Science-Metrix

Scientometric Study

March 2005

Potential for Scientific Collaboration between Canada and Nordic Countries, 1998-2003

Denmark - Finland- Iceland - Norway - Sweden

Prepared for

International Trade Canada

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and Benoît Michaud

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Introduction

Despite Canada and the Nordic countries being geographical neighbours, the level of cooperation between them countries is not high. For instance, Canada is not a party to nor an observer in the Nordic Council, established in 1952 as a forum for inter-parliamentary co-operation between five of the Nordic countries: Denmark, Finland, Iceland, Norway and Sweden. (The territories of the Faroe Islands and Greenland, which are part of the kingdom of Denmark, and the Åland Islands, which belong to the republic of Finland are part of the Nordic country group, but are not considered in this report.) Canada and the Nordic countries do, however, actively collaborate within the Arctic Council. Established in Ottawa in 1996, the Arctic Council aims to advance circumpolar cooperation and has a mandate to protect the Arctic environment and promote the economic, social and cultural well-being of northern peoples. The Council comprises eight arctic states (Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the US) and promotes scientific collaboration through its five working groups:

- Arctic Monitoring and Assessment Program (AMAP);
- Conservation of Arctic Flora and Fauna (CAFF);
- Emergency Prevention, Preparedness and Response (EPPR);
- Protection of the Arctic Marine Environment (PAME);
- Sustainable Development Working Group (SDWG).

There is a strong basis for collaboration between the Nordic countries and Canada. Although Canada's landmass is much greater than that of all Nordic countries combined, all these countries are similar in terms of socio-political orientation due to a strong social-democrat tradition. In addition, the wealth of all these countries is similar measured by gross domestic product (GDP) per capita and all score well in the United Nation Development Programme's (UNDP) Human Development Index.

Table I Geopolitical & socioeconomic features of Canada and the Nordic countries

	Canada	Denmark	Finland	Iceland	Norway	Sweden
Area (thousand sq km)	9,984	43	338	103	324	450
Population (million, July 2004 est.)	32.5	5.4	5.2	0.29	4.6	9.0
Labour force (million, 2003 est.)	17.0	2.9	2.6	0.16	2.4	4.4
GDP (billion US$ p.p.p. 2003 est.)	$958.7	$167.2	$142.2	$8.7	$171.7	$238.3
GDP per capita (p.p.p. 2003 est.)	$29,800	$31,100	$27,400	$30,900	$37,800	$26,800
Human Development Index (ranking)	0.943 (4)	0.932 (17)	0.935 (13)	0.941 (7)	0.956 (1)	0.946 (2)
Government type	Parliamentary democracy	Constitutional monarchy	Republic	Constitutional republic	Constitutional monarchy	Constitutional monarchy

GDP = gross domestic product; p.p.p. = purchasing power parity
Source: CIA. The World Factbook 2004; UNDP. Human Development Report 2004.

Although trade with the Nordic countries is relatively small, it is growing exponentially (see Figure 1). Canada's exports to the Nordic countries between 1995 and 2004 were worth Can$19 billion, which was equivalent to 0.5% of Canada's exports in that period. Although this figure of Can$19 billion may at first sight seem small, exports have been growing at an average of 5% per year. The

Nordic countries as a group, have a fairly healthy balance of trade with Canada since they export nearly 3.5 times more to Canada than they import from their circumpolar neighbours. The Nordic countries' exports to Canada amounted to Can$65 billion and have been growing at 8% a year on average. Trade balance is growing in favour of the Nordic countries at a rate of 9% per year with Canada accumulating a trade deficit of Can$46 billion over the ten years from 1995.

