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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

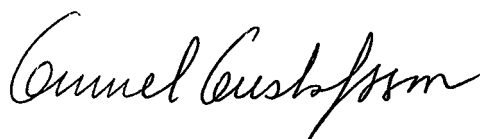
NordForsk is a platform for joint Nordic research and research policy development. The aim is to promote cooperation which adds value to what is going on nationally, and thereby contribute to the knowledge society through continuous efforts to improve the quality of Nordic research and innovation.

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.¹ 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*.² 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 1984.³

FIGURE 2.1. TOTAL NUMBER OF PUBLICATIONS, 1984–2008

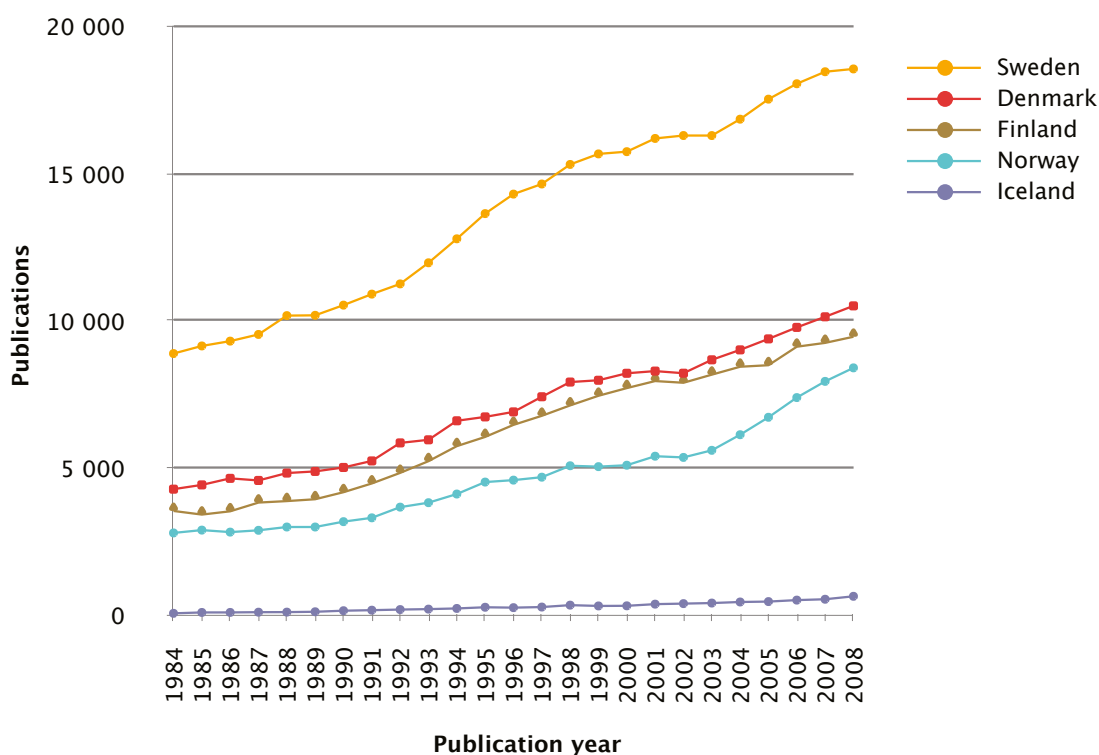
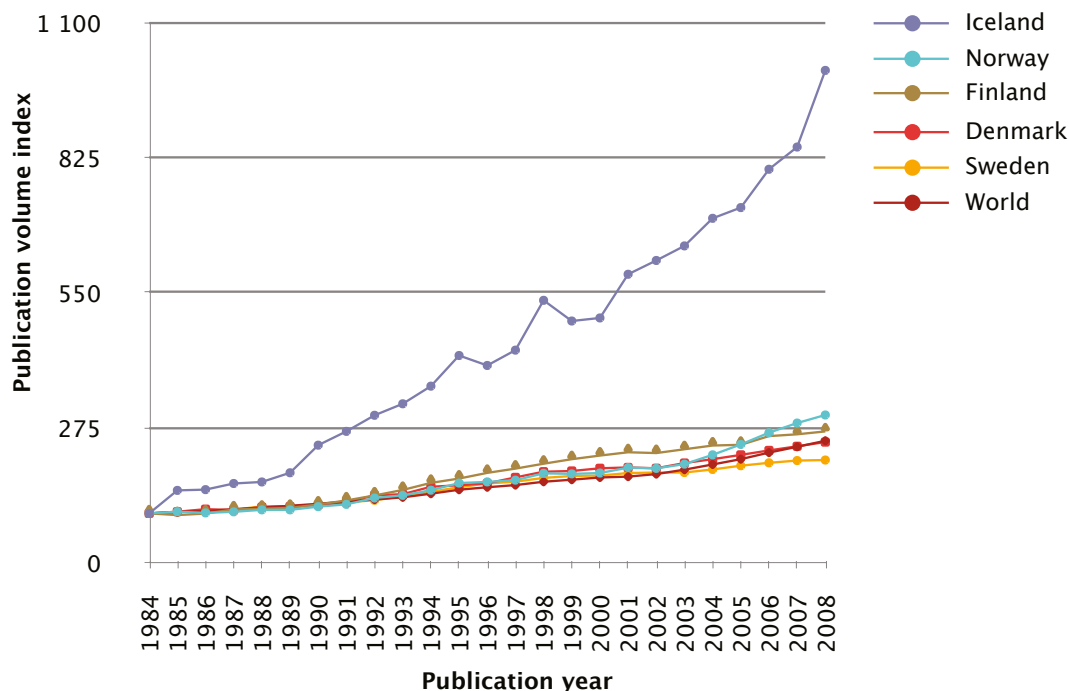


FIGURE 2.2. PUBLICATION INCREASE 1984–2008 (1984=100)



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%
Entire database	50%	44%	6%	100%

* 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

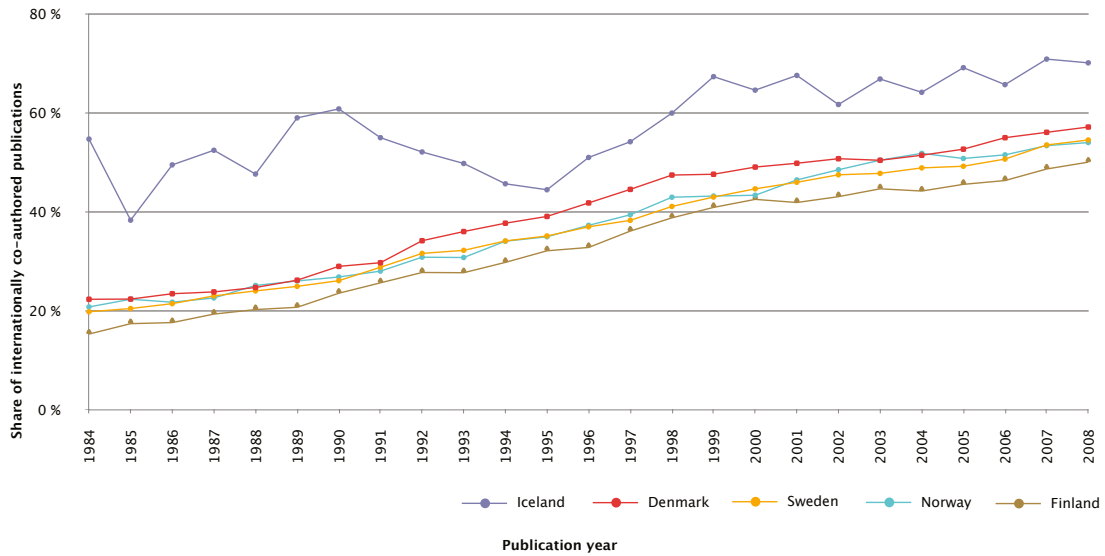
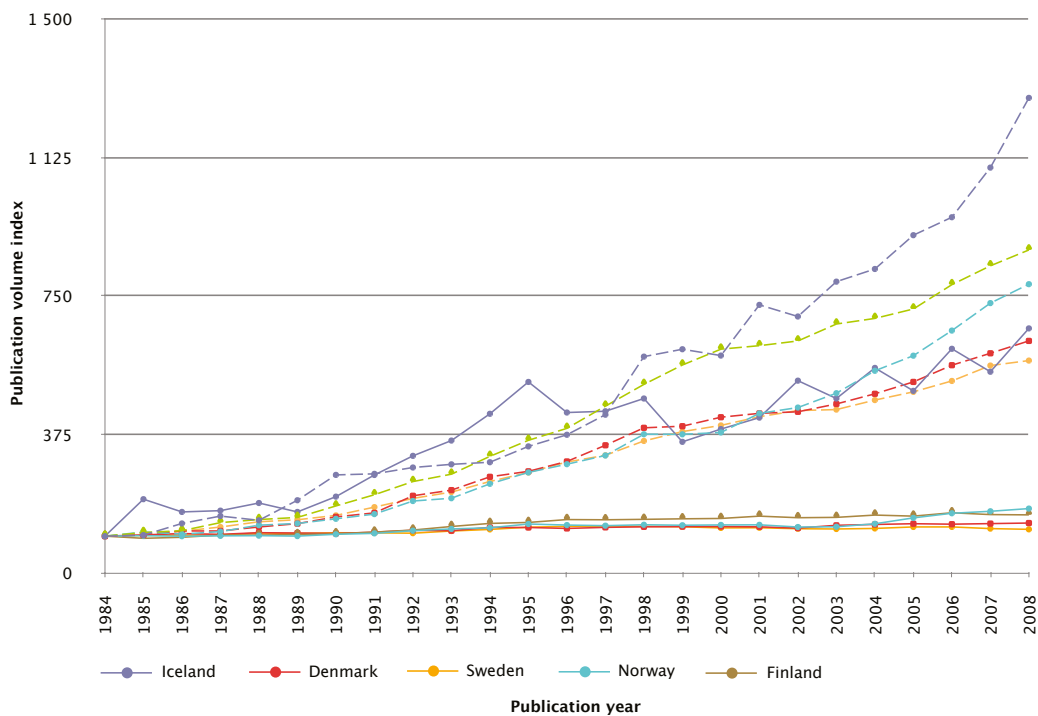


