The Research Council of Norway

Bibliometric Study in Support of Norway's Strategy for International Research Collaboration

Final report

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Background

Science-Metrix has been commissioned to provide the Research Council of Norway (RCN) with bibliometric indicators of scientific performance and collaboration for Norway and its international partners in the sciences in general and in thematic areas of high relevance to Norway in particular. The presentation of these indicators was organised with a view to guiding the RCN's efforts to establish long-term institutional cooperation between Norwegian institutions and similar institutions in other countries under its International Strategy.

The report

More specifically, this report aims at characterising the scientific production profiles and collaboration patterns of Norway and 57 selected countries in Europe and elsewhere around the world.

Firstly, the report provides a brief comparative analysis of the current scientific performance of Norway and the 57 selected countries, along with their collaboration patterns in the sciences in general (i.e., as indexed in the entire Scopus database). Collaboration is measured from both an international (co-authorship with any foreign country) and a bilateral (co-authorship specifically with Norway) perspective. The analysis of collaboration with Norway is also performed across the organisational sectors of Higher Education, Government, and Business Enterprise. The ***key questions*** addressed include:

- Which are the leading scientific nations and those that co-publish most with foreign partners and with Norway in particular?
- What has changed in the past decade — in terms of countries' relative performance and collaboration patterns — and what is likely to change in the near future?

Secondly, the report analyses in more detail these countries' performance and collaboration in 15 scientific themes of significant importance to Norway. This analysis is intended to provide ***strategic information*** to the RCN about the scientific partnerships that are most beneficial to the country in each strategic field. It also identifies which of those promising partnerships appear to be under-exploited with a view to providing ***recommendations*** as to potential candidates with which Norway could strengthen partnerships by thematic area.

Thirdly, the report presents further information at the micro-level (i.e., organisational level) to help the RCN target organisations — within the countries identified as potential candidates with which Norway could strengthen partnerships — in the context of setting up specific bilateral agreements. Information on the scientific performance and collaboration patterns of organisations is synthesised in the form of collaboration networks.

Finally, the report presents a detailed analysis of various types of multilateral scientific partnerships to address the following questions: Which type of scientific partnership is most beneficial to a country's scientific impact and what are the mechanisms underlying such gains in impact?

The production profiles and collaboration patterns presented in this report are based on a selected set of bibliometric indicators designed to compare scientific performance and cooperation activity across countries (see Section 9.4 for a more comprehensive description of these indicators). These indicators include:

- **Number of publications:** The number of publications produced by a country (based on both full [FULL] and fractional [FRAC] counting – FULL referring to the method of assigning a publication to a given entity each time this entity appears among the author addresses of a publication, and FRAC referring to the method of assigning only a fraction of a paper to a given entity when this paper involves more than one geographical entity; for example, if three countries are represented in a paper, each country is assigned one-third of this paper).
- **International co-publications:** These are defined as papers that include not only domestic co-authors but also collaborators from other countries. They were counted using FULL and FRAC.
- **International co-publications with Norway:** The number of a country's co-publications with Norway (both FULL and FRAC are presented).
- **International collaboration rate:** This rate is equal to the number of international co-publications of a given country divided by the country's total number of publications (based on FRAC).
- **Collaboration rate with Norway:** This rate is equal to the number of international co-publications with Norway of a given country divided by the country's total number of publications (based on FRAC).
- **Specialisation Index (SI):** This index indicates the research intensity of a country in a given research area in relation to the world as a whole. A score above 1 indicates a relative specialisation.
- **Growth ratio (GR):** This refers to the ratio between a country's total number of publications in the second half of the studied period (2008–2012) and its total number of publications in the first half (2003–2007) for a given indicator (when available, it is based on the indicator computed using FRAC). A GR of 1 thus indicates stability, a value above 1 indicates an increase, and a value below 1 indicates a decrease.
- **Relative Citations (RC):** This refers to the total number of citations accrued by a paper since its publication year relative to (i.e., divided by) the average number of citations received by all papers published the same year in the same scientific subfield. In other words, it compares the number of citations a paper received to expectations based on the world average, taking account of life length and disciplinary differences in the number of citations accrued.
- **Relative Number of Authors:** This refers to the number of authors on a paper relative to (i.e., divided by) the average number of authors of all papers published the same year in the same scientific subfield. In other words, it compares the number of authors on a paper to expectations based on the world average, taking account of temporal changes in the number of authors on scientific papers as well as disciplinary differences in the size of scientific teams.
- **Average of Relative Citations (ARC):** This indicates the impact that the publications or co-publications of a given country have had on the scientific community relative to expectations (i.e., the world level); it is the average of the RC scores of an entity's papers. An ARC above 1 indicates that the country's papers are cited above expectations. This indicator is based on full counting.
- **Average of Relative Impact Factors (ARIF):** This is a measure of the scientific impact of papers produced by a given entity (e.g., the world, a country) based on the impact factors of the journals in which they were published.
- **Transdisciplinarity (TD):** This indicator measures the average diversity of scientific subfields referenced by a country's papers. It varies from 0 (no diversity at all) to 1 (very high diversity) and is based on full counting.
- **Collaboration Index (CI):** This index measures countries' propensity to collaborate internationally. A score above 1 indicates that a country collaborates more than expected, whereas a score below 1 means the opposite. This index is based on full counting of publications and co-publications.
- **Affinity Index (AI):** Similarly to the CI, the affinity index measures whether a country has an affinity for a specific international partner – i.e., whether it co-authors more papers with this partner than expected. It can thus be computed from the perspective of both countries in a given pair (e.g., Canada's affinity for collaborating with Norway and Norway's affinity for collaborating with Canada). A score above 1 indicates that collaboration with the given partner is above expectation. It is based on full counting of publications and co-publications.
- **PageRank:** It measures the centrality of an entity in a network of collaboration. The higher the score, the more important an entity is in the network.

- **Betweenness Centrality:** This indicator measures how often a node (or entity) appears on the shortest paths between any two nodes in a network.
- **Share of output available in Open Access (OA):** It estimates (it is therefore associated with a margin of error) the share of a country's papers that is available in OA. It is based on full counting.

Key findings — Scientific performance of Norway and selected countries and their collaboration patterns in the sciences in general (see Section 2)

Largest producers of scientific papers and other general findings

- In terms of overall scientific output, the **US** tops the list, with close to 4.6 million papers (FULL) published between 2003 and 2012, followed by **China** with 2.5 million. The **UK**, **Japan**, **Germany**, **France**, **Canada**, **Italy**, **India** and **Spain** (from 1.2 million to 541,000 papers respectively) complete the top ten.
- **Norway** ranks 31st among the 58 countries selected, with 114,000 papers (FULL).
- For all selected countries, including Norway, the average transdisciplinarity of their output is similar to the world level, (TD = 0.44) with only slight variations.
- With 50% (± 6%) of its output in Open Access (OA), Norway is clearly above the world average of 40%. South American countries (i.e., Chile, Colombia and Brazil) lead in this respect, most likely as a result of the OA initiative.

Upcoming global leaders in terms of output

- Among the 15 countries with the highest publication output (FRAC) for the entire 10-year period, **China** and **India** show by far the largest increases in the number of papers produced during the study period. In fact, they both overtook many countries within this timeframe and China very likely surpassed the US in 2013 as the leading nation in terms of its share of world output.
- Among the top 15 largest producers of scientific output, **Brazil**, the **Republic of Korea** and **Taiwan** follow, with increases in the volume of their scientific output above 50% from 2003 to 2012.

Smaller countries that are making significant progress in their output growth

- **Malaysia**, currently ranking in 33rd place in terms of production among the 58 countries analysed, increased its publication output by slightly more than fourfold. Given its overall output of 88,775 publications (FULL) over the 10-year period, Malaysia could become an important producer of scientific output in the future if this trend continues.
- Other small producers of publications such as **Iran**, **Luxembourg**, **Romania**, **Indonesia** and **Colombia** also exhibit high increases in output.

Propensity of countries to collaborate internationally

- **Switzerland** leads in terms of collaboration with foreign countries given the volume of its overall publication output, followed by **Belgium**, **Vietnam** and **Germany**.
- **Norway**, with a collaboration rate of about 25% above expectations, ranks 15th among the selected countries. In fact, all the **Nordic countries** collaborate more than expected.
- Of the other countries that collaborate more than expected, **Singapore**, **Spain**, the **US** and **Australia** show the largest increase in their propensity to collaborate with foreign partners.
- Of the countries that currently collaborate less than expected, **Pakistan**, **Egypt** and **Taiwan** show the largest increase in their propensity to collaborate with foreign partners.

Countries' scientific impact

- Based on the ARC, **Iceland**, **Switzerland** and **Denmark** have the highest scientific impact for their overall publications. Even when considering their international co-publications only, they maintain this status, with Iceland in the lead, followed by Denmark and Switzerland.
- On average, the ARC for international co-publications is 48% higher than that for overall publications, and all countries without exception benefit from international partnerships in terms of scientific impact.
- In this respect, **Norway** ranks 11th for its overall output and 12th for its international collaborations.
- Among countries with overall below average ARCs, **China**, **Croatia**, **Poland** and **Russia** reap the most benefit from international collaborations.
- Of those countries that already meet or exceed expectations respecting citation impact, **Malta**, **Italy** and **Estonia** show the highest increase between overall citation rates and the ARCs of their international co-publications.