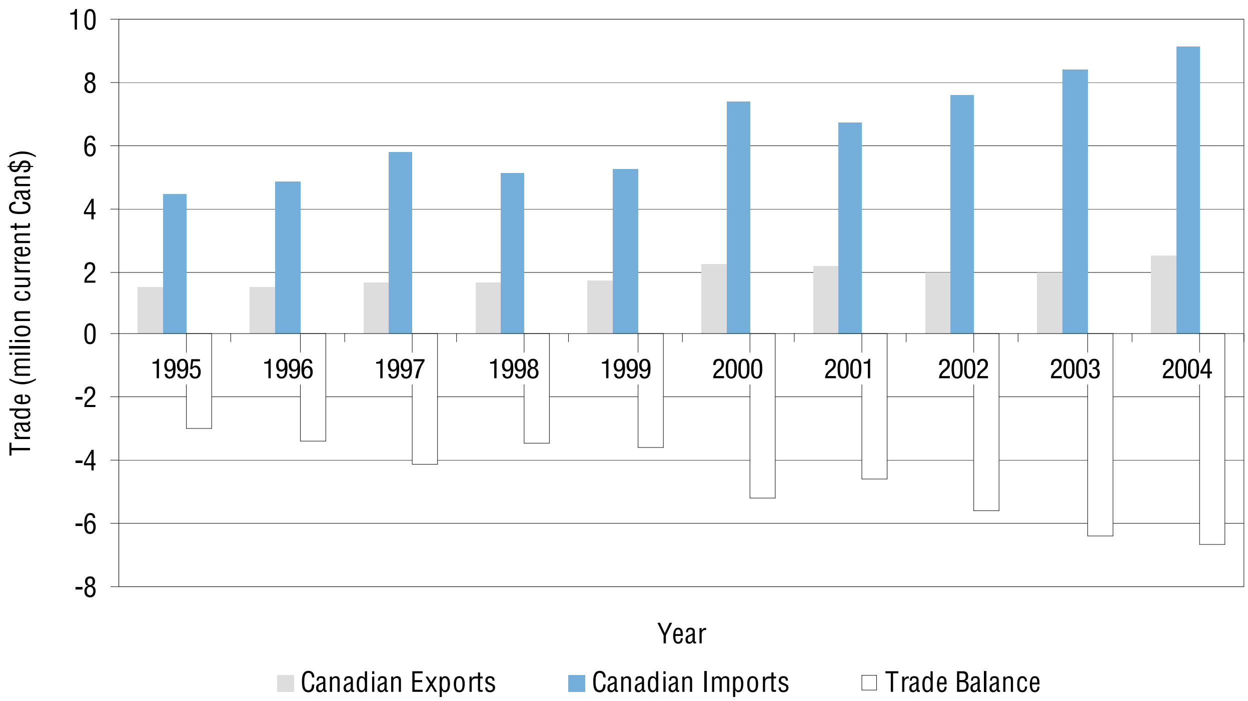

Figure 1 Trade between Canada and the Nordic Countries

Source: Compiled by Science-Metrix using data from Statistics Canada

This report aims to describe the main features of the scientific production of Canada and the Nordic countries, and identify the fields that present the greatest potential for mutually beneficial collaboration. Section II briefly presents the features of these countries' scientific output measured using bibliometric methods. Scientific output is measured by extracting and standardizing publications data contained in the Thomson ISI Science Citation Index, which indexes the scientific papers in a total of about 4,000 of the most highly cited journals. Three types of indicators are used: number of paper published; specialization index (SI), which indicates whether a country has greater (SI>1) or lower intensity (SI<1) of production in a field compared to the pattern at world level; and the average of relative impact factor (ARIF), which is an indicator of the quality of research, and measures the expected scientific impact of papers. ARIF is obtained by considering how often the journals in which papers are published are cited. ARIF indicates whether a country's scientific output can be expected to have a greater (ARIF>1) or lower (ARIF<1) than the world average. Section 3 uses these indicators to identify the fields where Canada and the Nordic countries produce better than world average science in terms of intensity and of expected impact, and to determine where these countries might benefit from greater collaboration.

Scientific output of Canada and the Nordic countries

As can be seen in Table II, with 155,301 papers, Canada ranks 7th in the world in scientific output for the year 1998 to 2003. Canada published twice as many papers as Sweden (76,522), the highest scientific producer among the Nordic countries and ranked 13th at world level. Denmark is second among Nordic countries with 40,150 papers and ranking 22nd at world level. Finland ranks third among Nordic countries (23rd at world level) with 36,406 papers, Norway fourth (26th at world level) with 23,758 papers, and Iceland is last (69th at world level) with 1,590 papers. Although the Nordic countries' scientific output is lower than Canada's, their productivity is higher in terms of publications per capita. While Canada produced 4,827 papers per million inhabitants between 1998 and 2003, Sweden produced 8,606, Denmark 7,468, Finland 7,015, Iceland 5,662 and Norway 5,230 per million inhabitants.

Each of the Nordic countries has a higher proportion of papers coauthored with international collaborators than Canada. Iceland ranks highest in this respect with 66% of its scientific papers coauthored with at least one foreign partner. Sweden has the greatest number of collaborations with Canada (1,651 papers). This represents 4.6% of Sweden's international collaborations and 2.7% of Canada's. Norway has the greatest preference for collaboration with Canada: 5.9% (676 papers) of international collaborations. It is followed by Finland with 5.2% (838 papers), Denmark with 5% (1,012 papers), Sweden 4.6% (1,651 papers) and finally, Iceland 3.8% (40 papers) of international collaborations. For Canada, the shares of international collaborations with these countries are lower, which is linked to the fact that they publish fewer papers generally. The most important Nordic collaborator for Canada is Sweden: 2.7% of Canadian collaborations are with Sweden. Next is Denmark (1.7%), Finland (1.4%), Norway (1.1%) and Iceland (0.1%). The scientific collaboration between Nordic countries and Canada is presented in greater details in Part 3 of the report.

Table II Number of scientific papers and percentage of scientific collaboration, 1998-2003

Rank	Country	Papers	Papers per capita	International collaboration	Collaboration with Canada	Collaboration of Canada
7	Canada	155,301	4,827	38.9%	n.a.	n.a.
13	Sweden	76,522	8,606	47.0%	4.6%	2.7%
22	Denmark	40,150	7,468	50.5%	5.0%	1.7%
23	Finland	36,406	7,015	44.5%	5.2%	1.4%
26	Norway	23,758	5,230	48.4%	5.9%	1.1%
69	Iceland	1,590	5,662	66.4%	3.8%	0.1%

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Table III shows that Iceland's scientific output is the fastest growing among the Nordic countries at 5.7% on average per annum, but this figure should be interpreted with caution because of the small number of publications involved (output grew from 256 papers in 1998 to 317 papers in 2003). Finland is the country showing the next highest growth with 2.8% on average per year (from 5,473 papers in 1998 to 6,509 papers in 2003).The remaining countries, including Canada, all have growth rates of below 2% per year.

Table III Number of papers per year by Canada & Nordic countries, 1998-2003

	1998	1999	2000	2001	2002	2003	1998-2003	Average growth
Canada	24,820	25,671	25,581	25,316	25,608	28,305	155,301	1.8%
Sweden	12,289	12,598	12,475	13,153	12,721	13,286	76,522	1.4%
Denmark	6,415	6,582	6,682	6,753	6,488	7,230	40,150	1.6%
Finland	5,473	5,927	6,158	6,283	6,056	6,509	36,406	2.8%
Norway	3,781	3,830	3,941	4,065	3,925	4,216	23,758	1.9%
Iceland	256	223	232	282	280	317	1,590	5.7%
World	**572,063**	**582,986**	**588,921**	**601,250**	**592,980**	**645,472**	**3,583,672**	**1.9%**

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Potential for scientific collaboration between Nordic countries and Canada

Table IV can be used to identify potential avenues for fruitful collaboration between the Nordic countries and Canada. The specialization index (SI), which is above 1 in every case, shows that all these countries are very specialized in biology. In other words, there is greater intensity of publications in biology compared to other fields. Also, the data show that the scientific output of these countries in biology is published in journals that are highly cited on average as indicated by the ARIF, which is also above 1 for every country. Thus, papers in biology from all the Nordic countries have an average greater expected scientific impact than the world average.

All these countries also specialize in clinical medicine. Only Finland and Norway are not specialized in biomedical research. In clinical medicine, four countries have an impact factor above 1 which means that their papers are published in journals that are cited more often than the world average. Therefore, health and life sciences provide great opportunities for circumpolar scientific collaboration. With the exception of Iceland (which is not specialized in this field) SI values are highest for earth and space. Three countries (Finland, Canada and Sweden) publish in highly cited journals, which means that earth and space presents great opportunities for achieving excellence through collaboration amongst these countries.

Output in the fields of engineering and technology, mathematics and more especially physics is of high quality, as revealed by the impact factor measure which is above 1, but are not areas of specialization for either Canada or the Nordic countries. Increased collaboration could help raise the intensity of research and thus level of specialization.

In biology, clinical medicine and earth and space, the combined scientific output of Canada and of the Nordic countries accounts for about 10% of world output. Thus, establishing a common circumpolar scientific research program in any of these areas would seem to offer mutually beneficial opportunities.

