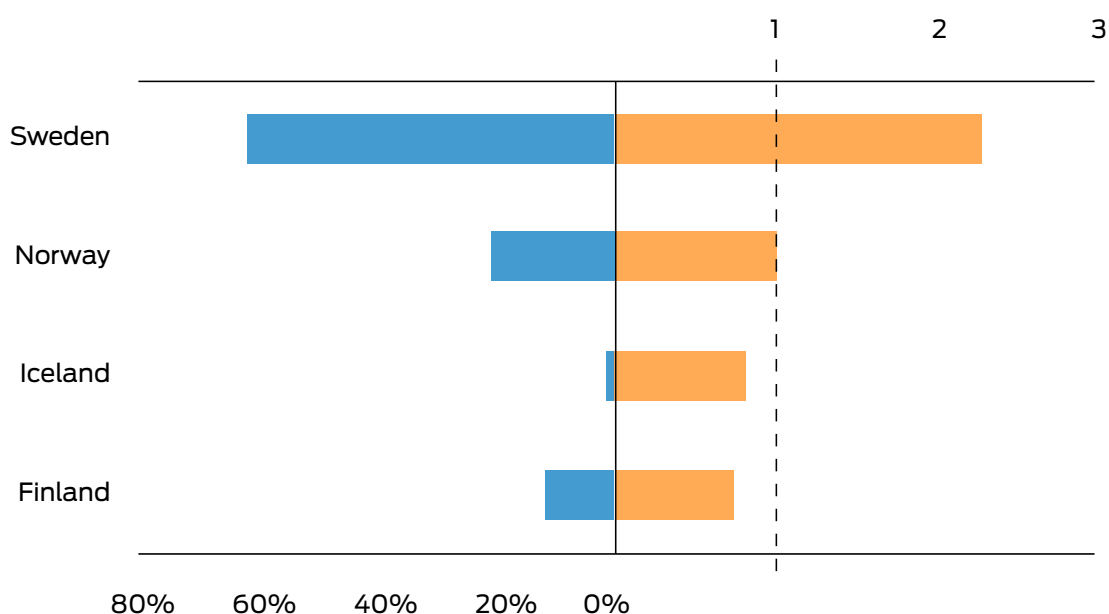
$C_{x,y}$  = the number of co-authorship links between countries X and Y;

$C_x$  = the total number of co-authorship links country X has with other countries;

$C_y$  = the total number of co-authorship links country Y has with other countries; and

T = the total number of co-authorship links.

**FIGURE A1. DENMARK'S COOPERATION WITH OTHER NORDIC COUNTRIES**



The measure is explained here in some detail.

The left-hand side of Figure A1 shows Denmark's co-authorship links with each of the other Nordic countries as shares of all Denmark's co-authorship links with Nordic countries. It seems that Denmark has closer ties with Sweden than with any other Nordic country, as far as research cooperation is concerned.

However, Sweden has more researchers than any other country in the Nordic region, and thus Danish researchers need not have a particularly strong inclination to work with Swedish researchers for Sweden to become the dominant cooperation partner for Denmark: If Danish researchers were to choose cooperation partners randomly among all available Nordic researchers, Sweden would come out as the dominant partner.

The right-hand side of Figure A1 is an attempt to overcome this problem and to show how inclined Danish researchers are to work with researchers from each of the other Nordic countries taking into account the respective sizes of those countries. The left-hand value, the observed value of Denmark's cooperation, is divided by the expected value. If, for a given country, the quotient is 1, that means that Danish researchers choose to cooperate with researchers from that country exactly as often as expected. If the quotient is 2, Danish researchers choose cooperation partners from that country twice as often as expected (and, since this is a zero-sum game, they have to cooperate less than expected with one or more of the other countries).

The tricky part is what 'expected' means here. How much do we expect Danish researchers to cooperate with, say, Swedish researchers? There is perhaps no good answer to that question, but the solution chosen here is to assume that the share a country has in the set of all co-authorship links is the expected share that country has in the set of co-authorship links for any particular country. That is, if Sweden has twice as many co-authorship links as Norway in the total set of co-authorship links, then Denmark is also expected to have twice as many co-authorship links with Sweden as with Norway. Another way to look at this is to say that the expected value is what you would get if the researchers of a country were to choose cooperation partners from the other countries at random, from the set of all available cooperation partners.