Collaboration profiles with Norway in the sciences in general

- Norway's most important collaborator in terms of absolute number of co-publications is the **US**, followed by the **UK**, **Sweden** and **Germany**.
- In terms of their collaboration rates and pairwise affinities with Norway, all the **Nordic countries** are noteworthy (in descending order: Iceland, Sweden, Denmark and Finland), as are **Estonia** and **Luxembourg**. These findings reflect the strong influence of **geographic proximity** and **cultural similarity** on countries' collaboration patterns.
- Norway is also an important collaborator for **South Africa**, **Israel**, **Russia** and **Canada**, which all have strong affinities for Norway. However, Norway's affinities for these countries are less strong.
- Although Norway presents very little affinity for collaborating with **China**, China **shows a certain affinity for Norway**, co-publishing 19% more with Norwegian researchers than expected. The case of China is worth examining in more detail. Indeed, within the subset of countries identified as key scientific partners with which Norway should expand and/or reinforce future collaboration, **China** heads the list given the rapidly changing nature of its scientific system:
    - China should have surpassed the United States as the nation with the largest yearly scientific production in 2013 if the trends highlighted in this study continued.
    - Because China's impact is still relatively low, it does not often appear in the report's recommendations by theme (Section 3.2 to 3.16).
    - However, even if its impact remains relatively low in many areas, this is changing and will continue to do so in the future, which means that China should definitely be on the radar screen of any nation planning future international collaboration strategies.
- Among the Nordic countries, **collaboration** between Norway and **Sweden is increasing,** even though it is already significant. The greatest increase within the EU is noted with the **Czech Republic**, **Hungary** and **Belgium**.
- International collaboration **with Norway** leads to a particularly **high ARC** score of 1.76 on average (all countries pooled). All of the 57 selected countries have ARC scores above 2 for their co-publications with Norway.
- Of the traditional leaders in science, those with which collaboration with Norway was most beneficial include **Belgium**, **Switzerland**, **Italy**, **Australia** and **Canada**.

Key findings — Scientific performance and collaboration profiles of selected countries with Norway by strategic theme (see Section 3)

The following findings and recommendations are based on a comparative analysis of objective bibliometric indicators of scientific performance, including the number of papers, the growth ratio (GR) of the volume of output, the specialisation index (SI), and the average of relative citations (ARC) of a country's total production and of its co-publications with Norway. This analysis was performed with a view to ranking a country according to the likelihood that co-authorships between this country's researchers and Norwegian authors would be beneficial to Norway in the given area. In other words, such co-authorship ***must have a high potential for increasing Norway's research capacity in a given area and, most importantly, for increasing its scientific impact on the international scientific community.***

Since multiple indicators are involved, Science-Metrix analysts have made use of expert judgement, aided by an in-house tool for dimensionality reduction in the synthesis of complex datasets. This allowed for the identification of countries that stand out ***when considering all indicators jointly*** in each individual theme. In particular, emphasis was placed on the ***scientific impact*** of a country's total publication output by giving twice as much weight to the ARC as to the weight given to each of the other indicators.

In view of this approach, ***it is not surprising to see some of the smaller producers of scientific papers*** (e.g., Cyprus, Luxembourg and Malaysia) among the set of countries identified as potentially beneficial collaborators for Norway since these countries may very well excel in other respects, such as in GR, SI or ARC. ***Some of the larger countries*** (e.g., Germany and China) may not be as potentially beneficial as collaborators, because they perform less well on these indicators, especially as regards their scientific impact (ARC). ***Nevertheless, they can still represent important partners since collaboration opportunities with them are more diverse due to a potentially larger pool of high impact research groups than in smaller countries that have a higher ARC***. Our goal was to identify potential partners throughout the full range of country sizes.

Science-Metrix' final recommendations also rely on an analysis of a country's ***collaboration affinity*** for Norway and vice versa, as well as on the ***collaboration rate***. These indicators enable an assessment of whether partnerships are over- or underexploited from the perspective of both Norway and the collaborator.

Based on the above approach, ***the rationale for these recommendations is as follows:*** Countries that scored high in the analysis of scientific performance are tagged as potentially beneficial collaborators. Among these countries, those that Norway does not yet collaborate with preferentially or frequently are considered suitable candidates for a future intensification of partnerships.

This report also presents additional information at the micro-level (i.e., at the level of organisations) for the countries identified as beneficial collaborators for Norway. An approach similar to that presented above was used to rank top institutions. More specifically, the choice of organisations was based on the following three indicators: number of publications, specialisation index and ARIF (see Section 1 for further explanation). Since one of the study's goals was to highlight organisations of interest within the countries identified as potential partners with which Norway could strengthen its collaboration, and because these potential partners had to cover the full spectrum of country sizes (see above explanation), ***the organisations highlighted in this study are not necessarily the world's top performing organisations***.

Note that Science-Metrix's recommendations ***rely exclusively on an analysis of bibliometric data*** characterising the scientific performance and collaboration pattern of the selected countries or organisations with Norway. There is obviously a much wider set of parameters that need to be accounted for in targeting specific entities with which a country should enhance its efforts to develop an international science strategy. ***Accordingly, Science-Metrix's selection should not be viewed as a definitive statement of the countries and organisations with which Norway should expand and/or strengthen its collaboration by thematic area***.

Top performing countries in the sciences in general

- Considering the sciences in general (i.e., for all scientific fields included in the Scopus database), the top performing countries, taking into account output, growth ratio, specialisation and average of relative citations combined, are Singapore, Iceland, Switzerland, Denmark, the Netherlands, Belgium, the UK, Canada, the US and Australia. These countries thus represent strategic partners for improving the scientific impact of Norway's output. Among them, we recommend intensifying collaboration with **Singapore**, **Canada**, the **US** and **Australia** since they are the countries with which Norwegian researchers collaborate less than expected.

Norway's general performance in the selected strategic themes

- Norway's highest output of scientific papers is in **Health & Care**, **Biotechnologies**, **ICT** and **Environment**.
- Norway's scientific impact is above the world average for all strategic themes except for Maritime Research, where it is slightly below. Norway's impact is the highest for **Climate Change**, **Environment**, **Environmental Technologies** and **Healthcare**. For all of the themes, with the exception of Nanotechnology & New Materials, Norway's scientific impact increased between the periods 2003–2007 and 2008–2012.
- Norway is highly specialized in **Arctic & Antarctic Research**, **Fisheries & Aquaculture Research**, **Maritime Research** and **Climate Change**, but its performance is less than expected in the fields of Nanotechnologies and New Materials, Environmental Technology, ICT and Biotechnology

Potential key partners for Norway by strategic theme and for which expansion and/or reinforcement of collaboration is recommended

- **Arctic & Antarctic Research:** Based on their overall performance in Arctic & Antarctic Research, strategic partners for improving the scientific impact of Norwegian publication output include Iceland, Canada, Switzerland, Denmark, the UK, the US and New Zealand. Of these, Norway's collaborations with **Canada**, the **US** and **New Zealand** are below expectations and could thus be further strengthened. At the micro-level, organisations that stand out among key potential partners, in terms of output, specialisation and impact, include: **University of Iceland** (Iceland), **Laval University** (Canada), **University of Bern** (Switzerland), **University of Aarhus** and **University of Copenhagen** (Denmark), **University of Southampton** and **University of Bristol** (UK), **NASA** and **Caltech** (US) and **Victoria University of Wellington** (New Zealand).
- **Biotechnology:** Based on overall performance, Iceland, Luxembourg, the US, Denmark, Switzerland, the Netherlands, Ireland, Belgium and Germany emerge as strategic partners that could improve Norway's scientific impact in Biotechnology. Collaborations with **Ireland** and **Switzerland** should be particularly increased. At the micro-level, organisations that stand out in Biotechnology include: **DeCODE Genetics** (Iceland), **Public Research Center for Health** (Luxembourg), **NIH** and **Harvard University** (US), **University of Copenhagen** (Denmark), **University of Zurich** and **University of Lausanne** (Switzerland), **Erasmus MC**

and **WUR** (the Netherlands), **University College of Dublin** (Ireland), **KU Leuven and Ghent University** (Belgium) and **Max Planck Society** (Germany).