Table IV Scientific output by field by Canada and Nordic countries, 1998-2003

Field		Canada	Sweden	Denmark	Finland	Norway	Iceland	World
Biology	*SI*	1.48	1.48	1.31	1.85	1.90	1.02	
	ARIF	1.03	1.07	1.03	1.04	1.01	1.09	
	n	17,512	5,935	4,527	3,631	3,443	224	273,435
Biomedical Research	*SI*	1.11	1.21	1.02	0.99	0.91	1.12	
	ARIF	1.05	1.00	0.99	1.11	0.91	0.96	
	n	26,644	13,227	7,495	5,737	3,329	242	551,499
Chemistry	*SI*	0.67	0.56	0.61	0.28	0.55	0.64	
	ARIF	1.21	1.19	1.03	0.84	0.99	1.18	
	n	13,424	6,338	2,889	2,856	1,688	57	464,054
Clinical Medicine	*SI*	1.05	1.14	1.26	1.27	1.16	1.27	
	ARIF	1.12	1.02	1.05	1.03	0.94	0.98	
	n	50,121	29,733	14,041	14,045	8,426	618	1,098,703
Earth and Space	*SI*	1.57	1.38	1.09	2.75	2.02	0.92	
	ARIF	1.04	1.03	0.99	1.13	0.98	1.00	
	n	13,865	3,989	3,153	2,247	2,722	249	203,743
Engineering & Tech.	*SI*	0.95	0.49	0.76	0.34	0.67	0.73	
	ARIF	0.97	1.23	0.95	1.05	1.02	1.03	
	n	14,004	5,307	1,882	2,632	1,505	51	339,546
Mathematics	*SI*	1.07	0.66	0.67	0.79	0.83	0.63	
	ARIF	0.98	1.09	0.99	1.02	1.05	1.03	
	n	3,719	1,086	594	547	440	28	80,310
Physics	*SI*	0.62	0.86	0.80	0.45	0.52	0.88	
	ARIF	1.15	1.23	1.09	1.01	1.15	1.11	
	n	14,013	9,804	4,992	4,233	1,798	104	520,093
Unknown	*n*	1,999	1,103	577	478	407	17	52,289
Total papers	*n*	**155,301**	**76,522**	**40,150**	**36,406**	**23,758**	**1,590**	**3,583,672**

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

The remainder of this section presents a series of graphs, devised by Cartesian plots of the specialization index (on the x-axis) and of ARIF (on the y-axis), which show the strengths of Canada and the Nordic countries. In the graphs, number of scientific papers by the Nordic countries and by Canada is represented by the surface area of the circles. Because they have been log-transformed, ARIF and SI lower than 0 means that a country performs below the world average and, conversely, figures above 0 denote an above average impact or intensity. The thick grey line is the demarcation between above or below the world average. The graphs should facilitate identification of the most promising opportunities for collaboration between Canada and the Nordic countries.

Potential for Canadian-Swedish collaboration

Biology, clinical medicine, biomedical research and earth and space, are the fields that offer the greatest potential for mutually beneficial, competence strengthening collaboration between Canada and Sweden (Figure 2). Sweden would gain from collaborating in earth and space since currently in this field Sweden does not have a great expected impact and is not specialized. Sweden would also benefit from collaboration with Canada in biology since the latter has higher quality output. On the other hand, Canada would benefit from collaboration with Sweden in biology since Sweden has a fairly high impact factor in this field. Collaboration in mathematics would benefit both countries, increasing the output of Sweden and increasing the quality of output for Canada. In physics and chemistry both countries produce good quality science, but do not display a great intensity of activity relative to other fields.