Figure A2 shows how much each Nordic country cooperates with the other Nordic countries, as shares of all Nordic co-authorship links.

**FIGURE A2. THE SHARES OF EACH NORDIC COUNTRY IN THE SET OF ALL NORDIC CO-AUTHORSHIP LINKS**

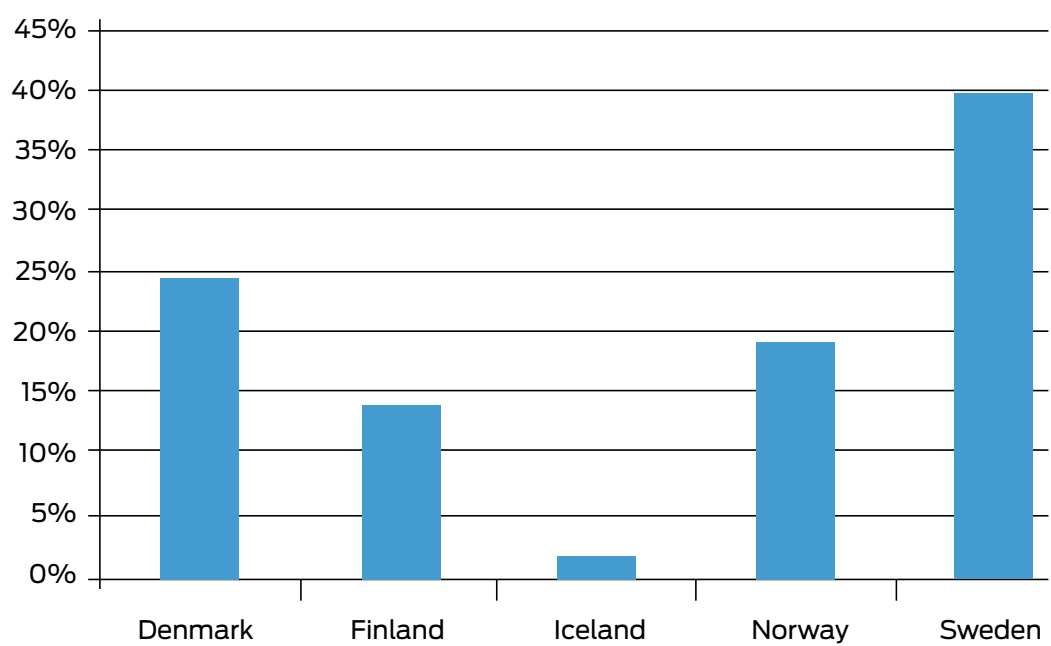


Figure A2 thus shows how much the countries are expected to work with each of the other countries. They are expected to work 25% with Denmark, 15% with Finland, etc.

Now, there is a flaw in this solution to the problem of the what the expected value is. The flaw derives from the fact that in the set of all Nordic co-authorship links there are five countries present, while in the set of any particular Nordic country there are only four countries present. This skews the expected value somewhat, and one of the effects of this is that Sweden cooperates more than expected with all the other Nordic countries.

### A3. COUNTRIES AND REGIONS

Recent geopolitical developments have caused some difficulties as regards certain countries. Publications from Czechoslovakia are accredited neither to the Czech Republic nor to the Slovak Republic, and all publications from the USSR have been accredited to the Russian Federation.

The geographic regions used in this paper were defined as follows:

- *Baltic countries:* Estonia, Latvia, Lithuania.
- *Nordic countries:* Denmark, Finland, Iceland, Norway, Sweden.
- *EU15:* Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom.
- *EU27:* Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.
- *Europe:* Albania, Andorra, Austria, Belarus, Belgium, Bosnia & Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Holy See (Vatican City State), Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia (Former Yugoslav Republic of), Malta, Moldova, Monaco, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, San Marino, Serbia & Montenegro, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.



- *North America*: Canada, Mexico, United States.
- *Asia*: Afghanistan, Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei, Burma/Myanmar, Cambodia, China, East Timor, Georgia, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Lebanon, Malaysia, Maldives, Mongolia, Nepal, North Korea, Oman, Pakistan, Palestine, Philippines, Qatar, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Taiwan, Tajikistan, Thailand, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Vietnam, Yemen.