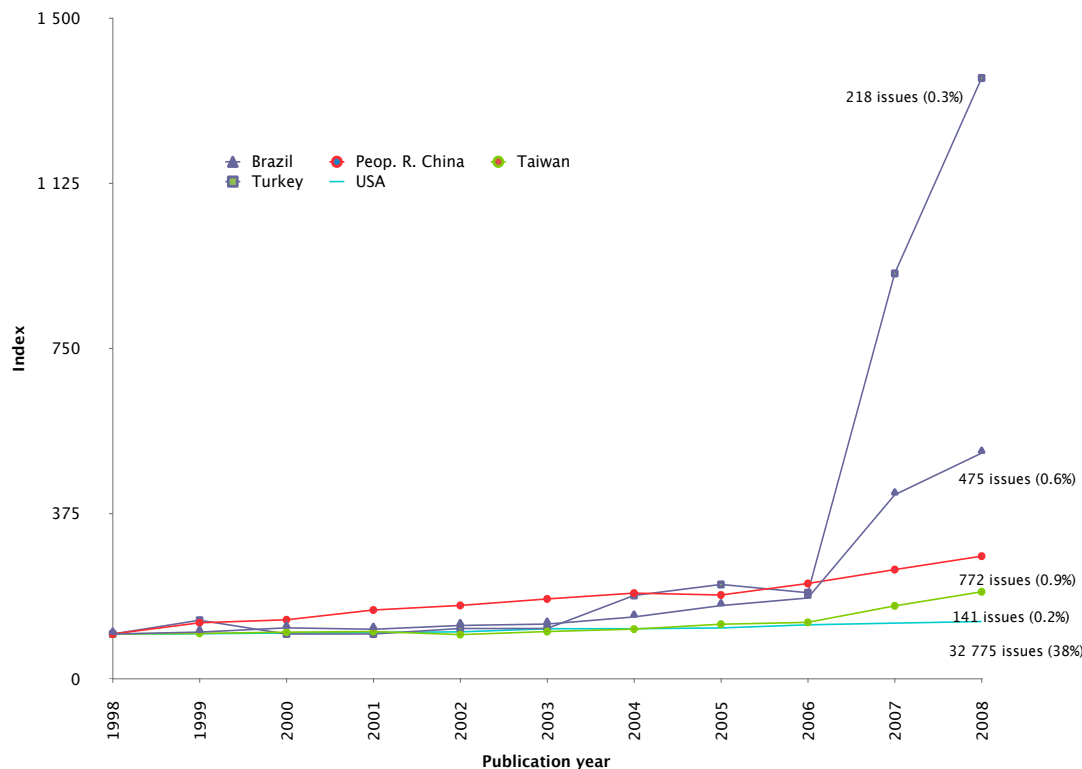
FIGURE 2.4. INTERNATIONAL CO-PUBLICATION GROWTH COMPARED TO NATIONAL PUBLICATION GROWTH (1984=100)



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.

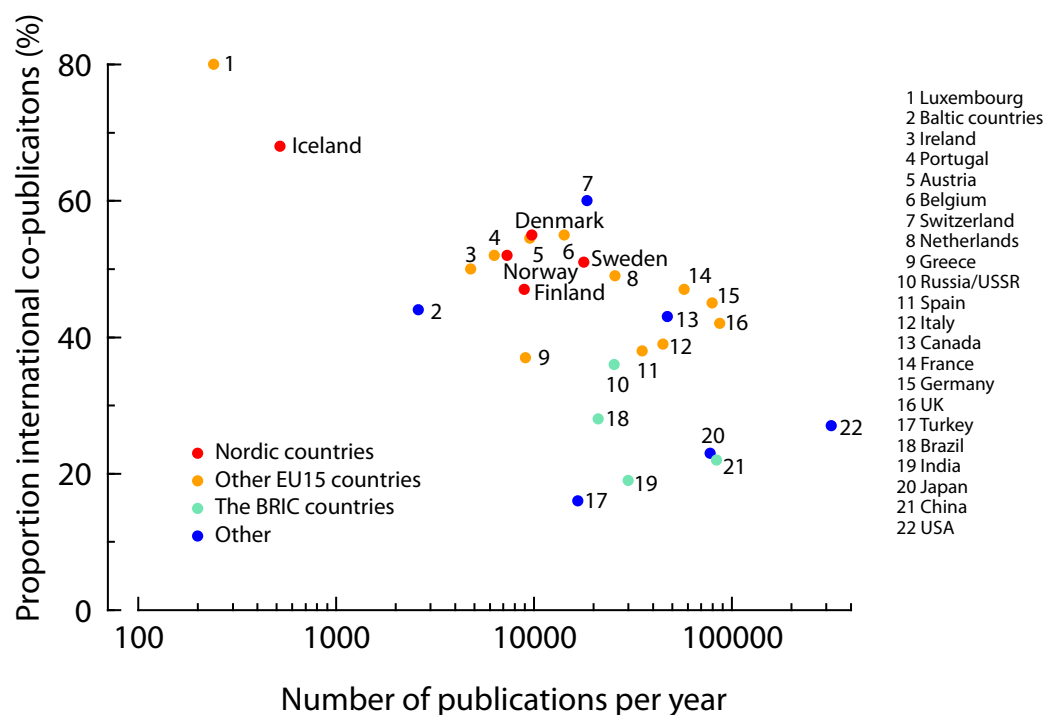
In Table 2.2, the data from Figure 2.3 are transformed into three five-year periods and compared both with the other EU15 nations and with some additional countries and regions (the selection of countries and regions is explained in the Appendix). A general pattern is that the smaller the size of the 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
Denmark	23%	42%	55%	22 755	35 575	48 803
Finland	18%	34%	47%	18 185	32 153	44 745
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
Iceland	48%	52%	68%	461	1 376	2 609
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
Norway	23%	38%	52%	14 384	22 985	36 579
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
Sweden	22%	37%	51%	47 042	70 665	89 415
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. ⁴

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.

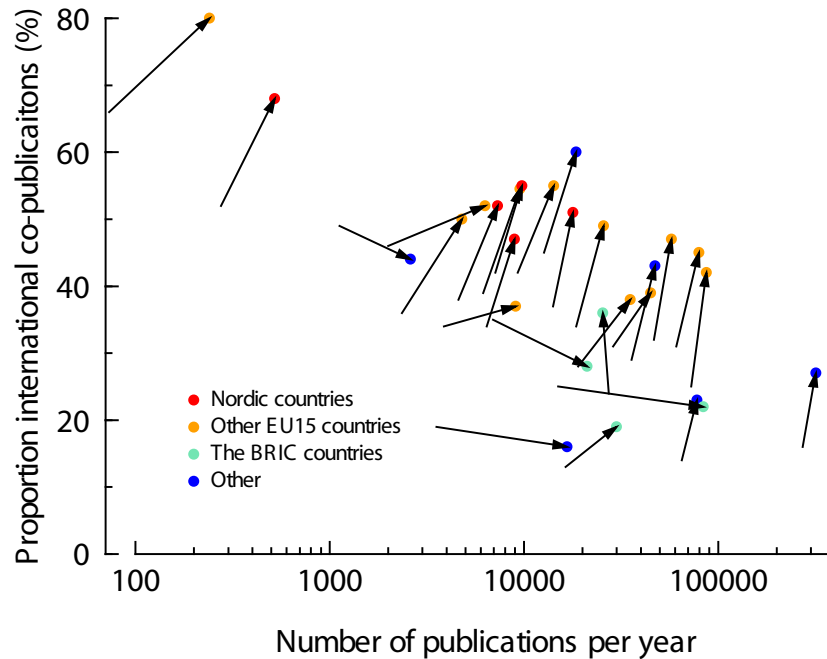
Luxembourg, Portugal, Singapore and Taiwan have all experienced dramatic increases in their publication volumes, but from very low levels. The disintegration of the USSR at the end of 1980s explains the extreme changes in Table 2.2 between the two first periods for the Baltic countries, Ukraine and Russia/USSR.

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).