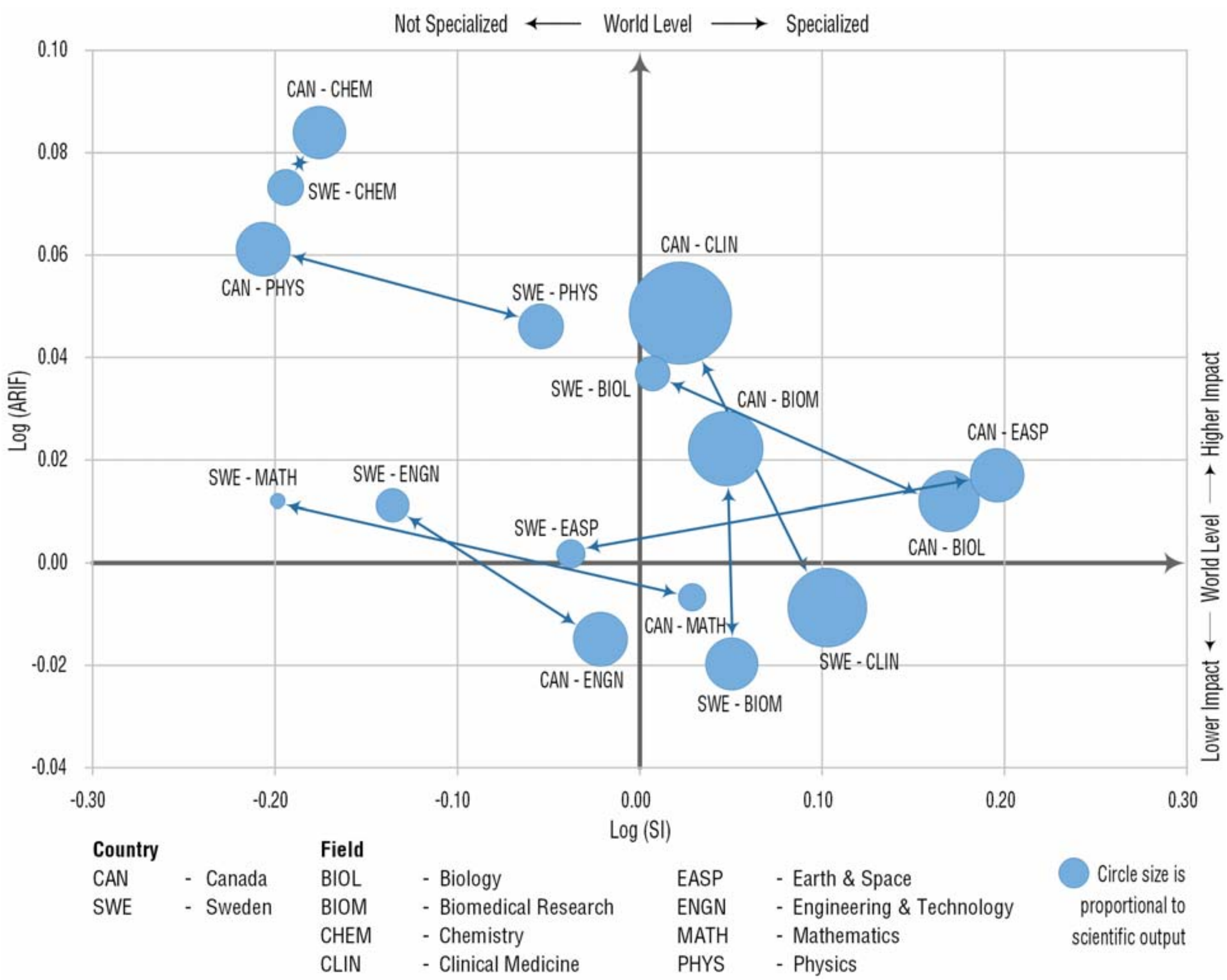

Figure 2 Scientific output of Canada and Sweden by field, 1998-2003

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Potential for Canadian-Danish collaboration

The most promising avenues for collaboration between Canada and Denmark are biology and earth and space where both countries have similar strengths both in terms of intensity and quality of scientific output (Figure 3). Canada and Denmark would also benefit from collaboration in clinical medicine and biomedical research. Denmark would possibly benefit more since, on average, Canada publishes in more highly cited journals. Figure 3 also shows that chemistry and physics are promising fields since both countries produce high quality output in these areas. Denmark's higher expected impact in maths and engineering means that Canada would benefit from collaboration in these fields.

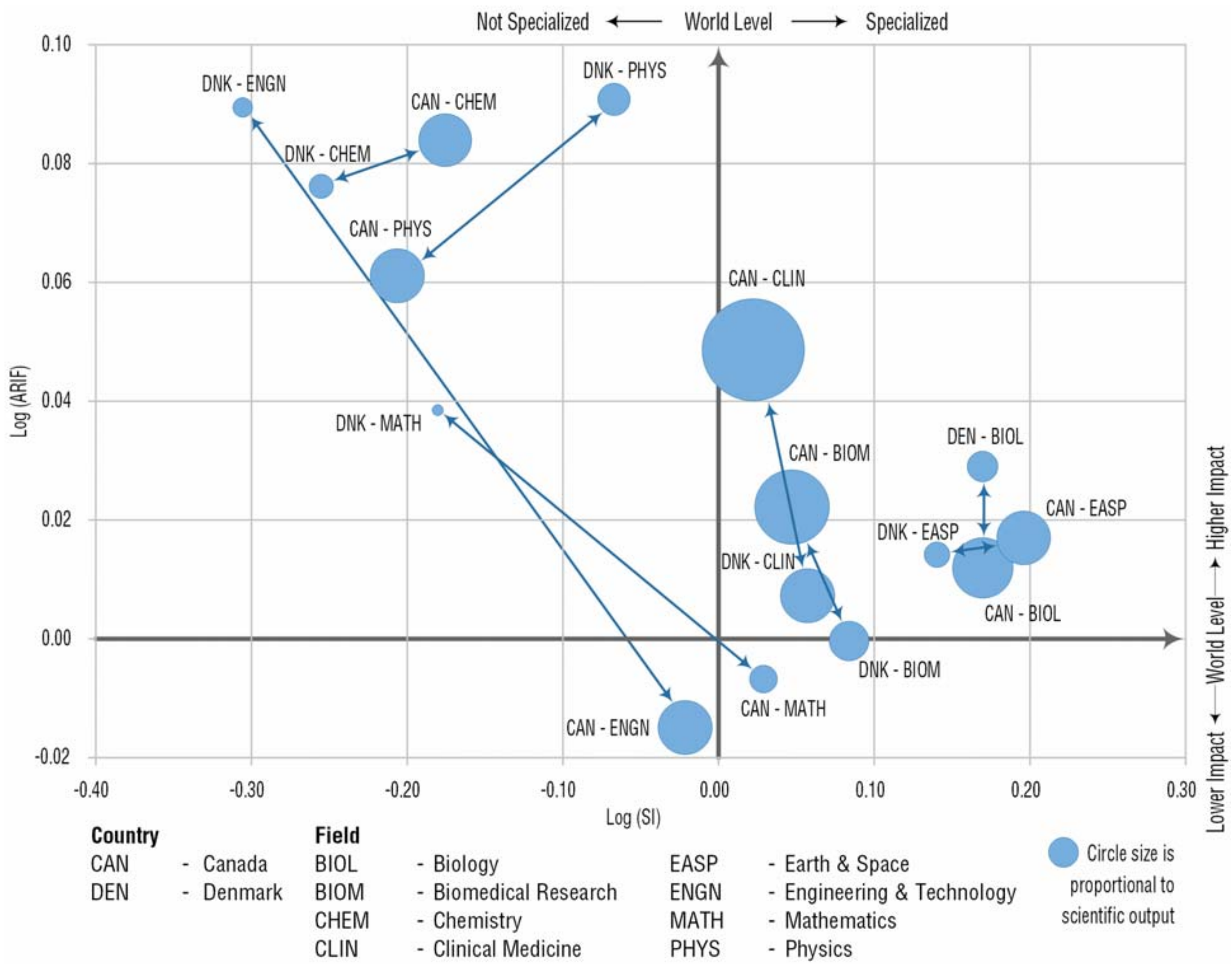

Figure 3 Scientific output of Canada and Denmark by field, 1998-2003

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Potential for Canadian-Finnish collaboration

Clearly, the most mutually self-reinforcing area for collaboration between Canada and Finland is clinical medicine where Canada has greater impact but Finland has higher specialization (Figure 4). Other areas where collaboration would be advantageous are biology, biomedical research and earth and space. In the latter two fields, Canada has a slightly higher expected scientific impact than Finland and is more specialized.