- **Education:** Based on their overall performance in Education, strategic partners for improving the scientific impact of Norwegian publication output include Belgium, Luxembourg, the Netherlands, the UK, Cyprus, Canada, Australia, Taiwan and the US. More specifically, Norway's collaborations with these countries are not significant and should especially be strengthened with Canada, Cyprus and Luxembourg due to these countries' high level of specialisation and impact. At the micro-level, organisations that stand out in Education are: **Ghent University** (Belgium), **Utrecht University** (the Netherlands), **University of Nottingham** and **University of Oxford** (UK), **Near East University** (Cyprus), **University of Toronto** (Canada), **Queensland University of Technology** (Australia), **National Central University** (Taiwan) and **University of Michigan** and **University of Texas at Austin** (US).
- **Energy:** Considering overall performance in Energy, Singapore, Denmark, Malaysia, the Republic of Korea, Switzerland, Canada and Taiwan can be identified as strategic partners to improve Norway's scientific impact. More specifically, Norway's collaborations with these countries are not significant and should especially be strengthened with **Singapore** and **the Republic of Korea**. At the micro-level, organisations that stand out in Energy in these strategic countries include: **Nanyang Technological University** and **National University of Singapore** (Singapore), **DTU** and **Aalborg University** (Denmark), **University of Malaya** (Malaysia), **KAIST** (Korea), **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **National Research Council** (Canada) and **National Cheng Kung University** and **National Chiao Tung University** (Taiwan).
- **Environment:** Strategic partners for improving Norway's scientific impact in Environment include Switzerland, Denmark, Australia, Portugal, the Netherlands, the UK, Canada, Spain and New Zealand, since these countries exhibit high general performance considering all indicators combined. Collaboration with **Australia**, **Portugal**, **Spain** and **New Zealand** could be emphasised since it is presently below expectations. Organisations that stand out in terms of output, specialisation and impact in Environment in these strategic countries include: **ETHZ** (Switzerland), **DTU** and **University of Aarhus** (Denmark), **CSIRO** (Australia), **University of Aveiro** (Portugal), **WUR** (the Netherlands), **University of Leeds** (UK), **University of British Columbia** (Canada) and **Spanish National Research Council** (Spain).
- **Climate Change:** Strategic partners for improving Norway's visibility and impact in Climate Change include Switzerland, Australia, Denmark, the UK, the Netherlands, Sweden, Finland, the US, Canada and New Zealand. More specifically, collaboration with **Australia, Canada, New Zealand** and the **US** could be further promoted given that it is currently below expectations. Organisations that stand out in Climate Change in these strategic countries include: **ETHZ** (Switzerland), **CSIRO** (Australia), **DTU** and **University of Aarhus** (Denmark), **University of Oxford** (UK), **WUR** and **Utrecht University** (the Netherlands), **Stockholm University** (Sweden), **University of Eastern Finland** and **University of Helsinki** (Finland), **NASA**, **Columbia University**, **US Department of Energy** and **University of California - Berkeley** (US), **University of British Columbia** (Canada) and **University of Otago** (New Zealand).
- **Environmental Technology:** Strategic partners for improving Norway's impact in Environmental Technology include Switzerland, Malaysia, Portugal, Denmark, Spain, Singapore, Australia, Canada and China since these countries are frontrunners in this field considering all indicators combined. Collaboration is presently below expectations and efforts should be made to build stronger scientific relations with these countries, especially with **Malaysia, Spain, Australia** and **China.** At the micro-level, the top-ranking organisations in Environmental Technologies in these countries are: **ETHZ** (Switzerland),

University of Science (Malaysia), **New University of Lisbon** and **University of Porto** (Portugal), **DTU** and **Aalborg University** (Denmark), **CSIC** and **University of Santiago de Compostela** (Spain), **Nanyang Technological University** (Singapore), **CSIRO** and **University of Queensland** (Australia), **University of Waterloo** (Canada) and **Tongji University** and **Chinese Academy of Sciences** (China).

- **Fisheries & Aquaculture: Norway** is a leader in Fisheries & Aquaculture research considering overall international performance, followed by Iceland, Denmark, Canada, Australia, Portugal, Spain, New Zealand and the UK. **Portugal** can be identified as a strategic partner countering Norway's relative decline in output. The strong partnership with **Denmark** should be further reinforced to increase citation impact. Organisations that stand out in this strategic field and with which Norway should consider intensifying its collaboration include: **Matís Ltd. - Icelandic Food and Biotech R&D** (Iceland), **DTU** (Denmark), **University of British Columbia** and **Dalhousie University** (Canada), **CSIRO** and **Australian Research Council** (Australia), **University of Aveiro** (Portugal), **Spanish National Research Council** (Spain), and **Imperial College London** (UK).
- **Food Sciences:** Strategic partners for improving the scientific impact of Norway's output in Food Sciences include the Netherlands, Ireland, Denmark, Switzerland, Spain, Luxembourg, the UK, Australia, the US, Belgium, New Zealand and Singapore. Of these, the **US** and **Singapore** post shares of co-publications with Norway below the world level. Organisations that stand out based on output, specialisation or impact in Food Science in these strategic countries include: **WUR** (the Netherlands), **University College Dublin** (Ireland), **University of Aarhus** (Denmark), **Spanish National Research Council** (Spain), **CSIRO** (Australia), **US Department of Agriculture and University of California – Davis** (US), **Ghent University** (Belgium) and **Massey University** (New Zealand).
- **Health & Care:** Strategic partners for improving the scientific impact of Norway's output in Health & Care include the Netherlands, the US, Denmark, Iceland, Switzerland, Canada, the UK, Belgium, Sweden, Australia, Ireland and Singapore. More specifically, Norway collaborates less than expected with the **US**, **Singapore**, **Canada** and **Australia**. Given the robust growth of its output, its strong scientific impact and the mutual affinity between both countries, **Luxembourg** should also be targeted for increasing collaborations. At the micro-level, Norway should consider the following organisations (among many others) that stand out in Health & Care in the above countries: **Academic Medical Centre** and **Erasmus MC** (the Netherlands), **Brigham and Women's Hospital** and **National Institutes of Health** (US), **Copenhagen University Hospital** (Denmark), **DeCODE Genetics** (Iceland), **University Hospital of Zürich** (Switzerland), **University Health Network** (Canada), **Medical Research Council** (UK), **UZ Leuven** (Belgium), **Karolinska Institute** and **Karolinska University Hospital** (Sweden), **University of Melbourne** and **University of Sydney** (Australia), **Trinity College Dublin** (Ireland) and **Singapore National Eye Centre** (Singapore).
- **Information & Communication Technologies (ICT):** Strategic partners for improving the scientific impact of Norway's output in ICT include the US, the UK, Israel, Singapore, Switzerland, Iceland, the Netherlands, Denmark, Canada, Turkey, Ireland, Taiwan and Luxembourg. More specifically, **Israel**, the **US**, **Taiwan** and **Turkey** show a lower share of co-publications with Norway than the world average. Finland, Greece and India could also be considered, the first two because of their high impact, specialisation and proven capacity to produce high impact co-publications with Norway, and India because of its high impact co-publications and the tremendous growth of its already substantial output. Organisations that stand out in ICT in these strategic countries include: **Georgia Institute of Technology** and **Massachusetts Institute of Technology** (US), **University of Southampton** (UK), **Technion** (Israel), **Nanyang Technological University** (Singapore), **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **Reykjavik University** (Iceland), **TUDelft** (the

Netherlands), **Aalborg University** (Denmark), **University of Waterloo** (Canada), **Middle East Technical University** (Turkey), **National Chiao Tung University** (Taiwan), **University of Luxembourg** (Luxembourg), **Aalto University** (Finland) and **University of Patras** (Greece).

- **Marine & Freshwater Biology:** Strategic partners for improving the scientific impact of Norway's output in the field of Marine & Freshwater Biology include Cyprus, Denmark, the UK, the Netherlands, Switzerland, Estonia, Australia, Sweden, New Zealand, Portugal, Canada and the US. Of these, Norway's co-publications with **Cyprus**, **Australia**, the **US** and **Portugal** are below the world level. However, in the case of the US, this still results in a positive affinity for Norway. The most important organisations in terms of output, specialisation or impact in this strategic field include: **University of Aarhus** (Denmark), **University of Southampton** (UK), **WUR** (the Netherlands), **ETHZ** (Switzerland), **Estonian University of Life Sciences** (Estonia), **Australian Research Council** and **CSIRO** (Australia), **Stockholm University** (Sweden), **University of Otago** (New Zealand), **University of Aveiro** (Portugal), **Dalhousie University** (Canada) and the **US Department of Agriculture** (US).
- **Maritime Research:** Strategic partners for improving the scientific impact of Norway's output in the sciences in Maritime Research include Denmark, Portugal, Sweden, Singapore, Belgium, Greece and New Zealand. Even though their impact on their own is slightly below the world average, special attention should also be paid to Canada, Germany and France as potential avenues for increasing Norway's impact since they all present sizable outputs in the field and have an extremely high impact when collaborating with Norway. Of the above, only **New Zealand**'s share of co-publications with Norway is below the world level. In terms of organisations that stand out in Maritime Research in these countries, the following are worth mentioning: **DTU** (Denmark), **University of Lisbon** (Portugal), **National University of Singapore** (Singapore) and **National Technical University of Athens** (Greece).
- **Nanotechnology & New Materials:** Strategic partners for improving the scientific impact of Norway's output in Nanotechnology & New Materials include Singapore, Iran, the US, Switzerland, the Netherlands, Denmark, Australia, Germany, China, the Republic of Korea and the UK. More specifically, countries for which the share of co-publications with Norway is below expectations include **Singapore**, **Iran**, the **US**, the **Republic of Korea** and **China**. At the micro-level, the following organisations stand out in this thematic field: **Nanyang Technological University** (Singapore), **Isfahan University of Technology** (Iran), **US Department of Energy** and **Northwestern University** (US), **ETHZ** and **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **University of Groningen** (the Netherlands), **DTU** (Denmark), **Australian Research Council** (Australia), **Max Planck Society** (Germany), **Chinese Academy of Sciences** and **Peking University** (China), **KAIST** (Republic of Korea) and **University of Cambridge** (UK).
- **Welfare & Working Life:** Strategic partners for improving the scientific impact of Norway's output in Welfare & Working Life include the Netherlands, the UK, Denmark, the US, Sweden, Australia, Switzerland, Canada, New Zealand and Belgium. Countries for which the share of co-publications with Norway ranks below the world level include the **US**, **Switzerland**, **Canada** and **New Zealand.** The **US**, **Switzerland** and **New Zealand** also collaborate less than expected with Norway based on their affinity score. The top performing organisations in these strategic countries in Welfare & Working Life include: **VU University Amsterdam** and **TUDelft** (the Netherlands), **University of Oxford** (UK), **Copenhagen Business School** (Denmark), **Harvard University** and **New York University** (US), **Stockholm University** (Sweden), **Griffith University** and **Deakin University** (Australia), **University of Zurich** (Switzerland), **University of Toronto** (Canada), **Massey University** (New Zealand) and **University of Antwerp** (Belgium).