## A4. MAIN SUBJECT AREAS

The 255 subject classes used by Thomson Reuters have been grouped into three main subject areas: Life Sciences, Natural Sciences, and Social Sciences & Humanities. The ISI class *Multidisciplinary Sciences*, which is used for journals that accept papers from several different disciplines – for example, *Nature* and *Science* – has undergone special treatment here. Each publication in journals in this class has been automatically reclassified under one or more of the other subject classes on the basis of the publication's references and citations. Publications that could not be reclassified in this way have been left out of the study.

The table below shows into which subject area each of the ISI classes was put. Note that the ISI subject *Psychology* belongs to the subject area *Life Sciences*.

| Subject Area  | ISI Subject                             |
|---------------|-----------------------------------------|
| Life Sciences | Agricultural Economics & Policy         |
| Life Sciences | Agricultural Engineering                |
| Life Sciences | Agricultural Experiment Station Reports |
| Life Sciences | Agriculture, Dairy & Animal Science     |
| Life Sciences | Agriculture, Multidisciplinary          |
| Life Sciences | Agronomy                                |
| Life Sciences | Allergy                                 |
| Life Sciences | Anatomy & Morphology                    |
| Life Sciences | Andrology                               |
| Life Sciences | Anesthesiology                          |
| Life Sciences | Biochemical Research Methods            |
| Life Sciences | Biochemistry & Molecular Biology        |
| Life Sciences | Biodiversity Conservation               |
| Life Sciences | Biology                                 |
| Life Sciences | Biology, Miscellaneous                  |
| Life Sciences | Biophysics                              |
| Life Sciences | Biotechnology & Applied Microbiology    |
| Life Sciences | Cardiac & Cardiovascular System         |
| Life Sciences | Cell Biology                            |
| Life Sciences | Chemistry, Medicinal                    |
| Life Sciences | Clinical Neurology                      |
| Life Sciences | Computer Critical Reviews               |
| Life Sciences | Critical Care Medicine                  |
| Life Sciences | Cytology & Histology                    |
| Life Sciences | Dentistry, Oral Surgery & Medicine      |
| Life Sciences | Dermatology                             |
| Life Sciences | Developmental Biology                   |
| Life Sciences | Ecology                                 |
| Life Sciences | Emergency Medicine                      |
| Life Sciences | Endocrinology & Metabolism              |
| Life Sciences | Entomology                              |
| Life Sciences | Environmental Sciences                  |
| Life Sciences | Evolutionary Biology                    |
| Life Sciences | Fisheries                               |
| Life Sciences | Food Science & Technology               |
| Life Sciences | Forestry                                |
| Life Sciences | Gastroenterology & Hepatology           |