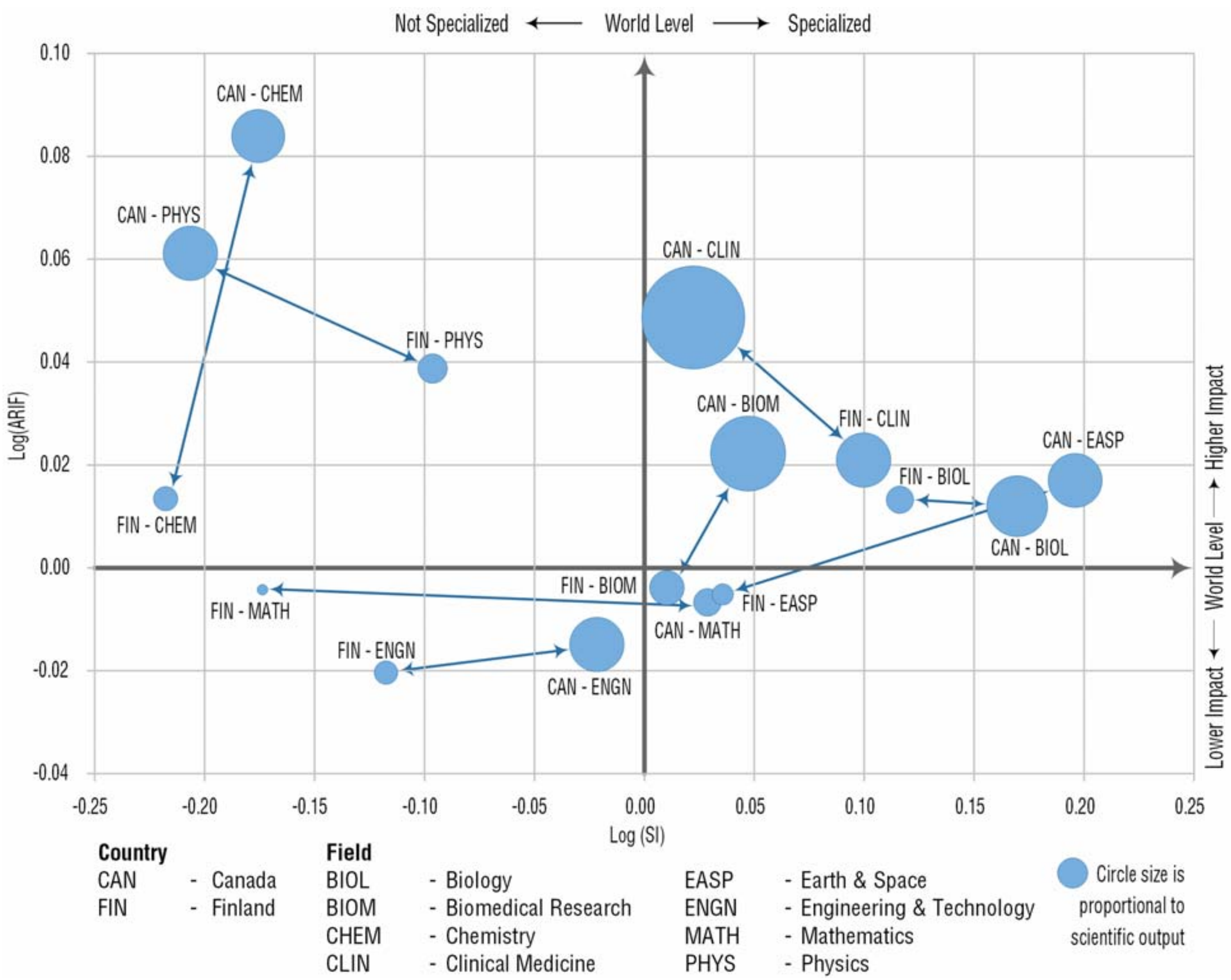

Figure 4 Scientific output of Canada and Finland by field, 1998-2003

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Potential for Canadian-Norwegian collaboration

The most promising fields for mutually beneficial collaboration between Canada and Norway are biology and earth and space. Collaboration in clinical medicine and in biomedical research would allow Norway to benefit from the greater expected impact of Canada's publications. In physics both countries produce good quality science but neither country emphasizes research in this field.