Key findings — Network analysis (see Section 4)

The bibliometric information supporting the identification – as described above in the key findings set out in Section 1 – of foreign organisations with which Norwegian institutions could potentially establish mutually beneficial partnerships is presented in the form of collaboration networks in Section 0. The general findings of this section are as follows:

- Apart from a few exceptions, most themes share many similar patterns in terms of organisational cooperation at the international level. **National aggregates are the norm with organisations generally presenting strong ties with other institutions in their own country**.
- **Geographical proximity** also plays a major role in the international network, as does **cultural proximity** (e.g., linguistic affinity). **American and European organisations often dictate the main structure of the network**, American organisations clustering together, while European organisations form a second cluster primarily dominated by French, UK and German organisations. Other national clusters tend to gather around these main groups.
- Norwegian organisations present strong national and regional ties and are often close to other Scandinavian organisations, especially in Denmark and Sweden. However, while Swedish and Danish organisations often come close to the main clusters, Norwegian organisations frequently appear as a distinct structure within the network. **This might be a bias induced by the over-representation of Norwegian organisations in the network; they are naturally predominant since the study focused on Norway.**

Key findings — Multilateral co-authorship and scientific impact (see Section 5)

- Authors and countries **benefit from collaborating** at both the national and the international level. **International co-publications receive more citations than domestic co-publications** and the latter have a greater impact than single author papers.
- Although it might be expected that the increase in citation impact for larger collaborations is the result of more self-citations, author **self-citations explain only 12% of the increase in impact** between single author and international co-publications.
- Compared to domestic-only co-publications, both international only and international/domestic co-publications have a higher average citation impact, irrespective of the number of authors. International only co-publications are, on average, cited 40% more often in relation to the world average than domestic-only co-publications, while international/domestic co-publications are, on average, cited 38% more than domestic-only co-publications. **This increase is mainly due to the lower frequency of uncited papers and higher frequency of highly cited papers (top 10%).**
- Thus, **increasing the number of collaborators is no guarantee of the increased citation impact of each paper**. However, the more authors on a paper, the greater the likelihood it will become a highly cited paper.
- **Recommendations for science policies:** The above findings on the effect of the number of authors and countries on the citation impact of co-publications provide strong incentives for the development of policies promoting scientific partnerships on a national scale, and even more so on an international scale. **The greater the number of authors and countries involved in a scientific publication, the greater the chances of its becoming a high impact paper (or potential "breakthrough").**

Key findings — Regional and cluster analysis (see Sections 6 and 7)

- To complement the analysis performed at the national level, Science-Metrix computed various bibliometric indicators for select regions and clusters. Regions such as Sao Paulo, Rio de Janeiro, Beijing, Shanghai, California and New York, along with NUTS regions from France, Germany, Italy and the UK, and clusters such as Bergen Marine Forskningsklynge, CalValleyTech iHub (CVTi) and Hedmark-Dalarna were compared in terms of output growth, specialisation and ARC. The latter was computed for total papers and for papers co-published with Norwegian authors, making it possible to assess whether collaborating with Norway affects the research impact of the selected regions and clusters. The data also allows for comparisons within each region, e.g., identification of the subjects of particular interest in each region, or the subject areas that most benefit from collaborating with Norway.

- A clear demarcation can be observed between regions in developed and developing countries. The regions in developed countries (France, Germany, Italy, Japan, the UK and the US) all tend to have low GR and SI scores in relation to world score, while the opposite is true for the regions in developing countries (Brazil and especially China and India). This implies that developing countries place more emphasis on these subject areas than developed countries. However, the data also shows that ARC scores tend to be higher for regions in developed countries other than Japan. Accordingly, although the regions in developing countries have been increasing their research output in most of the subject areas of interest, they have not caught up with developed regions in terms of scientific impact.
- It was also found that few of the clusters are growing their output faster than the world average. Only the CalValleyTech iHub (CVTi) and Hedmark-Dalarna (HD) clusters have relatively high GR scores in a number of subject areas.
- The most interesting finding is that ARC scores are significantly higher for papers co-authored with Norway compared to the total output of each region/cluster. In other words, collaborating with Norway increases the impact of research in all the regions and clusters under consideration.

1 Introduction

1.1 Background

The Research Council of Norway (RCN) is the national strategic and funding agency for research activities in Norway, serving as the chief source of strategic advice on and input into research policy for the Norwegian Government, the central government administration and the overall research community.

One of the RCN's primary missions is to enhance the capacity and quality of Norwegian research. As noted on the Council's website, "a knowledge-based society is dependent on a research establishment that is on the cutting edge internationally."[1] Among other things, this focus on quality has resulted in a greater need for evidence-based performance evaluations of scientific output. As discussed below, the RCN has recognised the role of bibliometrics as a key tool in this regard.

Aware that a minimum critical mass is usually required to produce world-class research,[2] the RCN also favours a coordinated, targeted approach to supporting research. This approach is aligned with the policy of the Government of Norway, which in past years has emphasised the need for more focused research policies in specific thematic areas that are relevant to key social and industrial challenges.[3] To develop such policies, one of the RCN's central tasks is to "initiate and prepare strategic plans and policy documents for individual disciplines, subject areas and research topics."[4]

Another important policy objective for both the Government and the RCN is internationalisation, in particular increasing Norway's participation in the EU's framework programme; developing the European Research Area (ERA); promoting further Nordic research cooperation; and supporting the development and/or strengthening of bilateral research collaborations with key countries such as the US and China. According to the RCN's International Strategy, the establishment of long-term institutional cooperation between Norwegian institutions and similar institutions in other countries is a crucial priority in this respect.[5] Internationalisation supports the goal of improving Norway's standing in world research. In fact, numerous studies have found that articles co-authored with international partners are cited significantly more often than articles co-authored with domestic authors only.

Finally, the RCN also emphasises the promotion of research collaborations involving Norway's private, public and service sectors, as well as the transfer of technology from the research and academic sector to Norwegian businesses.[6] This is considered to be an important means of translating research results into action, a key goal for the Norwegian government.

1 http://www.forskningsradet.no/en/Vision_and_mandate/1138785841810.

2 "In the Vanguard of Research: Strategy for the Research Council of Norway 2009-2012."

3 "Climate for Research." Report No. 30 (2008-2009) to the Storting (Summary in English).

4 http://www.forskningsradet.no/en/Other_strategic_plans/1185261825639.

5 http://www.forskningsradet.no/en/International_strategy/1253964686548.

6 "Innovation Strategy for the Research Council of Norway. The Research Council's innovation activities 2011–2014."

1.2 Overall purpose and scope of the proposed study

It is in this context that Science-Metrix has been commissioned to provide the RCN with bibliometric indicators of scientific performance (e.g., specialisation, impact) and collaboration (based on co-authorship of peer-reviewed scientific publications), focusing on Norway and its international partners (i.e., 57 countries) in thematic areas of high relevance to Norway. The analyses provide yearly as well as aggregated data for the past decade (i.e., 2003 to 2012) based on the Scopus database of peer-reviewed scientific literature. These indicators have been designed to provide guidance to RCN's funding strategies and efforts to establish international partnerships aimed at improving Norway's scientific standing. The indicators presented in this study are as follows:

- **No. of publications (FULL, Section 9.4.1):** The number of publications of a country obtained by counting once each publication in which the name of the given country appears at least once among the addresses of the authors. Double counting is avoided (i.e., if more than one author of a given country appears on a paper, it is counted only once for that country).
- **No. of publications (FRAC, Section 9.4.1):** As a large share of papers is co-published by authors from multiple countries, the sum of the full paper counts across countries often exceeds the actual number of publications in Scopus. Thus, publications were also counted fractionally (FRAC) by giving each author on a paper an equal fraction of the publication. The sum of all fractional paper counts across countries thus adds up to the number of publications in Scopus.
- **International co-publications (Section 9.4.2):** These are defined as papers that include not only domestic co-authors but also collaborators from other countries. They were counted using FULL and FRAC.
- **International co-publications with Norway (Section 9.4.2):** The number of a country's co-publications with Norway indicates how many papers researchers affiliated with a country have published with at least one colleague from Norway (both FULL and FRAC are presented).
- **International collaboration rate (Section 9.4.3):** This rate is equal to the number of international co-publications of a given country divided by the country's total number of publications. This report presents only rates based on FRAC.
- **Collaboration rate with Norway (Section 9.4.3):** This rate is equal to a given country's number of international co-publications with Norway divided by the country's total number of publications. This report presents only rates based on FRAC.
- **Specialisation Index (SI, Section 9.4.4):** This index indicates the research intensity of a country in a given research area in relation to the world as a whole. A score above 1 indicates a relative specialisation, whereas a score below 1 indicates that a country devotes less of its total research effort to the given area than does the rest of the world. This index is based on FRAC.
- **Growth ratio (GR, Section 9.4.5):** This is the ratio between a country's score in the second half of the period (2008–2012) and its score in the first half (2003–2007) for a given indicator (when available, it is based on the indicator computed using FRAC). A GR of 1 thus indicates stability, a value above 1 indicates an increase, and a value below 1 indicates a decrease. If a country has a GR above 1 but below the world's GR, it has increased its score in absolute terms but lost ground in relation to the world level. ***Trend columns in this report's tables*** help visualise annual indicator fluctuations over the past decade.
- **Relative Citations (RC):** This refers to the total number of citations accrued by a paper since its publication year relative to (i.e., divided by) the average number of citations received by all papers published the same year in the same scientific subfield. In other words, it compares the number of citations received by a paper to expectations based on the world average, taking account of life length and disciplinary differences in the amount of citations accrued.
- **Relative Number of Authors:** This refers to the number of authors on a paper relative to (i.e., divided by) the average number of authors of all papers published the same year in the same scientific subfield. In other words, it compares the number of authors on a paper to expectations based on the world

average, taking account of temporal changes in the number of authors on scientific papers as well as disciplinary differences in the size of scientific teams.

- **Average of Relative Citations (ARC, Section 9.4.6):** This indicates, based on paper citations, the impact the publications or co-publications of a given country has had on the scientific community relative to expectations (i.e., the world level). It is assumed that the more frequently a paper is cited, the greater its influence on the scientific community. An ARC above 1 indicates that a country's papers are cited above expectations, whereas a value below 1 indicates the opposite. It is based on full counting.
- **Average of Relative Impact Factors (ARIF):** This is a measure of the scientific impact of papers produced by a given entity (e.g., the world, a country) based on the impact factors of the journals in which they were published.
- **Transdisciplinarity (Section 9.4.8):** This indicator measures the average diversity of scientific subfields referenced by a country's papers. It varies from 0 (no diversity at all) to 1 (very high diversity). It is assumed that the higher the diversity of referenced subfields in a given paper, the greater the paper's transdisciplinarity. In turn, it is assumed that interdisciplinary work (i.e., research performed by teams including researchers from various fields) leads to a higher transdisciplinarity score. It is based on full counting.
- **Collaboration Index (CI, Section 9.4.9):** This index measures whether a country co-authors more papers with international partners than expected, taking account of the non-linear relationship between the number of publications and the number of international co-publications of countries (i.e., as a country's output rises, the corresponding increase in its number of international co-publications decreases). A score above 1 indicates that a country collaborates more than expected, whereas a score below 1 signals the opposite. It is based on full counting of publications and co-publications.
- **Affinity Index (AI, Section 9.4.9):** Similarly to the CI, the affinity index measures whether a country has an affinity for a specific international partner — i.e., whether it co-authors more papers with this partner than expected, taking account of the non-linear relationship between the number of publications of all its partners and the number of international co-publications with this partner. It can thus be computed from the perspective of both countries in a given pair (e.g., Canada's affinity for collaborating with Norway and Norway's affinity for collaborating with Canada). A score above 1 indicates that collaboration with the given partner is above expectations, whereas a score below 1 indicates the opposite. It is based on full counting of publications and co-publications.
- **PageRank:** This measures the centrality of an entity in a network of collaboration. The higher the score, the more important the entity in the network.
- **Betweenness Centrality:** This indicator measures how often a node appears on the shortest path between nodes in a network.
- **Share of output available in Open Access (OA; Section 9.4.12):** This estimates (and is therefore associated with a margin of error) the share of a country's papers that is available in OA. It is based on full counting.

As noted, collaborations are a major topic of analysis for this study. Collaboration indicators are based on data extracted from publications, specifically the addresses of authors. In the example presented in Figure 1, a publication is shown to have eleven co-authors based in five distinct institutions (TU Dresden, Max Planck Society, Karolinska Institute, University of Montreal and University of Bergen), which are in turn based in four different countries (Canada, Germany, Norway and Sweden). This publication is therefore counted as a co-publication for each of these institutions and countries, and as a collaboration between each of these entities. For instance, this publication would be considered as an example of a Norway-Canada collaboration, a Norway-Germany collaboration and a Norway-Sweden collaboration.

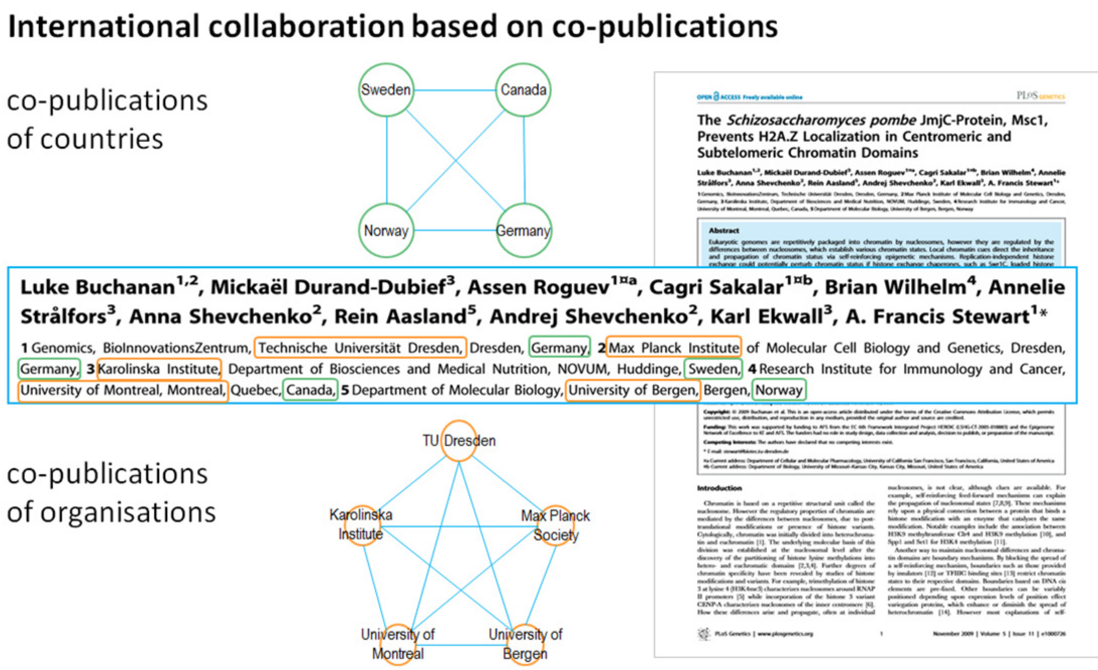


Figure 1 How research collaborations are counted

When assessing indicators of collaboration as well as topics such as research impact and specialisation, it is useful to make comparisons with world averages. Many of the results are therefore colour-coded to facilitate analysis. An indicator highlighted in green signals that the result is higher than the world average for that indicator. An indicator highlighted in red signals the opposite. The darker the green, the higher the result relative to the world average; the darker the red, the lower the result relative to the world average.

A more detailed description of indicators is provided in the discussion on methods in Section 9.4.

1.3 Structure of the report

Section 2 provides a brief comparative analysis of the current scientific performance of Norway and the 57 selected countries, along with their collaboration patterns in the sciences in general. Collaboration is measured from both an international (i.e., co-authorship with any foreign countries) and a bilateral (co-authorship specifically with Norway) perspective. This analysis aims to ***identify leading scientific nations as well as those that co-publish most frequently with foreign partners and with Norway in particular***. Trends for some of the presented indicators are also provided to address the following question: ***What has changed in the past decade — in terms of countries' relative performance and collaboration patterns — and what is likely to change in the near future?*** Values for aggregates of the Nordic countries, EU-15 and EU-28 member states, and the world as a whole are also shown, providing benchmarks to assess scientific progress.

Section 1 subsequently presents an analysis of the scientific strengths and weaknesses of the 57 selected countries, along with their propensity to collaborate with Norway by themes of significance to this country. The purpose of this analysis is to provide ***strategic information*** to the RCN about the international scientific partnerships that are most likely to be beneficial to the country, based on a comparative analysis of scientific performance. It is also intended to determine which of these partnerships appears to be underexploited based on an investigation of pairwise collaboration affinities with the selected countries. This section also highlights some of the bilateral partnerships that, although they have been beneficial to Norway's partners, have been less so to Norway's scientific performance. Again, the analysis of pairwise affinities will help assess whether any of these partnerships are over- or underexploited. Based on this information, this section provides ***recommendations*** to the RCN as to potential candidates with which Norway could strengthen its partnerships by thematic area.