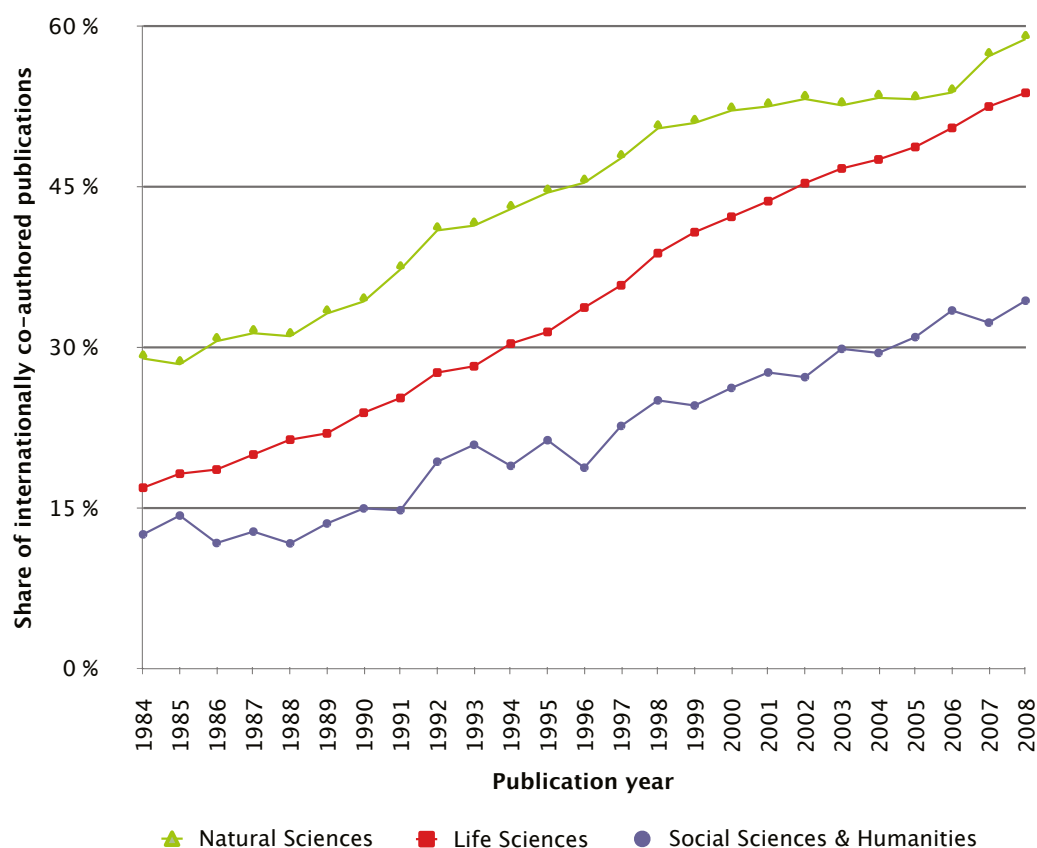
Mainly five countries deviate from the general pattern (marked in green in Figure 2.6 and Figure 2.7): Brazil, China, Taiwan, Korea and Turkey. As mentioned above, this can at least partly be explained by changes in database coverage. These countries have a strong increase in publication volume, but 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.⁵

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

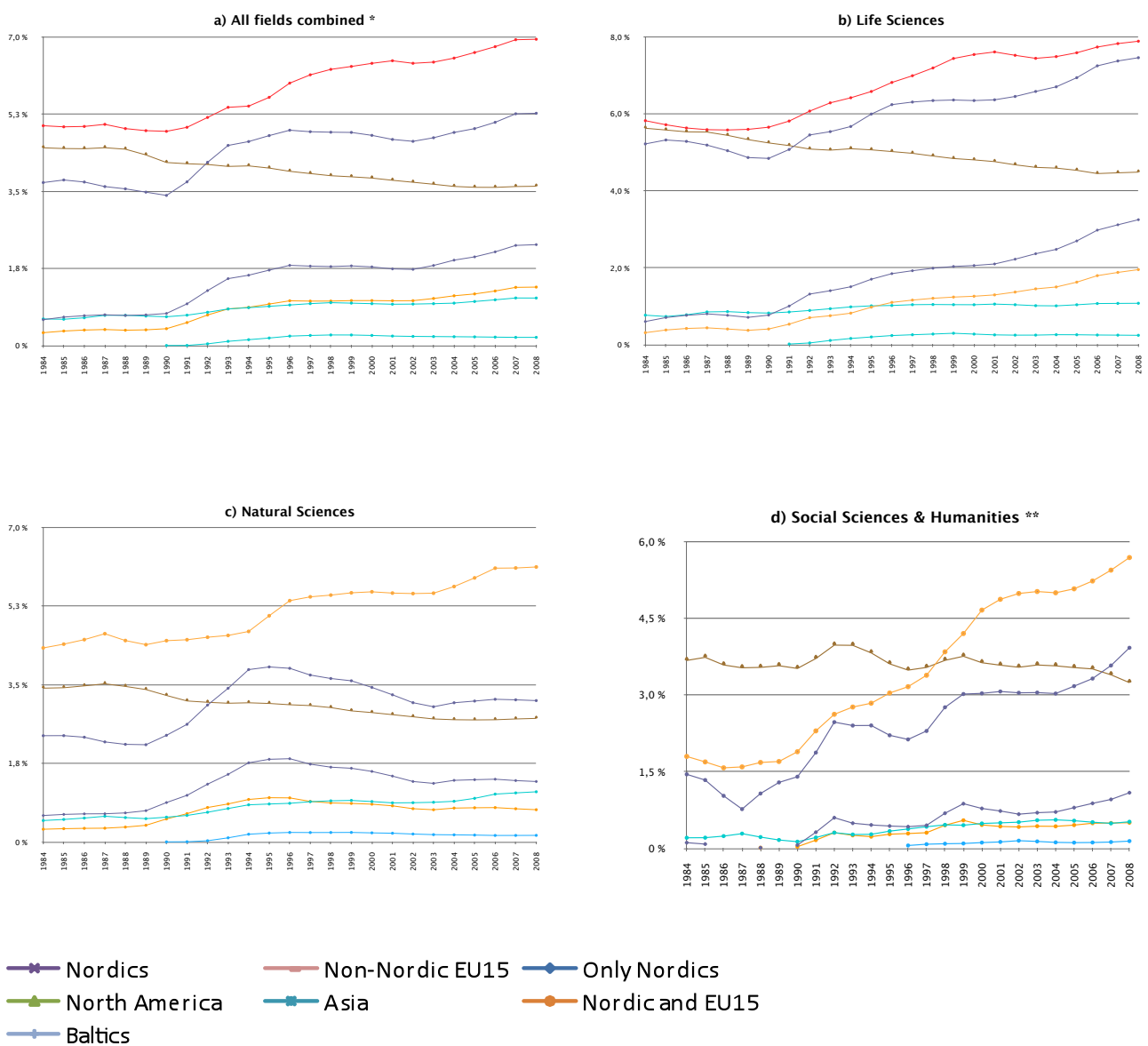
This chapter deals with international cooperation between the Nordic region and other large geographic regions. International co-publications involving at least one Nordic address were placed in one or more categories based on the other countries represented in the list of author addresses (see the Appendix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