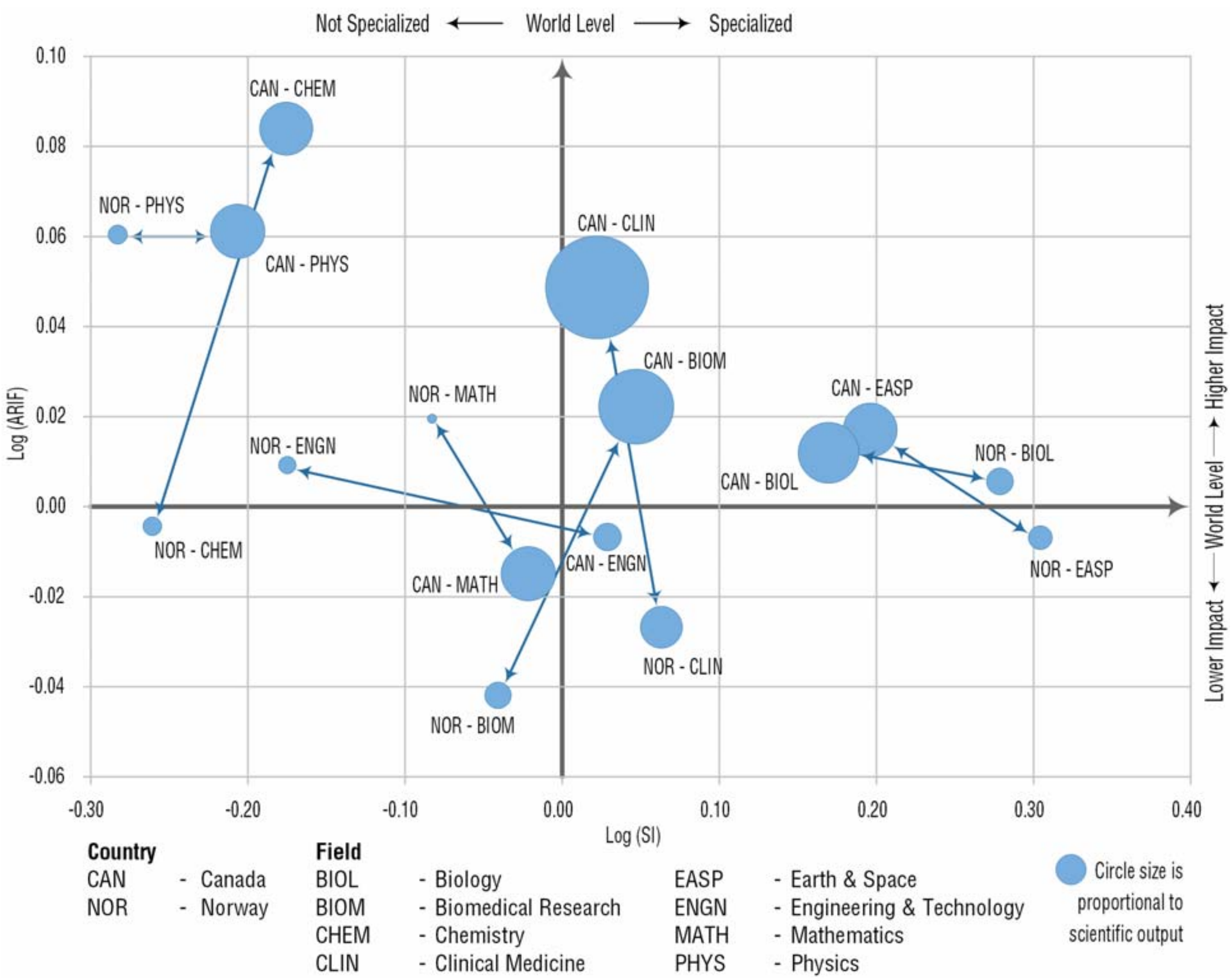

Figure 5 Scientific output of Canada and Norway by field, 1998-2003

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Potential for Canadian-Icelandic collaboration

Collaboration with Iceland would be beneficial for Canada in earth and space where Iceland shows both higher specialization and higher expected impact. In terms of more mutually beneficial areas, there is a great potential for collaborating in biology, clinical medicine and biomedical research, but in every case the difference in size between Canada's and Iceland's output means that the impact on Canadian would necessarily be minor.

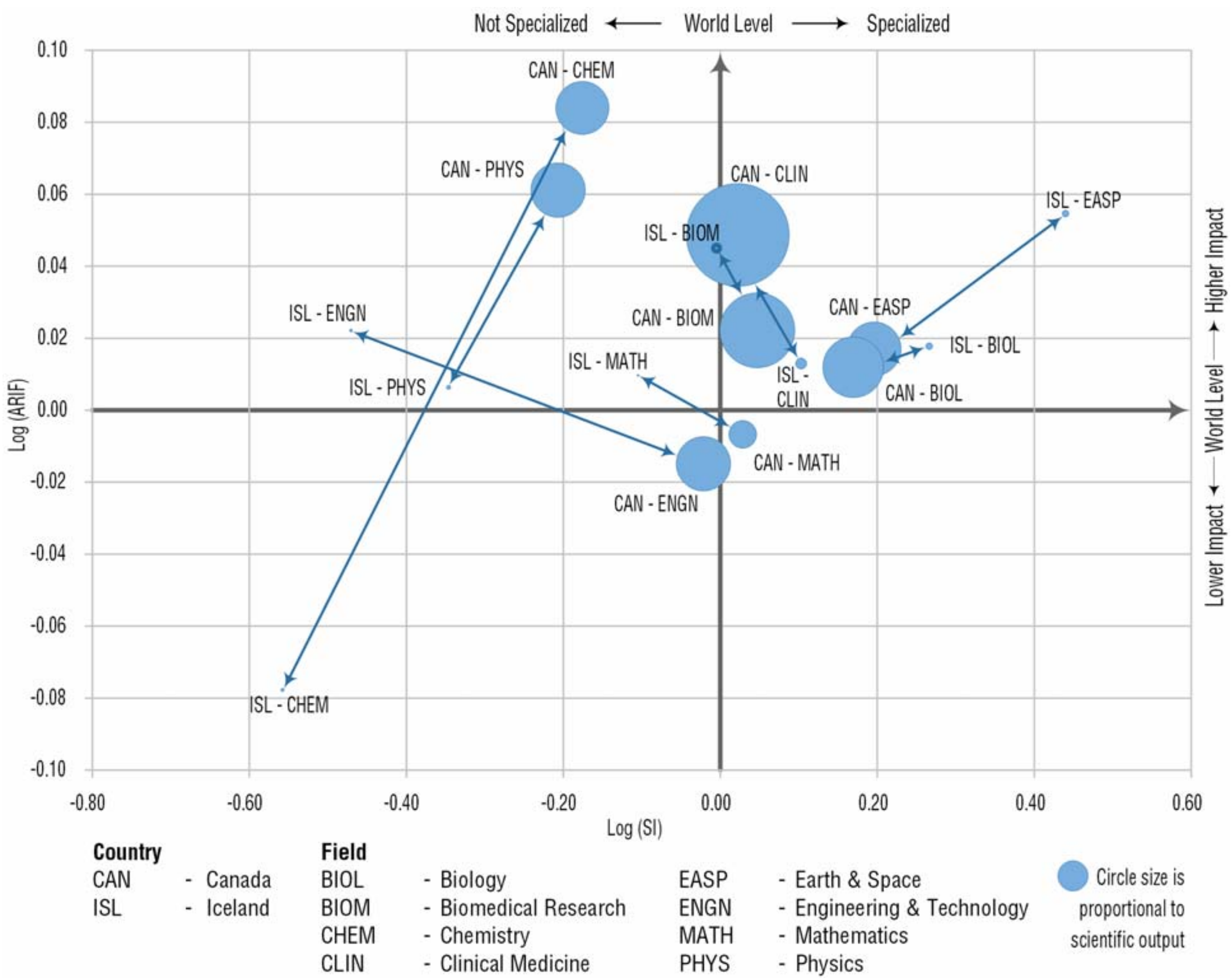

Figure 6 Scientific output of Canada and Iceland by field, 1998-2003

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Current Nordic country–Canada scientific collaborations

Table V shows that scientific collaboration between Canada and the Nordic countries has increased by nearly 50%, from 534 papers in 1998 to 789 papers in 2003, which corresponds to an annual growth rate of close to 8%. Sweden is the Nordic country with the highest number of scientific collaborations with Canada (1,651 papers) accounting for 4.6% of Sweden's international collaborations. Collaboration between Sweden and Canada is growing at an average of 7% per annum. Denmark is Canada's second most important collaborator among the Nordic countries with 1,012 papers written by at least one Canadian and one Danish author between 1998 and 2003, and this accounts for 5% of Danish international collaborations. The level of collaboration between Canada and Denmark is fairly stable with growth of 4% on average per year. Finland produced 838 papers in collaboration with Canada accounting for 5% of its international collaboration, and Norway 676 papers accounting for 6% of its international collaboration, but the frequency of collaboration with Canada is increasing growing by about 11% and 15% respectively. Iceland has 40 papers co-authored with Canadians, accounting for 4% of Iceland's international collaborations.