Section 0 presents international collaboration networks of organisations in the sciences overall (the entire Scopus database) and for each selected strategic theme. The main clusters are identified and analysed, as well as the position of Norwegian organisations within the international community. The scientific performance of Norway's collaborators is addressed to determine whether or not Norway's current ties at the international level involve high performance organisations. Analyses of countries and organisations identified as key strategic partners in Section 1 are developed to complement the analysis and provide potential avenues for Norway to improve its performance and position internationally.

Section 5 aims to address the following questions: ***Which type of scientific partnership is most beneficial to a country's' scientific impact (and to Norway in particular) and what are the mechanisms underlying such gains in impact?*** These questions will be addressed by comparing various types of multilateral partnerships. For instance, it is well known that international co-publications have more impact than domestic co-publications, and that the latter have more impact than single author publications irrespective of scientific area or discipline. However, what is less well known is the extent to which this is attributable to the increased number of authors on individual papers (through self-citation) or to the co-authors' actual geographic location. In general, international co-publications tend to involve more authors than co-publications produced by strictly domestic authors. In turn, this could influence citation impact. The analysis will therefore compare the impact of international and domestic co-publications while controlling for the number of authors on publications.

Lastly, Sections 6 and 7 complement the analysis performed at the national level by presenting bibliometric indicators computed for a select number of regions (such as Sao Paulo, Beijing, California and various NUTS regions of Europe) and research clusters (such as the Bergen Marine Forskningsklynge cluster).

The report also includes a conclusion, presented in Section 0, highlighting key findings of strategic relevance to the RCN as well as comprehensive methods (Section 9) detailing the work that has been carried out. Additional data on the scientific strengths and weaknesses of leading Norwegian research institutions and on Norway's most important partnering institutions abroad are included in a companion database of bibliometric indicators provided to the RCN.

2 Overview of Norway's Collaboration Patterns with Selected Countries in the Sciences in General

Section 2.1 provides a brief overview of the current scientific performance of Norway and the 57 selected countries, along with their propensity to collaborate internationally in the sciences in general. Trends for some of the presented indicators are also provided to show what has changed in the past decade — in terms of the countries' relative performance — as well as what is likely to change in the near future. Values for aggregates of the Nordic countries, EU-15 and EU-28 member states, and the world as a whole are also shown, providing benchmarks for assessing scientific progress.

In particular, Section 2.1.1 identifies countries that are worthy of note for their transdisciplinarity and the share of their output available in Open Access (OA). Section 2.1.2 identifies the leaders among the selected countries in terms of the volume of their respective scientific production. It also attempts to answer the following questions: ***Which of these countries will likely lead in the future based on the volume of their scientific output and which of the smaller countries will make significant progress in this respect?*** Section 2.1.3 identifies leading countries in terms of their propensity to collaborate internationally. It also endeavours to answer the following question: ***Which of the selected countries are likely to be key international collaborators in the not too distant future?***

Section 2.1.4 seeks to identify which of the selected countries stand out for their scientific impact. It also attempts to answer the following question: ***Which countries have made the largest gains in impact from their involvement in international partnerships?*** Finally, Section 2.1.5 indicates which of the subset of countries (i.e., Brazil, Canada, China, India, Japan, Russia and the United States) that Norway has identified as key scientific partners with which to expand and/or reinforce future collaboration are currently the leaders in terms of:

1) share of world output in the sciences in general;
2) international collaboration rate;
3) collaboration rate with Norway; and
4) scientific impact.

This sub-section also strives to answer the following questions: ***Which of these countries will likely lead in the future based on each of the above indicators and when are they likely to overtake the others?***

Section 2.2 investigates the current status of and trends in the selected countries' propensity to collaborate specifically with Norway. These countries' collaboration patterns with Norway were also characterised according to the sector of activity (i.e., Higher Education, Government and Business Enterprise) in which their participating organisations are involved (Section 2.3). Similarly to Section 2.1.3, this section attempts to answer the following question: ***Which of the selected countries will likely be Norway's key international collaborators in the not too distant future?***

2.1 Scientific Performance of Norway and Selected Countries and their Propensity to Co-Publish Internationally in the Sciences in General

Table I presents the number of publications per country and for aggregates of the Nordic countries, EU-15 and EU-28 member states, using full (FULL) and fractional (FRAC) counting of publications for the period from 2003 to 2012. The transdisciplinarity, the share of papers published in Open Access (OA; estimate based on a sample of publications, see Section 9.4.12), and the scientific impact of publications (as measured by the ARC) are also shown to characterise countries' scientific performance. In addition, annual trends and a growth ratio (GR) based on FRAC are presented to identify: (a) which of the selected countries will likely lead in the future based on the volume of their scientific output, and (b) which of the smaller countries will make significant progress in this respect.

To determine which countries published the largest number of publications through international partnerships and the effect of these co-publications, Table I also lists the number of international collaborations (FULL) and their corresponding scientific impact (ARC). Furthermore, to investigate the countries' propensity to co-publish with international partners, the collaboration rate (based on FRAC) and the collaboration index (based on FULL) were produced. They are both presented alongside their GR and annual trends to identify which of the selected countries will likely be key international collaborators in the not too distant future.

2.1.1 Countries that stand out in terms of transdisciplinarity and share of output available in Open Access

It is still unclear how the average transdisciplinarity of a country's publications and the share of its output available in Open Access (OA; estimate based on a sample of publications, see Section 9.4.12) relate to its scientific performance. It can be hypothesised that highly innovative ideas are more likely to emerge from the concerted efforts of researchers in disconnected fields in comparison to research performed in silos by one or many researchers in any given field. Under such a hypothesis, the transdisciplinarity of countries would be expected to correlate positively with the production of scientific breakthroughs. Table I shows that the world average TD value is 0.44 (halfway from no transdisciplinarity [TD = 0] to maximum transdisciplinarity [TD = 1]) with only slight variations across countries. Therefore, in the sciences in general, it is not possible to clearly identify outstanding countries in this respect.

For all selected countries, including Norway, the average interdisciplinarity of their output is similar to the world level (TD = 0.44) with only slight variations.

With 50% (± 6%) of its output in OA, Norway is clearly above the world average of 40%. South American countries (i.e., Chile, Colombia and Brazil) lead in this respect, most likely as a result of the OA initiatives.

The OA indicator provides an estimate of the share of papers published in Open Access that are thus freely available to all readers. It can accordingly be hypothesised that the larger a country's share, the broader the readership of the country's papers. In turn, an increase in the country's scientific impact might also be expected. However, there does not appear to be a correlation between this indicator and the ARC. Moreover, the quality of OA literature has recently been severely questioned.[7] At 50% (± 6%), Norway is clearly above the world average of 40% and, together with Denmark (50% ± 5%), it outranks the other Nordic countries with the highest share of output in OA. Among traditional leaders, the Netherlands stands out with a share of 56% (± 3%). Of all the 58 countries, the South American states — i.e., Chile (69% ± 8%), Colombia (65% ± 11%) and Brazil (61% ± 3%) — reflect the highest OA rates, which can be explained by OA initiatives such as the Scientific Electronic Library Online (SciELO).[8] Lastly, China (21% ± 1%), Russia (23% ± 3%), Bulgaria (35% ± 12%) and Turkey (36% ± 3%) publish the fewest papers in OA in relation to their volume of production.

2.1.2 The largest producers of scientific papers

This section first focuses on identifying the largest producers of publication output in the sciences in general. More specifically, it answers the question as to which country is the most important actor in academic communication based on number of research papers. It also assesses where Norway stands in terms of the number of papers produced during the period from 2003 to 2012.

As Table I shows, the US clearly leads for overall scientific output, with close to 4.6 million papers in Scopus published between 2003 and 2012. With 2.5 million publications, China follows as the second-largest producer of scientific papers worldwide. Previous studies have demonstrated that China has shown particularly strong growth and surpassed many leading research nations based on publication output in the last 10 years.

After China, the UK, Japan and Germany rank third to fifth respectively with around 1.4 million papers. France, Canada, Italy, India and Spain complete the top 10 largest producing nations based on publication output for 2003 to 2012. Norway produced close to 114,000 papers (FULL), ranking 31st among the 58 selected countries. Based on fractional publication counts, where papers are fractionalised based on the number of countries per paper, the top 10 ranking changes only slightly, with Japan placing third, overtaking the UK, and Italy seventh, leaving Canada in eighth position. Fractional counting does not greatly affect the rankings of three-quarters of the 58 countries analysed. For example, Norway drops by only one position to rank 32nd (78,352 FRAC). Switzerland is impacted the most, since it falls four ranks (17th FULL, 21st FRAC), reflecting the fact that a large share of Switzerland's publication output is carried out in collaboration with international partners.

The **US** leads in terms of overall scientific output, with close to 4.6 million papers (FULL) published between 2003 and 2012, followed by **China** (2.5 million). Completing the top 10 are the UK, Japan, Germany, France, Canada, Italy, India and Spain (from 1.2 million to 541,000 papers respectively).

Norway ranks 31st among the 58 selected countries, with 114,000 papers. Upcoming global leaders include **Brazil**, the **Republic of Korea** and **Taiwan**.

[7] Bohannon, J. (2013). Who's Afraid of Peer Review? *Science*, 342(6154): 60-65.

[8] http://www.scielo.org.