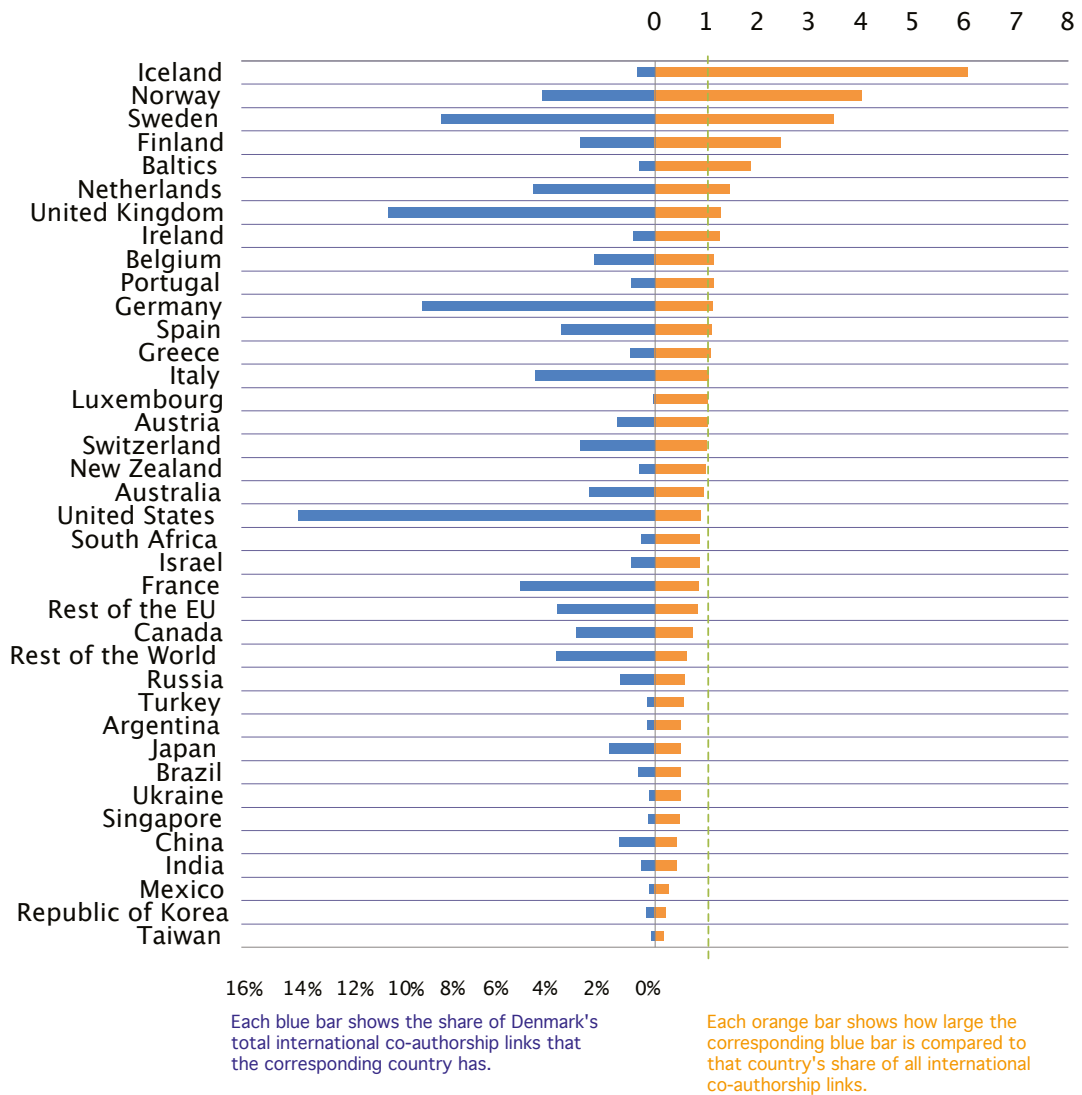
Cooperation patterns per country

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%

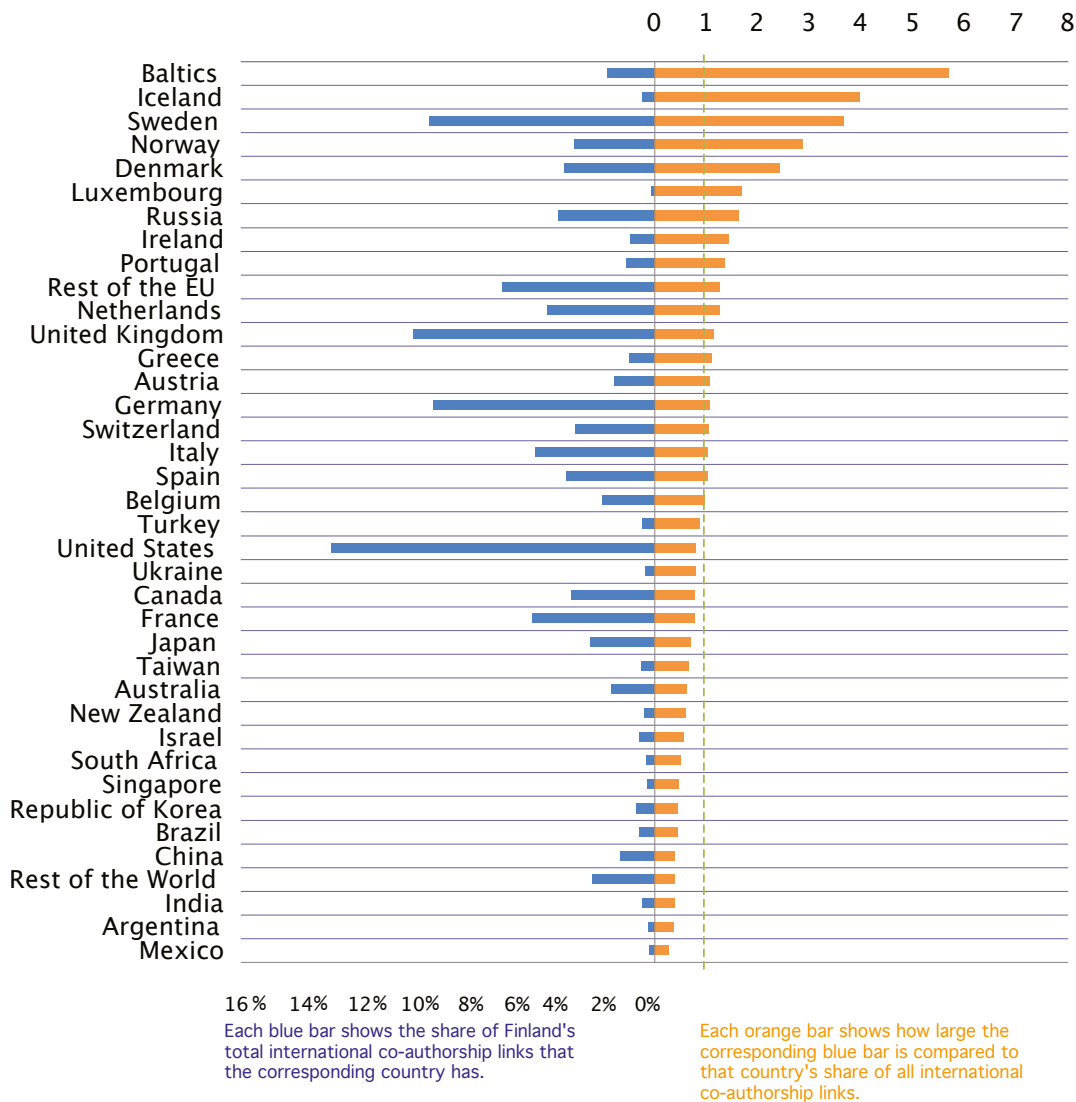
FIGURE 4.1. DENMARK'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.



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.

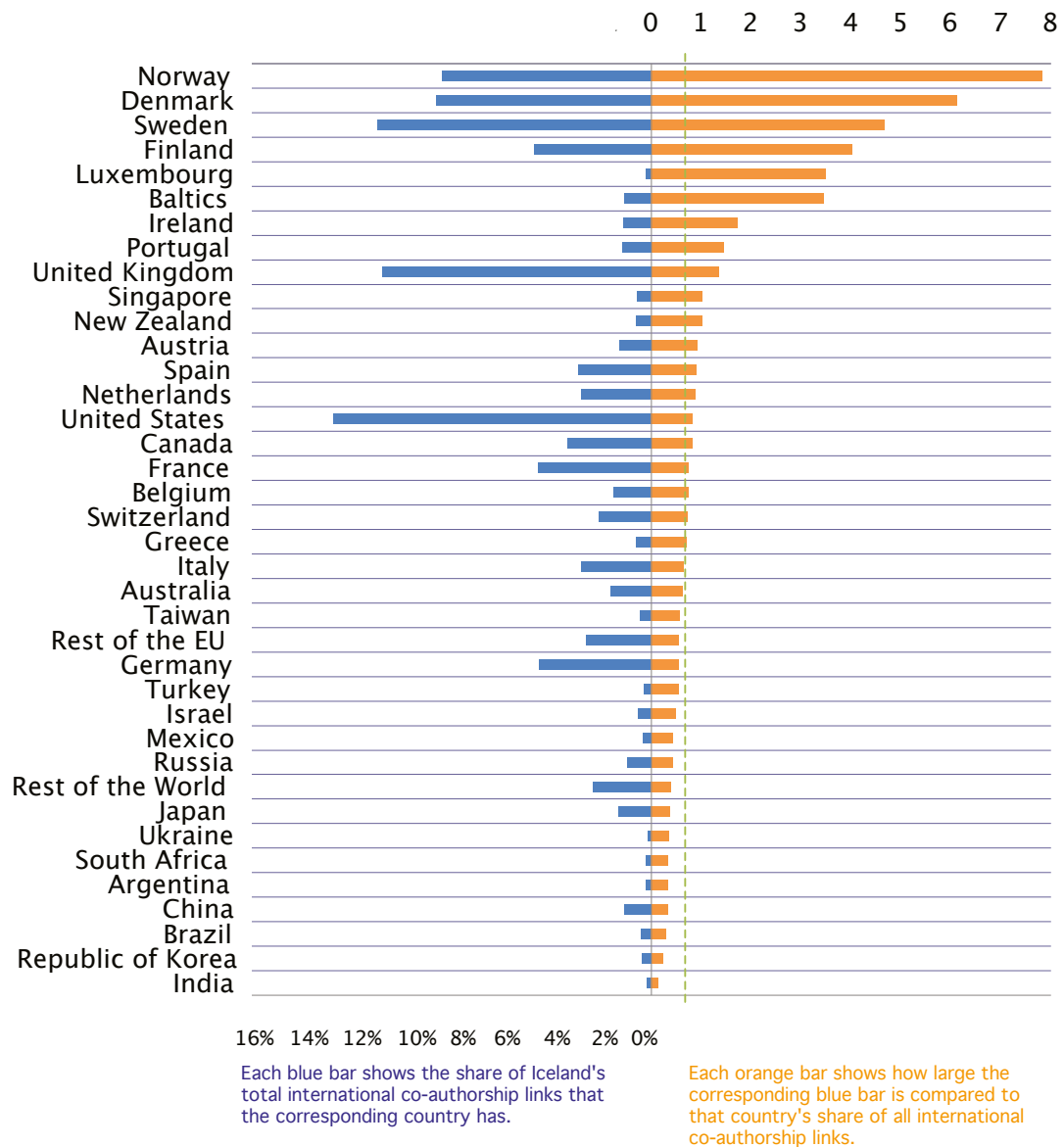
FIGURE 4.2. FINLAND'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.