|               |                                               |
|---------------|-----------------------------------------------|
| Life Sciences | Genetics & Heredity                           |
| Life Sciences | Geriatrics & Gerontology                      |
| Life Sciences | Gerontology                                   |
| Life Sciences | Health Care Sciences & Services               |
| Life Sciences | Hematology                                    |
| Life Sciences | Horticulture                                  |
| Life Sciences | Immunology                                    |
| Life Sciences | Infectious Diseases                           |
| Life Sciences | Integrative & Complementary Medicine          |
| Life Sciences | Limnology                                     |
| Life Sciences | Marine & Freshwater Biology                   |
| Life Sciences | Mathematical & Computational Biology          |
| Life Sciences | Medical Ethics                                |
| Life Sciences | Medical Informatics                           |
| Life Sciences | Medical Laboratory Technology                 |
| Life Sciences | Medicine, General & Internal                  |
| Life Sciences | Medicine, Legal                               |
| Life Sciences | Medicine, Miscellaneous                       |
| Life Sciences | Medicine, Research & Experimental             |
| Life Sciences | Microbiology                                  |
| Life Sciences | Microscopy                                    |
| Life Sciences | Mycology                                      |
| Life Sciences | Neuroimaging                                  |
| Life Sciences | Neurosciences                                 |
| Life Sciences | Nursing                                       |
| Life Sciences | Nutrition & Dietetics                         |
| Life Sciences | Obstetrics & Gynecology                       |
| Life Sciences | Oncology                                      |
| Life Sciences | Ophthalmology                                 |
| Life Sciences | Ornithology                                   |
| Life Sciences | Orthopedics                                   |
| Life Sciences | Otorhinolaryngology                           |
| Life Sciences | Parasitology                                  |
| Life Sciences | Pathology                                     |
| Life Sciences | Pediatrics                                    |
| Life Sciences | Peripheral Vascular Disease                   |
| Life Sciences | Pharmacology & Pharmacy                       |
| Life Sciences | Physiology                                    |
| Life Sciences | Plant Sciences                                |
| Life Sciences | Psychiatry                                    |
| Life Sciences | Psychology                                    |
| Life Sciences | Psychology, Applied                           |
| Life Sciences | Psychology, Biological                        |
| Life Sciences | Psychology, Clinical                          |
| Life Sciences | Psychology, Developmental                     |
| Life Sciences | Psychology, Educational                       |
| Life Sciences | Psychology, Experimental                      |
| Life Sciences | Psychology, Mathematical                      |
| Life Sciences | Psychology, Multidisciplinary                 |
| Life Sciences | Psychology, Psychoanalysis                    |
| Life Sciences | Psychology, Social                            |
| Life Sciences | Public, Environmental & Occupational Health   |
| Life Sciences | Radiology, Nuclear Medicine & Medical Imaging |
| Life Sciences | Rehabilitation                                |
| Life Sciences | Reproductive Biology                          |
| Life Sciences | Respiratory System                            |
| Life Sciences | Rheumatology                                  |
| Life Sciences | Soil Science                                  |
| Life Sciences | Substance Abuse                               |
| Life Sciences | Surgery                                       |
| Life Sciences | Toxicology                                    |
| Life Sciences | Transplantation                               |
| Life Sciences | Tropical Medicine                             |
| Life Sciences | Urology & Nephrology                          |

|                  |                                                  |
|------------------|--------------------------------------------------|
| Life Sciences    | Water Resources                                  |
| Life Sciences    | Veterinary Sciences                              |
| Life Sciences    | Virology                                         |
| Life Sciences    | Zoology                                          |
| Natural Sciences | Acoustics                                        |
| Natural Sciences | Astronomy & Astrophysics                         |
| Natural Sciences | Automation & Control Systems                     |
| Natural Sciences | Chemistry, Analytical                            |
| Natural Sciences | Chemistry, Applied                               |
| Natural Sciences | Chemistry, Inorganic & Nuclear                   |
| Natural Sciences | Chemistry, Multidisciplinary                     |
| Natural Sciences | Chemistry, Organic                               |
| Natural Sciences | Chemistry, Physical                              |
| Natural Sciences | Computer Applications & Cybernetics              |
| Natural Sciences | Computer Science, Artificial Intelligence        |
| Natural Sciences | Computer Science, Cybernetics                    |
| Natural Sciences | Computer Science, Hardware & Architecture        |
| Natural Sciences | Computer Science, Information Systems            |
| Natural Sciences | Computer Science, Interdisciplinary Applications |
| Natural Sciences | Computer Science, Software Engineering           |
| Natural Sciences | Computer Science, Theory & Methods               |
| Natural Sciences | Construction & Building Technology               |
| Natural Sciences | Crystallography                                  |
| Natural Sciences | Electrochemistry                                 |
| Natural Sciences | Energy & Fuels                                   |
| Natural Sciences | Engineering, Aerospace                           |
| Natural Sciences | Engineering, Biomedical                          |
| Natural Sciences | Engineering, Chemical                            |
| Natural Sciences | Engineering, Civil                               |
| Natural Sciences | Engineering, Electrical & Electronic             |
| Natural Sciences | Engineering, Environmental                       |
| Natural Sciences | Engineering, Geological                          |
| Natural Sciences | Engineering, Industrial                          |
| Natural Sciences | Engineering, Manufacturing                       |
| Natural Sciences | Engineering, Marine                              |
| Natural Sciences | Engineering, Mechanical                          |
| Natural Sciences | Engineering, Multidisciplinary                   |
| Natural Sciences | Engineering, Ocean                               |
| Natural Sciences | Engineering, Petroleum                           |
| Natural Sciences | Ergonomics                                       |
| Natural Sciences | Geochemistry & Geophysics                        |
| Natural Sciences | Geography, Physical                              |
| Natural Sciences | Geology                                          |
| Natural Sciences | Geosciences, Multidisciplinary                   |
| Natural Sciences | Imaging Science & Photographic Technology        |
| Natural Sciences | Instruments & Instrumentation                    |
| Natural Sciences | Materials Science, Biomaterials                  |
| Natural Sciences | Materials Science, Ceramics                      |
| Natural Sciences | Materials Science, Characterization, Testing     |
| Natural Sciences | Materials Science, Coatings & Films              |
| Natural Sciences | Materials Science, Composites                    |
| Natural Sciences | Materials Science, Multidisciplinary             |
| Natural Sciences | Materials Science, Paper & Wood                  |
| Natural Sciences | Materials Science, Textiles                      |
| Natural Sciences | Mathematics                                      |
| Natural Sciences | Mathematics, Applied                             |
| Natural Sciences | Mathematics, Interdisciplinary Applications      |
| Natural Sciences | Mechanics                                        |
| Natural Sciences | Metallurgy & Metallurgical Engineering           |
| Natural Sciences | Metallurgy & Mining                              |
| Natural Sciences | Meteorology & Atmospheric Sciences               |
| Natural Sciences | Mineralogy                                       |
| Natural Sciences | Mining & Mineral Processing                      |
| Natural Sciences | Nanoscience & Nanotechnology                     |