Table V Collaboration between Canada and the Nordic countries, 1998-2003

Country	1998	1999	2000	2001	2002	2003	1998-2003	Average growth
Sweden	250	224	269	277	291	340	1,651	7.0%
Denmark	155	169	155	164	169	200	1,012	3.9%
Finland	111	106	132	155	151	183	838	11.2%
Norway	73	102	84	127	131	159	676	15.5%
Iceland	8	3	2	7	5	15	40	n.s.
Nordic Countries (n)	**534**	**547**	**586**	**641**	**666**	**789**	**3,763**	**7.8%**

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Table VI shows that the Nordic countries and Canada actively collaborate in the fields of biology and earth & space as indicated by collaboration specialization index value above 1. The table also shows that these papers are published in frequently cited journals (ARIF>1). These data show that Canada–Nordic country collaboration occurs in those fields where there is most specialization and where the scientific output is high quality, as can be seen from Table IV in Section 2.2. Clinical medicine and biomedical research are fields where many countries are specialized and have a high expected scientific impact and where collaboration enhances these strengths. In physics, although Canada and the Nordic countries do not collaborate extensively (ARIF < 1), the quality of collaborative output is very high.

Table VI Collaboration by field, 1998-2003

Field		Sweden	Denmark	Finland	Norway	Iceland
Biology	*SI*	1.26	1.28	1.35	1.37	2.27
	ARIF	1.16	1.14	1.09	1.17	1.31
	n	149	127	87	109	11
Biomedical Research	*SI*	0.98	0.92	0.93	0.92	1.82
	ARIF	1.30	1.13	1.39	1.18	1.24
	n	312	183	143	95	12
Chemistry	*SI*	0.60	0.74	0.52	0.45	
	ARIF	1.39	1.10	1.20	0.94	
	n	73	50	32	20	
Clinical Medicine	*SI*	1.12	1.05	1.02	0.87	0.69
	ARIF	1.46	1.58	1.46	1.30	2.79
	n	630	309	280	188	10
Earth & Space	*SI*	1.65	1.51	1.92	1.44	n.s.
	ARIF	1.12	1.03	1.00	1.17	n.s.
	n	183	155	130	142	4
Engineering & Tech.	*SI*	0.72	0.94	1.10	0.81	n.s.
	ARIF	1.03	1.26	0.94	0.86	n.s.
	n	66	43	52	30	1
Mathematics	*SI*	0.66	1.29	0.40	n.s.	n.s.
	ARIF	1.07	0.97	0.95	n.s.	n.s.
	n	16	21	6	4	2
Physics	*SI*	0.70	0.67	0.71	1.09	
	ARIF	1.23	1.41	1.26	2.21	
	n	197	115	101	81	
Unknown	*n*	25	9	7	7	
Total papers	*n*	**1,651**	**1,012**	**838**	**676**	**40**

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

Institution-level collaboration

Between 1998 and 2003, nearly 3,000 papers were co-authored by Canadian and Nordic countries' scientists (see Table VII). During the same period, about collaborations with Canadian institutions in the hospital sector and with federal government institutions accounted for about 500 papers each, while about 200 papers involved Canadian private firms. About 100 papers were related to institutions affiliated with provincial governments, the two most frequent partners being the British Columbia Cancer Agency and Cancer Care Ontario.

Table VII reveals that the University of Toronto is the most active Canadian institution –(448 collaborations in 6 years) followed by the University of British Columbia (400 collaborations) and McGill University (372 collaborations). Important partners for the University of Toronto are the University of Helsinki (65 collaborations), the University of Copenhagen (35 collaborations), the

Karolinska Institute (32 collaborations) and Lund University (30 collaborations). The University of British Columbia has the most collaborations with the University of Bergen (69 collaborations), followed by the University of Helsinki (36 collaborations), the University of Lund (25 collaborations) and the University of Copenhagen (23 collaborations).

Table VII Most active Canadian institutions in Nordic country scientific collaboration, 1998-2003

	Sweden	Denmark	Finland	Norway	Iceland	Total
University sector	1261	751	649	493	26	2888
UNIV-TORONTO	193	128	128	52	5	448
UNIV-BRITISH-COLUMBIA	136	96	94	113	2	400
MCGILL-UNIV	131	87	97	91	6	372
MCMASTER-UNIV	138	65	29	21		234
UNIV-MONTREAL	82	48	26	69	1	211
UNIV-ALBERTA	88	42	55	37		192
UNIV-CALGARY	57	31	55	24	2	138
UNIV-WESTERN-ONTARIO	75	22	23	16	2	124
DALHOUSIE-UNIV	68	26	25	14		118
UNIV-GUELPH	47	34	11	25	2	113
UNIV-LAVAL	33	20	50	19		111
Hospital sector	279	133	114	79	5	526
HOSP-SICK-CHILDREN	28	26	20	7		80
MT-SINAI-HOSP-TORONTO	31	6	13	5		51
UNIV-HLTH-NETWORK	31	10	10	9		48
CHUQ	20	11	6	6		38
CHUM	13	9	2	6		23
HAMILTON-HLTH-SCI-CORP	18	10	2	2		22
VANCOUVER-HOSP-&-HLTH-SCI-CTR	14	6	7	4		22
SUNNYBROOK-&-WOMENS-COLL-HLTH-SCI-CTR	14	2	2	4	1	20
Government sector	223	152	124	114	9	518
NATL-RES-COUNCIL-CANADA	72	43	26	10	1	137
ENVIRONM-CANADA	46	33	28	34	1	99
FISHERIES-&-OCEANS-CANADA	26	28	11	39	5	97
NAT-RESOURCES-CANADA	26	22	33	18	1	93
AGR-&-AGRIFOOD-CANADA	22	25	8	9	1	56
Enterprise sector	83	46	26	37	3	172
ASTRAZENECA	13	1	2			15
AECL-RES	10	1	2			13
MERCK-FROSST-CANADA-INC	6	1	1	1		8
HYDRO-QUEBEC	3		3	1		6
SANOFI-AVENTIS	3		1	2		6
WECC-WANIA-ENVIRONM-CHEM-CORP	2		1	3		6

Source: Compiled by Science-Metrix from data prepared by OST (Thomson-ISI SCI)

McGill University's joint publications are mostly with the University of Bergen (54 collaborations), the University of Helsinki (42 collaborations) and the University of Lund 31 collaborations).