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.⁶

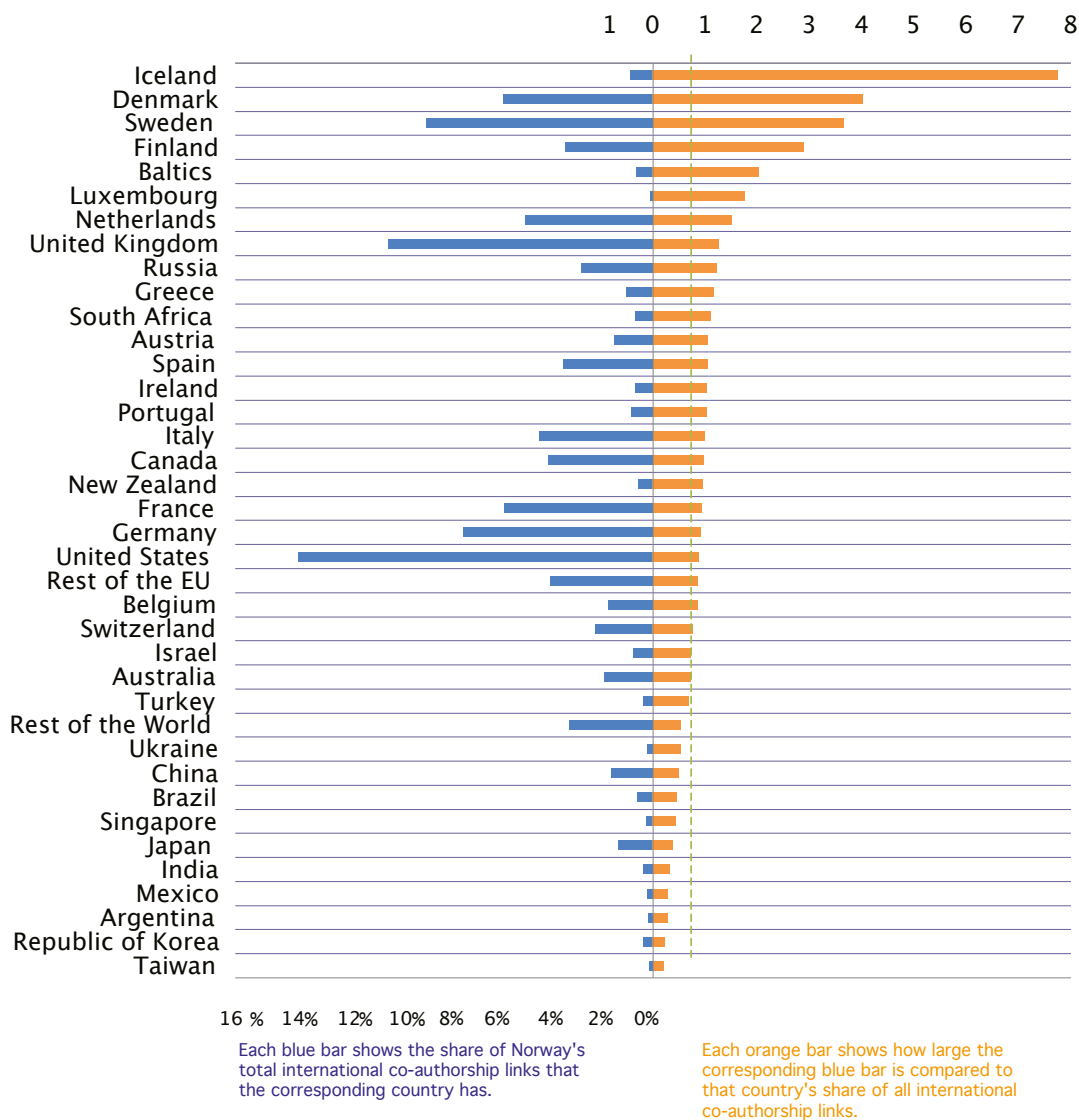
Looking at the bloc of countries below the Nordic and Baltic ones, we see that Finnish researchers are somewhat less focused on the Western world than their Danish counterparts (compare Figure 4.1). Russia is found in seventh place, and Turkey, Ukraine and Japan are all located above Australia, Israel 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.



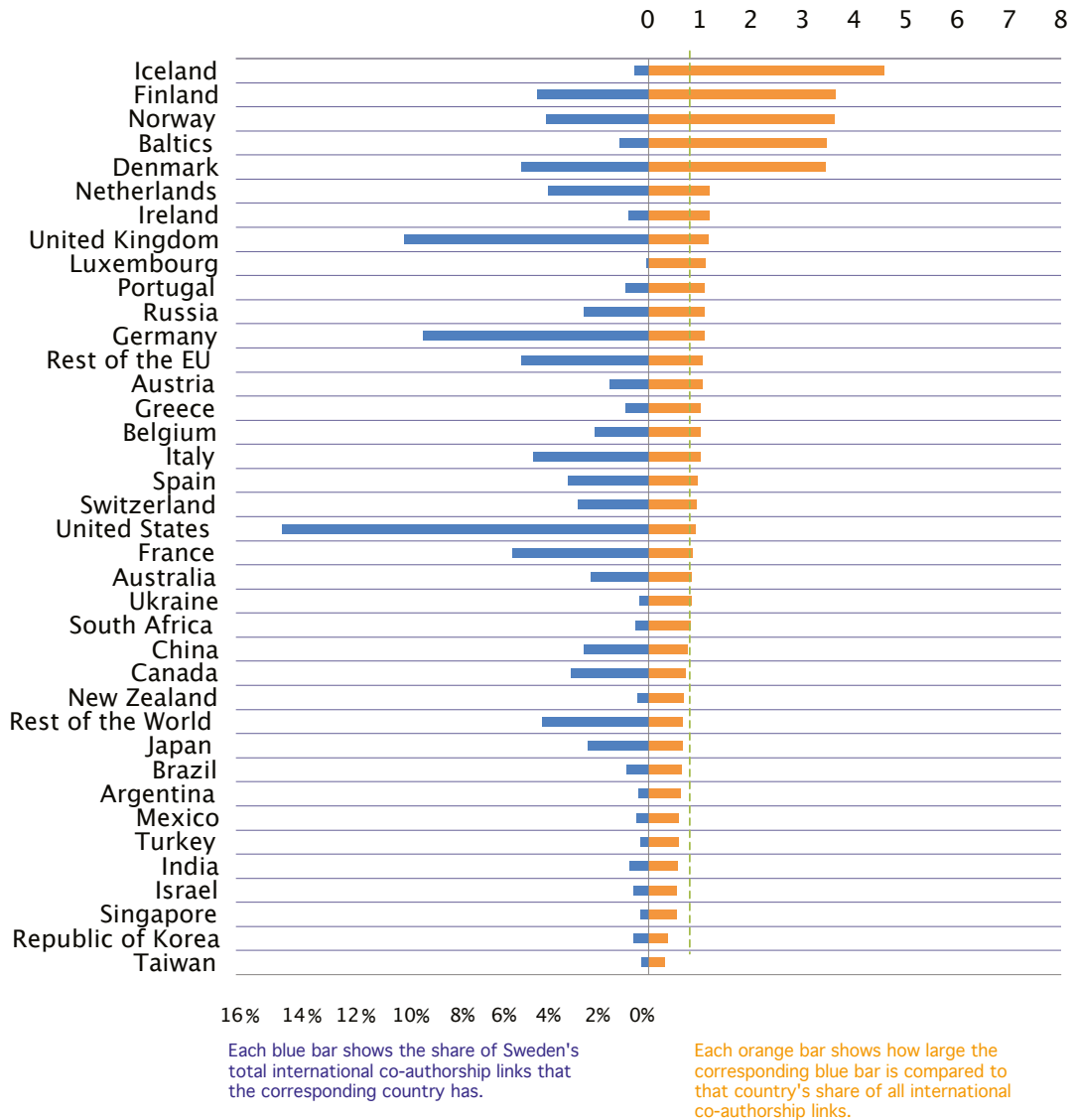
For Iceland, the Nordic and Baltic domination is greater than it is for the other Nordic countries (see Figure 4.3). Outside the Nordic and Baltic countries, the other Western countries dominate the list, very much in the same way as in the case of Denmark. The somewhat unexpected rankings of Singapore 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).

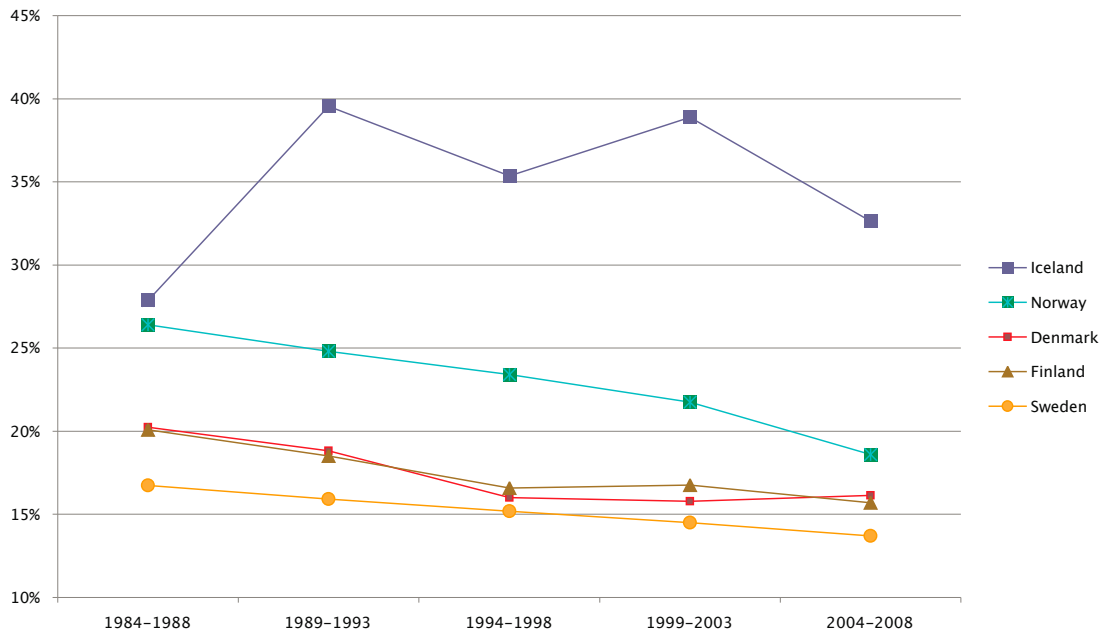
FIGURE 4.5. SWEDEN'S PATTERN OF INTERNATIONAL COOPERATION. THE DOTTED GREEN LINE SHOWS THE AVERAGE SHARE.