|                              |                                          |
|------------------------------|------------------------------------------|
| Natural Sciences             | Nuclear Science & Technology             |
| Natural Sciences             | Oceanography                             |
| Natural Sciences             | Operations Research & Management Science |
| Natural Sciences             | Optics                                   |
| Natural Sciences             | Paleontology                             |
| Natural Sciences             | Physics, Applied                         |
| Natural Sciences             | Physics, Atomic, Molecular & Chemical    |
| Natural Sciences             | Physics, Condensed Matter                |
| Natural Sciences             | Physics, Fluids & Plasmas                |
| Natural Sciences             | Physics, Mathematical                    |
| Natural Sciences             | Physics, Multidisciplinary               |
| Natural Sciences             | Physics, Nuclear                         |
| Natural Sciences             | Physics, Particles & Fields              |
| Natural Sciences             | Polymer Science                          |
| Natural Sciences             | Remote Sensing                           |
| Natural Sciences             | Robotics                                 |
| Natural Sciences             | Spectroscopy                             |
| Natural Sciences             | Sport Sciences                           |
| Natural Sciences             | Statistics & Probability                 |
| Natural Sciences             | Telecommunications                       |
| Natural Sciences             | Thermodynamics                           |
| Natural Sciences             | Transportation                           |
| Natural Sciences             | Transportation Science & Technology      |
| OTHER                        | Multidisciplinary Sciences               |
| Social Sciences & Humanities | Anthropology                             |
| Social Sciences & Humanities | Archaeology                              |
| Social Sciences & Humanities | Architecture                             |
| Social Sciences & Humanities | Area Studies                             |
| Social Sciences & Humanities | Art                                      |
| Social Sciences & Humanities | Asian Studies                            |
| Social Sciences & Humanities | Behavioral Sciences                      |
| Social Sciences & Humanities | Business                                 |
| Social Sciences & Humanities | Business, Finance                        |
| Social Sciences & Humanities | Classics                                 |
| Social Sciences & Humanities | Communication                            |
| Social Sciences & Humanities | Criminology & Penology                   |
| Social Sciences & Humanities | Dance                                    |
| Social Sciences & Humanities | Demography                               |
| Social Sciences & Humanities | Economics                                |
| Social Sciences & Humanities | Education & Educational Research         |
| Social Sciences & Humanities | Education, Scientific Disciplines        |
| Social Sciences & Humanities | Education, Special                       |
| Social Sciences & Humanities | Environmental Studies                    |
| Social Sciences & Humanities | Ethics                                   |
| Social Sciences & Humanities | Ethnic Studies                           |
| Social Sciences & Humanities | Family Studies                           |
| Social Sciences & Humanities | Film, Radio, Television                  |
| Social Sciences & Humanities | Folklore                                 |
| Social Sciences & Humanities | Geography                                |
| Social Sciences & Humanities | Health Policy & Services                 |
| Social Sciences & Humanities | History                                  |
| Social Sciences & Humanities | History & Philosophy of Science          |
| Social Sciences & Humanities | History of Social Sciences               |
| Social Sciences & Humanities | Hospitality, Leisure, Sport & Tourism    |
| Social Sciences & Humanities | Humanities, Multidisciplinary            |
| Social Sciences & Humanities | Industrial Relations & Labor             |
| Social Sciences & Humanities | Information Science & Library Science    |
| Social Sciences & Humanities | International Relations                  |
| Social Sciences & Humanities | Language & Linguistics                   |
| Social Sciences & Humanities | Law                                      |
| Social Sciences & Humanities | Linguistics                              |
| Social Sciences & Humanities | Literary Reviews                         |
| Social Sciences & Humanities | Literary Theory & Criticism              |
| Social Sciences & Humanities | Literature                               |