The National Research Council of Canada is clearly the most active institution in the government sector with 137 joint publications with numerous Nordic country institutions. Sweden has the most collaborations with the Council (72 papers). Other government institutions that are frequent collaborators with the Nordic countries are Environment Canada (99 collaborations), Fisheries and Oceans Canada (97 collaborations) and Natural Resources Canada (93 collaborations).

In the clinics and hospitals sector, the most active Canadian institutions are the Hospital for Sick Children (80 collaborations), the Mount Sinai Hospital (51 collaborations) and the University Health Network (48 collaborations), all based in Toronto. Coauthoring partnerships are with a variety of Nordic country institutions.

In the private sector, the most active collaborators are Astrazeneca Canada Inc. (15 collaborations), Atomic Energy of Canada Limited (13 collaborations) and Merck-Frosst Canada Inc. (8 collaborations). Partners in these collaborations are mainly universities, the Nordic countries' branches of these organizations, or other companies.

Conclusion

Although Canada publishes a greater number of papers than all the Nordic countries combined, it could benefit from increased collaboration with these countries. The Nordic countries publish more scientific papers per capita than Canada, which shows the importance they assign to science. In addition, there are several fields where the strengths of Canada and the Nordic countries coincide, especially biology, clinical medicine, biomedical research, and earth and space. These four areas form a strong basis for scientific collaboration since these fields have more potential for specifically northern oriented studies than, for instance, mathematics, chemistry and physics, which tend to be more universal.The ecology of the Arctic region, as well as the problems caused by pollution in the North, affects the life of the Canadian and Nordic populations in similar ways. There may also be common health issues and certainly all the countries have regions that have similar geological features.

The data presented in this report show that Canadian and Nordic country scientists have elected to collaborate in certain fields without particular knowledge of their countries' relative strengths, which means that there already exists a basis for fruitful and mutually beneficial scientific collaboration in fields that are relevant to circumpolar issues.

Appendix: Scientometric indicators and methods

Dataset

This scientometric study is based on the use of the Thomson ISI Science Citation Index (SCI). The statistics are drawn from three document types that are considered to be original contributions to scientific knowledge: articles, notes and reviews. The tables presented in this report refer to all these document types as "papers."

SCI provide the most effective coverage of high-quality scientific research in natural sciences and engineering in indexing approximately 5,900 of the world's leading scholarly science and technical journals in more than 150 disciplines.[1] These journals are considered to be the most important peer-reviewed journals in their respective fields. They reflect significant scientific achievements and are the most widely cited journals in the world (receiving over 80% of the world's citations). The choice of ISI indexes over other databases (e.g. Biological Abstract, Agricola) is also advantageous because it traditionally includes the addresses of every author listed in scientific papers. Therefore, it allows the collaboration rate between countries to be analyzed.

Indicators

The resulting datasets were used to produce detailed statistics based on the following indicators:

Number of papers – Number of scientific papers written by authors located in a given geographic, sectoral, organizational or individual entity (e.g.: country, city or institution).

Growth rate – The growth rate is calculated using an exponential regression model that best fits the experimental points. Put simply, this means that the indicator is the percentage of annual growth that would be calculated if the percentage of growth was the same for every year of the period. For example, the number of papers in 2004 should be the number of papers in 2003 multiplied by the growth rate and then added to the number of papers in 2003. Countries' effective growth never follows exactly an exponential growth, but an approximation is usually sufficient for descriptive statistics. In cases where the model does not provide a good fit for the experimental points, the statistics are not computed.

International collaboration rate – This is an indicator of the relative importance of international collaboration. The rate is computed by dividing the number of papers of an entity with at least one of the foreign countries in the address field, by the entity's total number of papers.

Preference index – This is an indicator of the intensity of the collaboration of a given entity (e.g. a country, a province, an institution) with a given collaborator in a given research area (domain, field) relative to the entity's collaboration in this research area generally. The preference index can be formulated as follows:

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[1] Data derived from information prepared by the Institute for Scientific Information, Inc. (ISI, Philadelphia, Pennsylvania, USA). Copyright Institute for Scientific Information. All rights reserved.

$$PI = \frac{(XY_S / XY_T)}{(XT_S / XT_T)}$$

XY_S = Number of collaborations of entity X with a collaborator Y in a given research area (e.g.: Canada with Denmark in physics);

XY_T = Number of collaborations of entity X with a collaborator Y in the whole database (e.g.: Canada with Denmark in SCI);

XT_S = Number of collaborations of entity X (with all collaborators) in a given research area (e.g.: international collaboration of Canada in physics);

XT_T = Number of collaborations of entity X (with all collaborators) in the whole database (e.g.: international collaborations of Canada in SCI).

An index above 1 indicates that collaboration in the research area is more intense with the given collaborator than with the average collaborator. Conversely, a score below 1 means that collaboration in the research area is less intense with this collaborator than with the average collaborator.

Average of relative impact factor – This indicator is a proxy for the quality of the journals in which an entity publishes. Each journal has an annual impact factor (IF), based on the number of citations it received, relative to its number of papers, which is ascribed to its papers. Each paper's IF is divided by the average IF of all papers in its subfield to obtain a Relative Impact Factor (RIF). The average relative impact factor (ARIF) of a given entity is computed using the average RIF of each paper belonging to it. When the ARIF is above 1, it means that an entity scores better than the world average for a given field; when it is below 1, this means that on average, an entity publishes in journals that are not cited as often as the world average.

Specialization index – This is an indicator of the intensity of research of a given geographic or organizational entity (e.g.: country) in a given research area (domain, field) relative to the intensity of the reference entity (e.g.: world) in the same research area. The specialization index (SI) can be formulated as follows:

$$SI = \frac{(X_S / X_T)}{(N_S / N_T)}$$

X_S = Papers from entity X in a given research area (e.g.: Canada in physics);

X_T = Papers from entity X in a reference set of papers (e.g.: Canada in the whole database);

N_S = Papers from the reference entity N in a given research area (e.g.: world in physics);

N_T = Papers from the reference entity N in a reference set of papers (e.g.: world in the whole database).

An index above 1 means that a given entity is specialized relative to the reference entity. Conversely, a score below 1 means that the given entity is not specialized relative to the reference entity.