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.

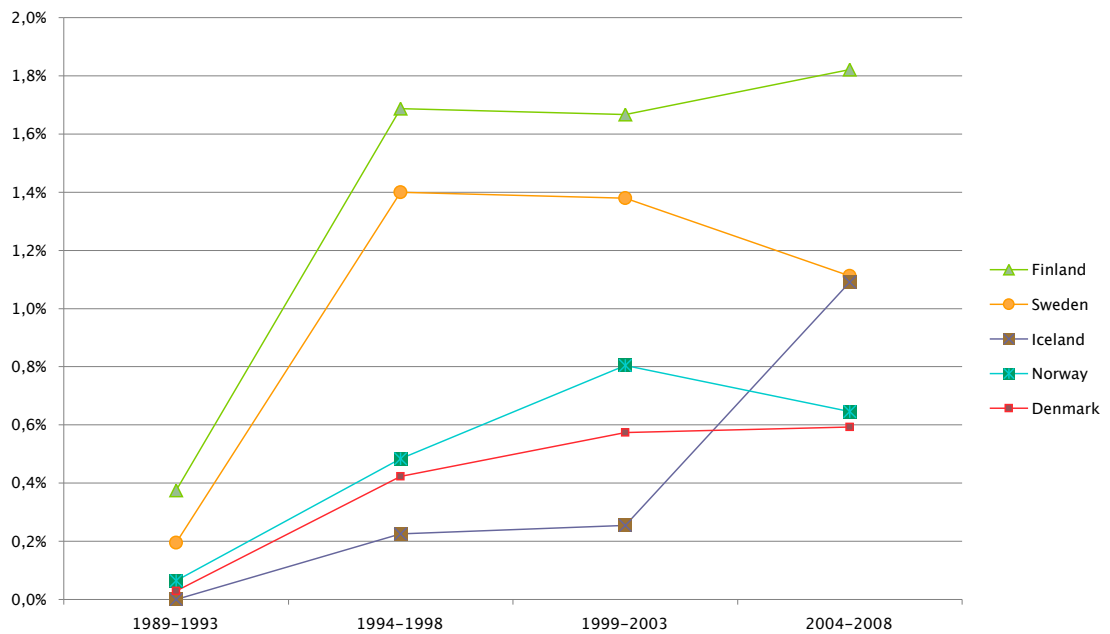


Changes in Nordic international cooperation

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.

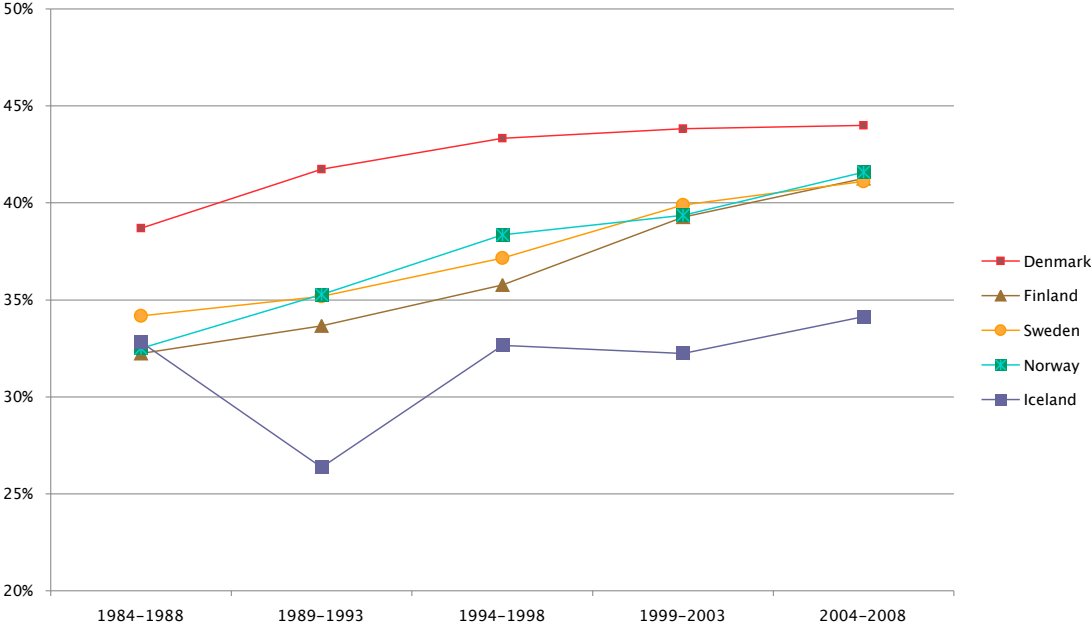
Figure 4.6 shows that cooperation with other Nordic countries has decreased somewhat in importance since the 1980s for Denmark, Finland, Norway and Sweden, compared to cooperation with other countries. Figure 3.1 showed that the number of intra-Nordic co-publications rose during the same period in relation 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.



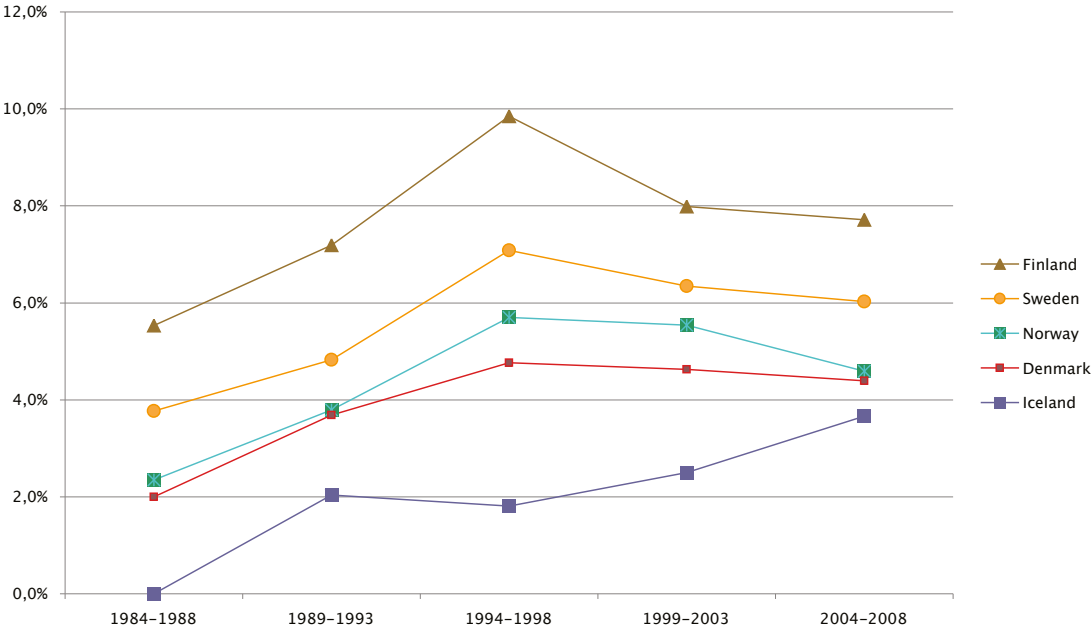
The Nordic cooperation with the Baltic countries increased dramatically during the 1990s, when the Baltic countries first appeared as research nations in their own right, but after that period the degree of cooperation levelled out. In the cases of Sweden and Norway, it even decreased somewhat during 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.



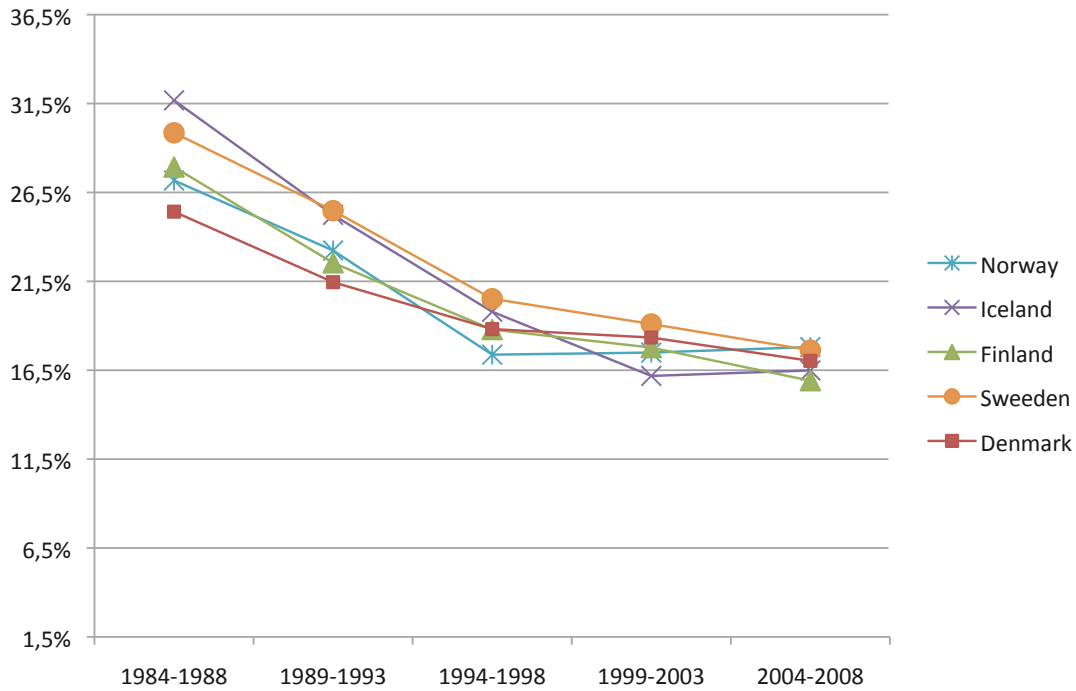
Non-Nordic EU15 countries, roughly corresponding to the rest of Western Europe, were important cooperation partners at the start of the period, and this importance increased somewhat during the period for all Nordic countries.