|                              |                                           |
|------------------------------|-------------------------------------------|
| Social Sciences & Humanities | Literature, African, Australian, Canadian |
| Social Sciences & Humanities | Literature, American                      |
| Social Sciences & Humanities | Literature, British Isles                 |
| Social Sciences & Humanities | Literature, German, Dutch, Scandinavian   |
| Social Sciences & Humanities | Literature, Romance                       |
| Social Sciences & Humanities | Literature, Slavic                        |
| Social Sciences & Humanities | Management                                |
| Social Sciences & Humanities | Medieval & Renaissance Studies            |
| Social Sciences & Humanities | Music                                     |
| Social Sciences & Humanities | Oriental Studies                          |
| Social Sciences & Humanities | Philosophy                                |
| Social Sciences & Humanities | Planning & Development                    |
| Social Sciences & Humanities | Poetry                                    |
| Social Sciences & Humanities | Political Science                         |
| Social Sciences & Humanities | Politics & Policy                         |
| Social Sciences & Humanities | Public Administration                     |
| Social Sciences & Humanities | Religion                                  |
| Social Sciences & Humanities | Social Issues                             |
| Social Sciences & Humanities | Social Sciences, Biomedical               |
| Social Sciences & Humanities | Social Sciences, Interdisciplinary        |
| Social Sciences & Humanities | Social Sciences, Mathematical Methods     |
| Social Sciences & Humanities | Social Work                               |
| Social Sciences & Humanities | Sociology                                 |
| Social Sciences & Humanities | Theater                                   |
| Social Sciences & Humanities | Urban Studies                             |
| Social Sciences & Humanities | Women's Studies                           |

# Endnotes

- 1 Non-Baltic countries of Eastern Europe that have recently become members of the European Union: Bulgaria, Cyprus, the Czech Republic, Hungary, Malta, Poland, Romania, Slovakia and Slovenia.
- 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, PA, USA. © Copyright Thomson Reuters® 2009. All rights reserved.
- 3 The numbers are taken from the Thomson Reuters database. We do not have independent measures to assess the actual world development of scientific publications. It is clear that the science system generally is expanding from year to year. More money is being spent on research activities, which involve an increasing number of scientists. This growth is also reflected in the publication counts. In addition, the coverage of the database in terms of the number of journals indexed has grown during the period (see, for example, Figure 2.5). Whether this increase in the database coverage correlates with the increase in the total scientific literature globally is hard to assess. But, at least part of the increase can be seen as a database artifact (Aksnes & Hessen 2009).
- 4 In the Thomson Reuters database, ‘journal’ is not a well-defined concept, while ‘journal issue’ is. For simplicity, we have chosen to study journal issues here.
- 5 Curiously, the shares of single-*address* publications are quite different: 53% for social sciences and humanities, 32% for life sciences, and 44% for natural sciences.
- 6 Out of a total of 807 co-authorship links between Finland and the Baltic states, 526 were with Estonia, 193 with Lithuania, and 88 with Latvia.
- 7 Numbers only represent articles in the co-authored set, not the full country production.
- 8 See <http://pajek.imfm.si>.
- 9 See <http://www.inkscape.org>.
- 10 If Norway, for instance, has published an article together with researchers both from North America and from an EU15 country, Pajek also displays a (correct) co-authoring relation between North America and EU15, which is not relevant for the present study.
- 11 Papers with more than 100 addresses were excluded in order to avoid very large cooperation projects with several hundred authors, since these are considered exceptional in the context of this study. Such papers could skew the cooperation patterns considerably.