Table I Scientific Performance of Norway and Selected Countries as well as their Propensity to Co-Publish Internationally in the Sciences in General (i.e., Scopus), 2003–2012

	Publications							International Co-Publications							
	FULL				FRAC			FULL		Coll. Index (FULL)			Coll. Rate (FRAC)		
Country	**Number**	**OA (%)**	**TD**	**ARC**	**Number**	**Trend**	**GR**	**Number**	**ARC**	**Score**	**Trend**	**GR**	**%**	**Trend**	**GR**
World	**16,847,218**	**40 ±0**	**0.44**	**1.00**	**16,847,218**		**1.36**	**2,888,551**	**1.48**	**n.a.**	**n.a.**	**n.a.**	**10%**		**1.03**
Nordic	**593,955**	**46 ±2**	**0.46**	**1.40**	**439,236**		**1.21**	**279,306**	**1.76**	**n.a.**	**n.a.**	**n.a.**	**17%**		**1.13**
Norway	113,861	50 ±6	0.45	1.38	78,352		1.41	57,116	1.76	1.24		1.05	17%		1.09
Iceland	8,026	n.c.	0.46	1.72	4,368		1.62	5,492	2.13	1.25		1.05	29%		1.08
Denmark (EU-15/28)	140,885	50 ±5	0.46	1.62	94,600		1.29	74,272	1.99	1.34		1.05	19%		1.10
Finland (EU-15/28)	128,781	46 ±5	0.45	1.36	93,433		1.15	59,367	1.73	1.16		1.08	15%		1.15
Sweden (EU-15/28)	244,533	45 ±4	0.46	1.46	168,484		1.11	125,190	1.81	1.39		1.07	18%		1.15
EU-28	**5,703,922**	**42 ±1**	**0.44**	**1.12**	**5,019,625**		**1.25**	**1,872,189**	**1.54**	**n.a.**	**n.a.**	**n.a.**	**14%**		**1.09**
EU-15	**5,143,797**	**43 ±1**	**0.44**	**1.19**	**4,443,620**		**1.22**	**1,787,271**	**1.57**	**n.a.**	**n.a.**	**n.a.**	**14%**		**1.11**
Austria	146,590	45 ±5	0.45	1.32	98,462		1.25	78,465	1.69	1.37		1.07	19%		1.14
Belgium	206,638	49 ±4	0.44	1.48	139,243		1.23	111,896	1.84	1.44		1.06	19%		1.13
France	847,869	43 ±2	0.44	1.17	629,489		1.17	375,442	1.60	1.39		1.05	15%		1.10
Germany	1,144,662	42 ±2	0.44	1.26	863,122		1.18	495,598	1.68	1.40		1.03	14%		1.08
Greece	132,896	40 ±5	0.43	1.13	103,998		1.32	49,591	1.56	0.94		1.06	12%		1.09
Ireland	78,989	48 ±7	0.46	1.35	55,359		1.53	38,311	1.72	1.15		1.04	17%		1.03
Italy	655,430	44 ±2	0.43	1.20	516,217		1.24	249,192	1.72	1.16		1.06	12%		1.12
Luxembourg	5,867	n.c.	0.46	1.30	3,073		2.93	4,279	1.51	1.28		1.07	35%		1.01
Netherlands	370,455	56 ±3	0.46	1.59	261,568		1.25	180,938	1.94	1.39		1.05	16%		1.10
Portugal	110,283	53 ±6	0.44	1.17	80,473		1.78	51,733	1.52	1.16		0.99	15%		0.98
Spain	541,176	48 ±3	0.43	1.17	425,318		1.40	204,467	1.65	1.12		1.10	12%		1.14
United Kingdom	1,218,794	45 ±2	0.45	1.41	910,783		1.15	518,581	1.80	1.39		1.08	15%		1.16
Bulgaria	30,453	35 ±12	0.42	0.71	21,187		1.27	14,817	1.09	1.04		0.89	17%		0.89
Croatia	43,103	50 ±10	0.44	0.63	35,932		1.53	11,947	1.32	0.61		1.08	8%		1.06
Cyprus	8,615	n.c.	0.40	1.30	4,963		2.34	5,492	1.57	1.17		1.03	28%		0.93
Czech Republic	122,799	38 ±5	0.43	0.85	95,138		1.46	45,349	1.41	0.92		0.97	11%		0.95
Estonia	14,557	60 ±15	0.45	1.19	10,146		1.70	6,976	1.69	0.94		1.01	16%		0.93
Hungary	77,053	40 ±7	0.43	0.93	55,750		1.19	34,518	1.44	1.06		0.95	15%		0.97
Latvia	7,104	n.c.	0.43	0.75	5,160		2.43	3,016	1.20	0.76		0.67	14%		0.55
Lithuania	21,261	51 ±15	0.44	0.81	17,161		1.67	6,781	1.32	0.65		0.89	9%		0.84
Malta	2,009	n.c.	0.43	1.01	1,367		2.32	966	1.58	0.75		0.89	18%		0.80
Poland	256,289	39 ±4	0.43	0.71	210,620		1.28	74,400	1.34	0.79		0.90	9%		0.89
Romania	77,302	45 ±8	0.43	0.66	62,025		2.86	25,288	1.15	0.78		0.68	10%		0.57
Slovakia	39,389	41 ±10	0.42	0.74	28,565		1.38	17,614	1.17	0.98		0.94	15%		0.95
Slovenia	37,293	43 ±10	0.44	1.00	27,992		1.47	14,856	1.42	0.87		1.05	13%		1.08
Argentina	82,306	46 ±7	0.44	0.94	62,111		1.43	34,683	1.40	1.01		0.95	14%		0.93
Australia	482,418	44 ±3	0.46	1.37	366,285		1.38	199,704	1.78	1.21		1.09	14%		1.12
Brazil	368,125	61 ±3	0.44	0.79	319,827		1.77	90,506	1.35	0.70		0.89	7%		0.83
Canada	684,860	47 ±2	0.45	1.39	513,863		1.23	290,318	1.79	1.30		1.03	14%		1.08
Chile	53,173	69 ±8	0.41	0.99	35,878		1.64	28,179	1.36	1.20		0.96	19%		0.92
China	2,507,201	21 ±1	0.44	0.71	2,336,110		2.10	342,815	1.52	0.49		1.01	4%		0.94
Colombia	30,445	65 ±11	0.45	0.81	20,895		2.81	15,183	1.29	1.06		0.93	18%		0.82
Egypt	68,496	41 ±7	0.43	0.77	52,583		1.80	25,861	1.05	0.88		1.17	13%		1.14
India	553,505	39 ±3	0.43	0.76	502,068		1.93	96,571	1.30	0.52		0.92	5%		0.88
Indonesia	16,285	52 ±18	0.45	0.88	9,073		2.82	10,538	1.13	1.28		0.83	28%		0.66
Iran	187,295	45 ±4	0.43	0.84	170,357		3.45	34,122	1.18	0.48		0.88	6%		0.76
Israel	146,416	50 ±5	0.45	1.34	110,389		1.07	61,395	1.78	1.07		1.01	14%		1.08
Japan	1,155,461	40 ±2	0.42	0.85	1,024,120		1.01	248,252	1.39	0.70		1.04	6%		1.10
Malaysia	88,775	48 ±6	0.44	0.74	73,357		4.58	27,833	0.99	0.76		0.93	10%		0.72
Mexico	125,404	50 ±6	0.43	0.79	96,798		1.38	49,478	1.24	0.99		0.96	13%		0.94
New Zealand	89,356	43 ±6	0.46	1.27	63,600		1.35	43,093	1.63	1.16		1.01	18%		1.03
Nigeria	35,735	55 ±8	0.47	0.44	31,536		1.98	7,245	0.91	0.44		1.04	6%		1.00
Pakistan	49,053	53 ±8	0.44	0.70	40,494		2.51	15,582	1.14	0.72		1.23	10%		1.13
Rep. of Korea	465,398	41 ±3	0.43	0.98	401,017		1.57	118,426	1.48	0.74		0.97	7%		0.95
Russia	357,384	23 ±3	0.39	0.51	291,606		1.06	110,783	1.11	0.88		0.87	10%		0.89
Singapore	115,418	40 ±6	0.43	1.50	85,533		1.28	53,040	1.79	1.14		1.22	16%		1.30
South Africa	89,157	48 ±6	0.45	1.05	66,078		1.55	39,064	1.54	1.06		1.02	15%		1.00
Switzerland	268,519	52 ±4	0.45	1.66	167,790		1.22	160,034	1.98	1.63		1.04	22%		1.12
Taiwan	302,901	41 ±4	0.43	1.08	271,289		1.53	57,588	1.47	0.53		1.10	5%		1.07
Thailand	68,736	51 ±7	0.45	0.91	52,621		2.01	27,961	1.29	0.95		0.84	13%		0.75
Turkey	244,381	36 ±3	0.43	0.81	221,320		1.49	40,560	1.40	0.45		1.03	5%		1.03
United States	4,580,396	50 ±1	0.46	1.39	3,921,016		1.11	1,213,153	1.73	1.01		1.10	8%		1.15
Viet Nam	13,870	49 ±19	0.43	1.04	7,324		2.74	10,134	1.21	1.42		0.92	35%		0.79

Note: n.a. = not applicable; n.c. = not computed. FULL and FRAC respectively mean no. of papers or co-publications based on full and fractional counting; OA = Share of papers in open access (based on FULL); TD = Avg. Transdisciplinarity; GR = Growth Ratio (based on FRAC for papers) = $Score_{2008\text{-}2012}/Score_{2003\text{-}2007}$; ARC = Average of Relative Citations (based on FULL). Trend = Sparkline showing growth for various indicators (the scale is not the same across countries).