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.



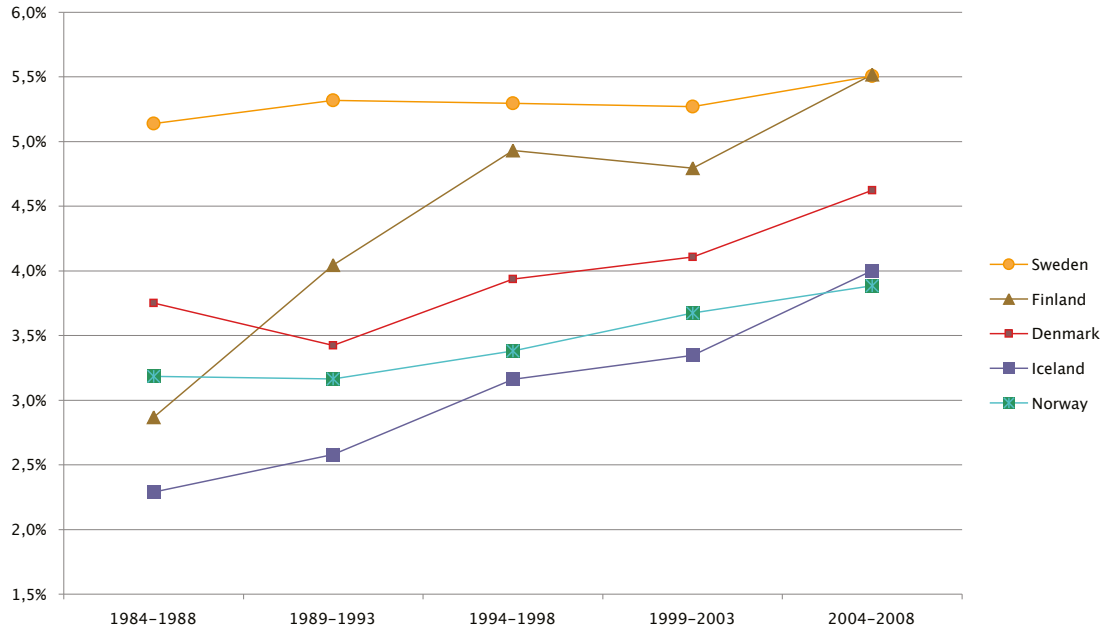
EU27 countries that are neither EU15, nor Nordic, nor Baltic are Bulgaria, Cyprus, the Czech Republic, Hungary, Malta, Poland, Romania, Slovakia and Slovenia. Danish, Finnish, Norwegian and Swedish cooperation with these countries increased rapidly (compared to cooperation with other countries) from 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.



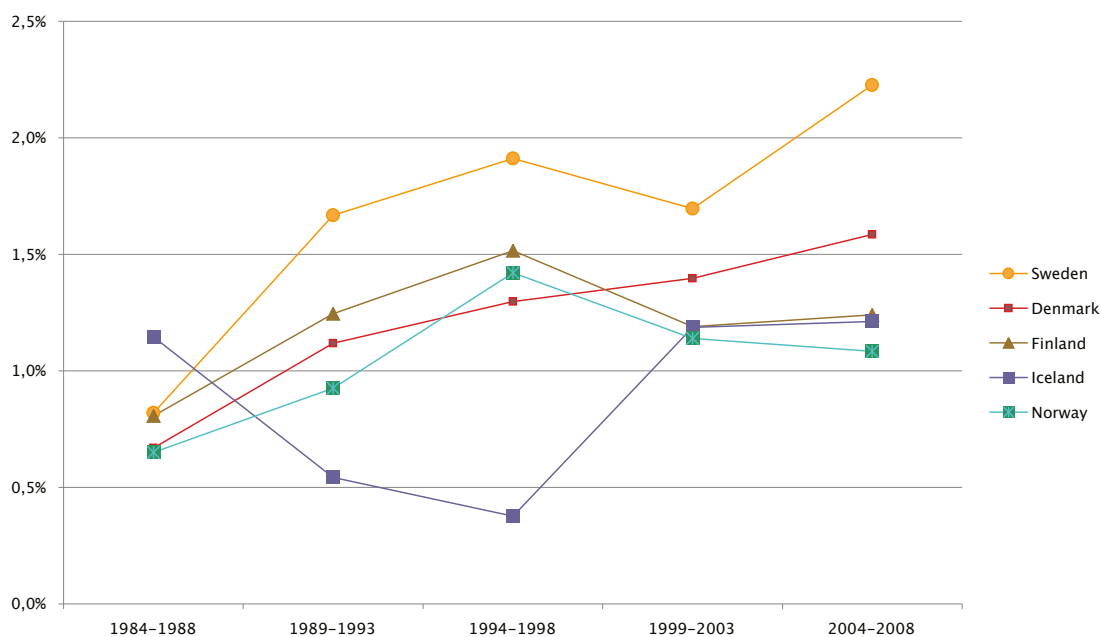
All Nordic countries follow the same patterns regarding cooperation with North American countries (where the USA dominates heavily). The relative importance of North American cooperation has fallen throughout the studied period.

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.



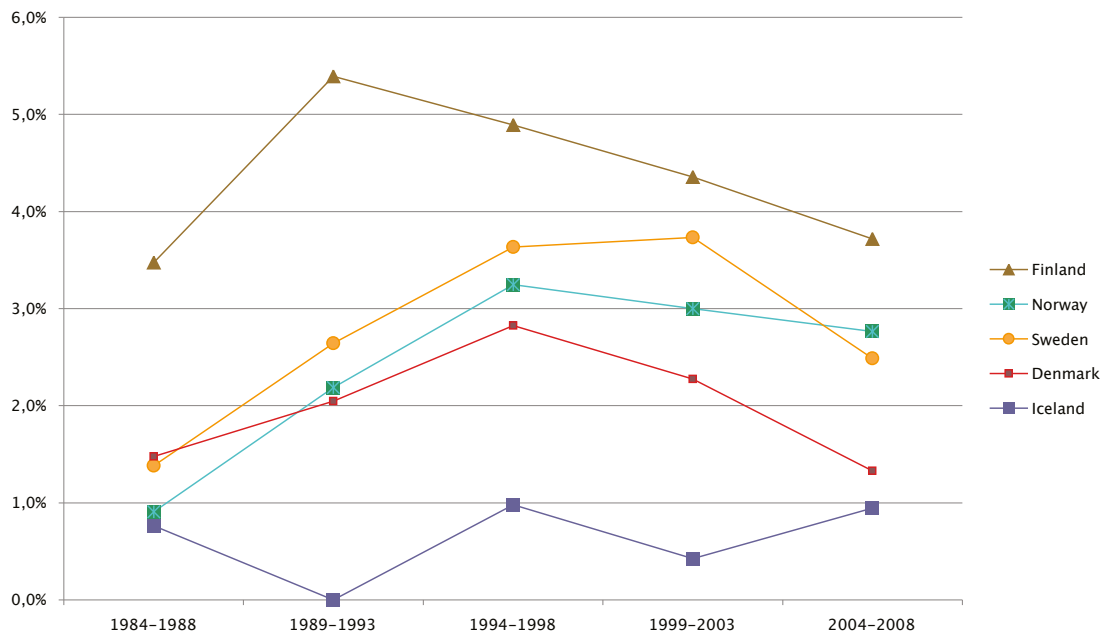
Cooperation with Asian countries has increased during the period for all Nordic countries, most so for Finland, which started at a low level, and least so for Sweden, which started at a high level.

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.



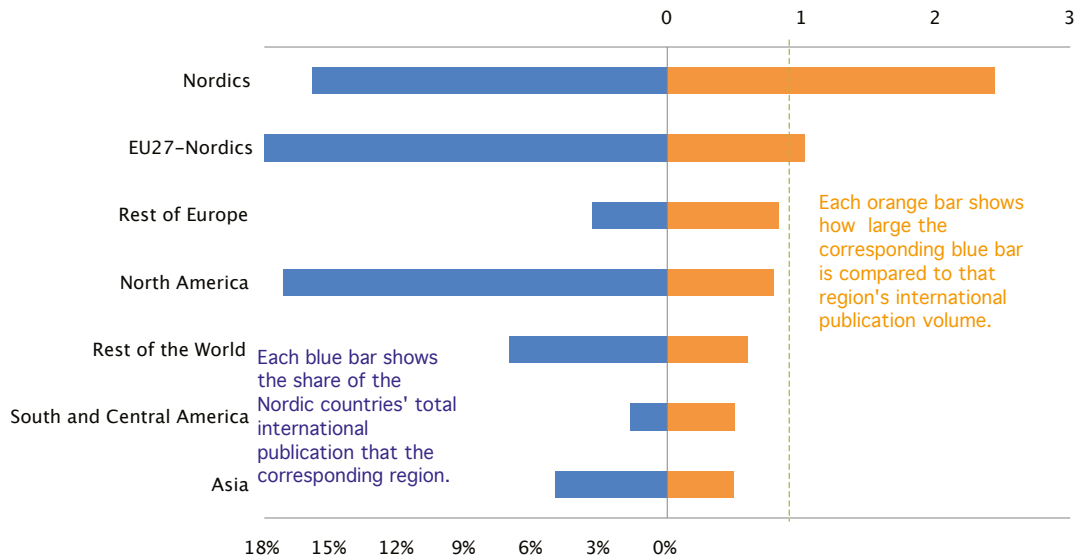
Sweden's cooperation with South and Central American countries rose considerably during the period, compared to its cooperation with other countries, with a dip around the turn of the millennium. Norway and Finland followed the Swedish development until the most recent five-year period, when Swedish 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.⁷

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.

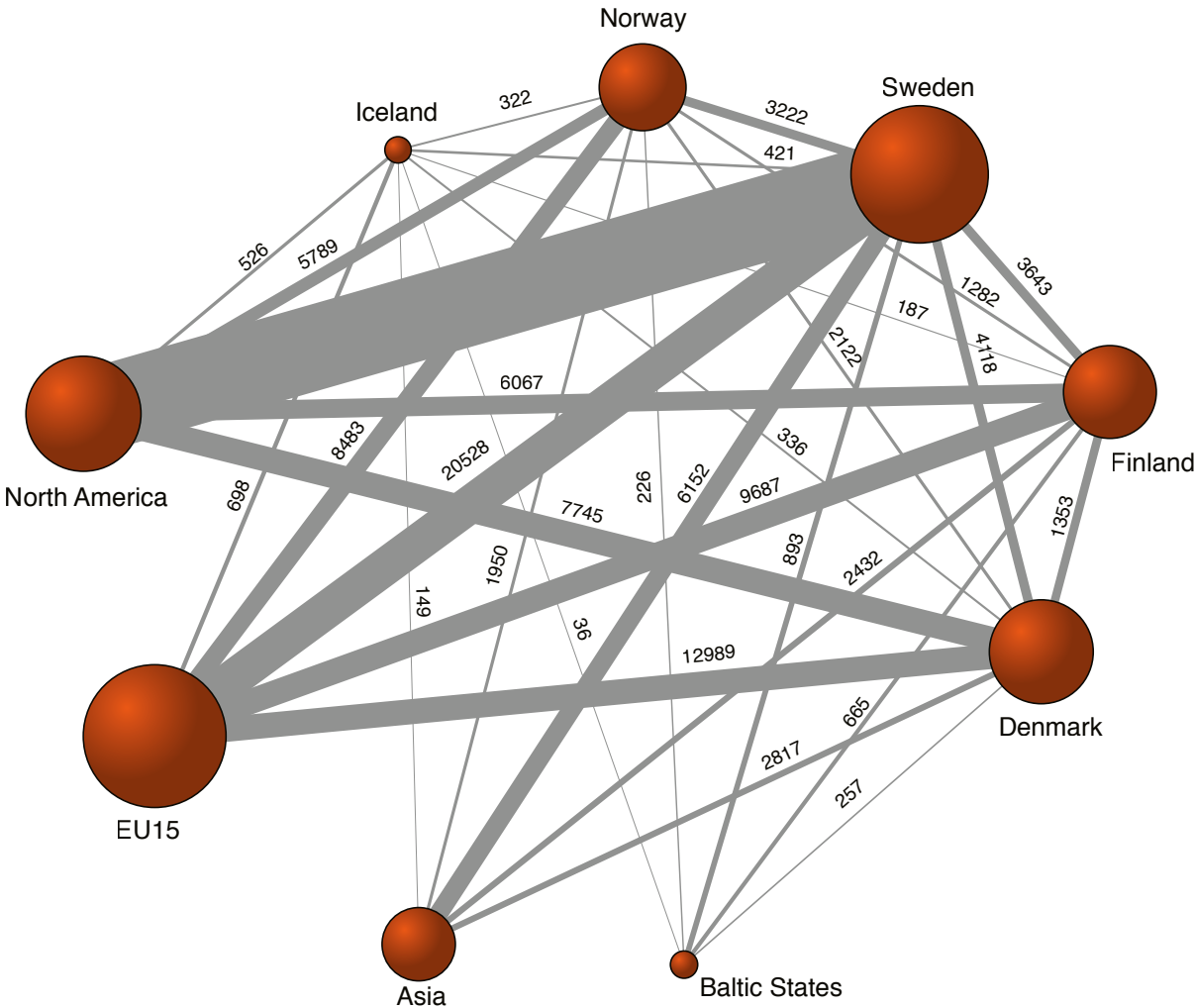
The visual presentation was done using the computer program Pajek.⁸ The final figures were edited with the computer program Inkscape,⁹ and some secondary cooperation patterns between non-Nordic regions were removed, since these did not form part of the focus of the present study.¹⁰

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%
Sum 2003–2007	198 523	100%

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.



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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,¹¹ 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

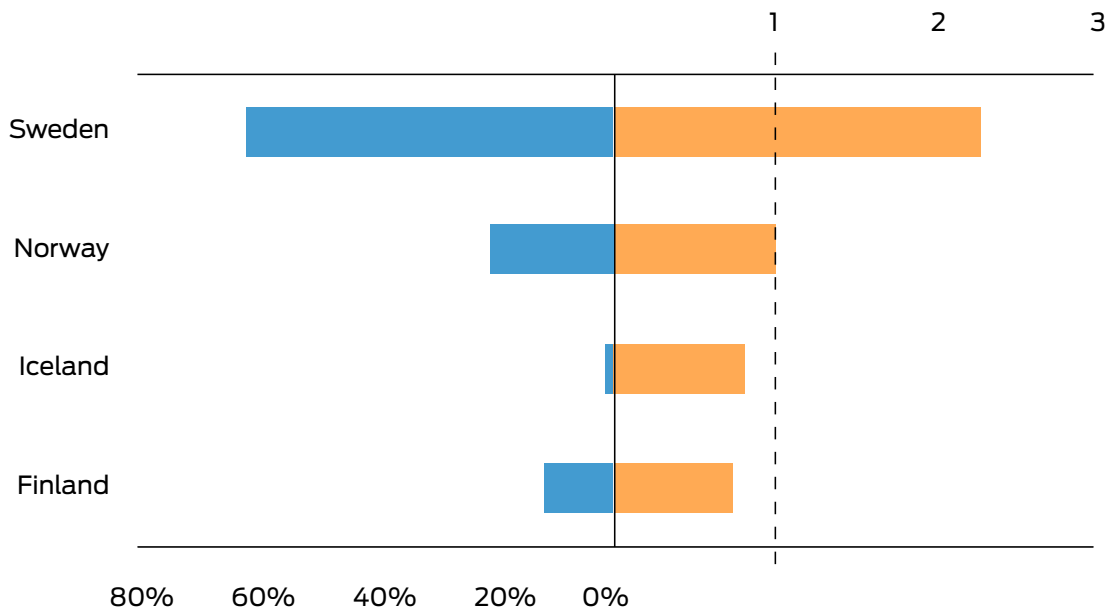
$C_{x,y}$ = the number of co-authorship links between countries X and Y;

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 is 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

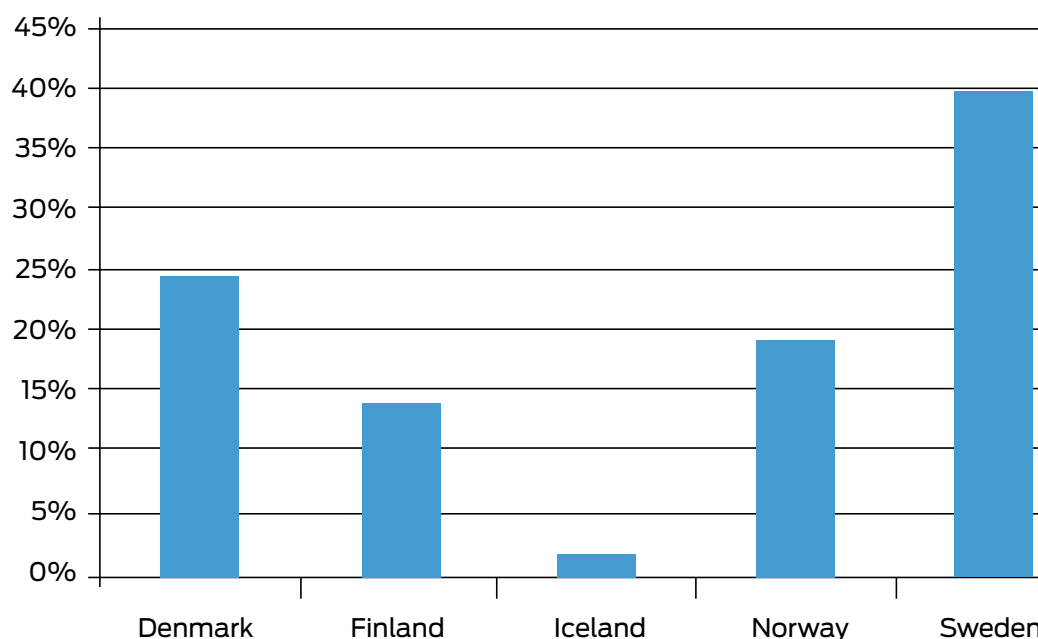


Figure A2 thus shows how much the countries are expected to work with each of the other countries. They are expected to work 25% with Denmark, 15% with Finland, etc.

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.