Source: Computed by Science-Metrix using Scopus (Elsevier)

Future trends and important actors based on publication output

This sub-section examines how the publication output of nations develops over time and attempts to answer the following questions: ***Which countries will likely lead in the future and which of the smaller countries will make significant progress?***

It actually identifies actors that may remain or become significant based on trends in their publication output expressed by the growth ratio (GR). Since it is easier to show large increases if starting from a small number of papers during the first five-year period of this study (2003–2007), small and large producers of output are considered separately. The highest GRs among the top 15 producers in volume of output (FRAC) identify those countries that, based on observed trends, might join the ranks of world leaders, surpassing some of the current frontrunners:

- Among the 15 countries with the highest publication output (FRAC) during the entire 10-year period, **China** (2,336,110 FRAC, rank = 2nd; GR = 2.10, rank = 12th) and **India** (502,068 FRAC, rank = 9th; GR = 1.93, rank = 15th) show by far the largest increases in the number of papers produced during the second relative to the first half of the study period. In fact, they both overtook many countries in this time period and China very likely surpassed the US in 2013 as the leading nation in terms of its share of world output if recent trends continued.
- **Brazil** (319,827 FRAC, rank = 13th; GR = 1.77, rank = 18th), the **Republic of Korea** (401,017 FRAC, rank = 11th; GR = 1.57, rank = 23rd) and **Taiwan** (271,289 FRAC, rank = 15th; GR = 1.53, rank = 26th) follow, with above 50% increases in output between 2003–2007 and 2008–2012.

Although not yet included among the largest producers, those countries with the highest GRs overall could play a greater role in the future based on an analysis of current trends.

- **Malaysia**, currently ranking as the 33rd country with the largest production of the 58 analysed (FRAC; 35th based on FULL), has increased its publication output by more than fourfold (GR = 4.58, rank = 1st). With an overall publication output of 88,775 publications (FULL; 73,357 FRAC), Malaysia is poised to become an important producer of scientific output in the future if this trend continues.
- Other small producers of publication output such as **Iran** (170,357 FRAC, rank = 19th; GR = 3.45, rank = 2nd), **Luxembourg** (3,073 FRAC, rank = 57th; GR = 2.93, rank = 3rd), **Romania** (62,025 FRAC, rank = 37th; GR = 2.86, rank = 4th)**, Indonesia** (9,073 FRAC, rank = 52nd; GR = 2.82, rank = 5th) and **Colombia** (20.895 FRAC, rank = 49th; GR = 2.81, rank = 6th) also exhibit high increases in output.

2.1.3 Countries' propensity to collaborate internationally

This section first examines countries' propensity to collaborate with foreign partners based on an analysis of two indicators of international collaboration (i.e., the international collaboration rate and the collaboration index [CI]). More specifically, it answers the question as to which country is most prone to co-publish its papers with international partners. It also assesses where Norway stands in this respect.

Table I shows that Switzerland frequently collaborates with other nations as indicated by its collaboration rate of 22% (compared to the world average of 10%) and a high CI of 1.63 – the highest of all the 58 selected countries. This certainly explains, at least partially, why this country so frequently stands out in terms of scientific impact regardless of the field. There is no doubt that international co-publications improve a country's impact. As the CI compares the observed number of co-publications to those expected based on the overall output of the country, a value greater than 1 indicates international collaboration above expectations and a value less than 1 indicates below world average collaboration. At 1.63, Switzerland's CI shows that its international collaboration score is 63% higher than expected given its overall co-publication output.

Switzerland is followed by Belgium (CI=1.44), Vietnam (1.42) and Germany (1.40), which each collaborate at least 40% more than expected. When the number of co-publications is not normalised by expectations based on the country's size, Vietnam, Luxemburg (both with collaboration rates of 35%) and Iceland (29%) show the highest levels of international collaboration. The Nordic countries collaborate more than expected, led by Sweden with a CI of 1.39 (7th ranking). Norway collaborates about 25% above expectations and ranks 15th among the selected countries. Norway publishes exactly as many papers in collaboration with international partners as the Nordic average (17%), which is above the global average of 10%. Nigeria, Turkey, Iran and China collaborate more than 50% below expectations, making them the least collaborative countries of the 58 selected. With as few as 4% of its fractional papers co-published with partners from other countries, China has the lowest non-normalised collaboration rate.

With a CI of 1.63, **Switzerland** leads in terms of collaboration with foreign counties given the size of its overall publication output. It is followed by **Belgium** (1.44), **Vietnam** (1.42) and **Germany** (1.41).

Norway collaborates about 25% above expectations (CI=1.24) and ranks 15th among the selected countries. All the Nordic countries collaborate more than expected.

Of those countries that already collaborate more than expected, Singapore, Spain, the US and Australia show the largest increase in their propensity to collaborate with foreign partners.

Of those countries that currently collaborate less than expected, Pakistan, Egypt and Taiwan show the largest increase in their propensity to collaborate with foreign partners.

Future trends and important actors based on international collaboration

This sub-section addresses the question of which of the selected countries are likely to become key international collaborators (in relative rather than in absolute terms) in the near future. As indicated by the GR of the CI in Table I, the propensity to collaborate increased slightly between 2003–2007 and 2008–2012 in the Nordic countries (at least 5% for each country), in the EU-15 countries, and in some of the non-European countries. This section identifies those countries that show positive trends towards international collaboration and are thus improving their position in the network of internationally co-publishing countries. As the capacity to increase the number of international co-publications depends on the current level of collaborations, countries with CIs above and below world average are considered separately.

- Among countries that already co-publish internationally above expectations given their overall publication output, **Singapore** (GR = 1.22, rank = 2nd; CI = 1.14, rank = 24th), **Spain**

(GR = 1.10, rank = 5th; CI = 1.12, rank = 25th), the **US** (GR = 1.10, rank = 6th; CI = 1.01, rank = 31st) and **Australia** (GR = 1.09, rank = 7th; CI = 1.21, rank = 16th) show the largest positive trends towards international collaboration.

- Of the countries that do not yet meet expectations in terms of their CIs, **Pakistan** (GR = 1.23, rank = 1st; CI = 0.72, rank = 48th), **Egypt** (GR = 1.17, rank = 3rd; CI = 0.88, rank = 39th) and **Taiwan** (GR = 1.10, rank = 4th; CI = 0.53, rank = 53rd) show the highest growth in collaboration from the first to the second five-year period.

2.1.4 Scientific impact of countries and international collaborations

This section focuses on the scientific impact as reflected by the average relative citations (ARC) received by a country's publications overall and those published with at least one international partner. This analysis demonstrates whether a country's papers are cited above or below the world average and to which extent countries benefit from co-publishing with international partners.

As Table I illustrates, collaborating internationally always pays off in citation impact. On average, the ARC of international co-publications are 48% higher than those of all papers (world ARC of co-publications = 1.48). In fact, the ARC based on international co-publications is higher than those of all publications for all of the 58 countries, showing that each country benefits from participating in international collaborations.

Iceland scores the highest ARC, based both on its overall publication output (1.72) and its international co-publications (2.13). China is the country that most benefits from collaborating internationally, as its ARC climb from 0.71 (51st rank) for papers with Chinese authors only to 1.52 (27th rank) for those including at least one author from another country. Vietnam shows the smallest increase comparing overall citation impact (1.04) and impact of international collaborations (1.21). This is to be expected since Vietnam's co-publications make up more than one-third of its overall publication output.

Based on the ARC, **Iceland** (1.72), **Switzerland** (1.66) and **Denmark** (1.62) post the highest scientific impact for their overall publications. Considering their international co-publications only, they still have the highest impact, with Iceland in the lead (2.13), followed by Denmark (2.99) and Switzerland (2.98).

On average, the ARC of international co-publications is 48% higher than that for overall publications, and all countries without exception benefit from international partnerships in terms of scientific impact.

With an ARC of 1.38, **Norway** ranks 11th based on its overall output and 12th[h] based on its international collaborations (1.76).

China, Croatia, Poland, Russia, Malta, Italy and Estonia significantly gain from collaborating with other countries.

Papers produced by the Nordic countries are, on average, cited 40% more often than the average world paper (ARC = 1.40) and benefit from co-publishing with international partners (1.76). In particular, Iceland and Denmark show outstanding ARC values, ranking first and third based on all papers and first and second respectively for international co-publications among the 58 countries. Iceland (ARC = 1.72) is followed by Switzerland (1.66), Denmark (1.62), the Netherlands (1.59) and Singapore (1.50) in terms of the citation impact of their total production. As concerns the ARC of international collaborations, the ranking changes with Denmark and the Netherlands switching places and Singapore dropping to eighth place. Belgium (1.84), Sweden (1.81) and the UK (1.80) have slightly higher ARCs than Singapore (.179) based on international collaborations.

Largest gains in scientific impact from international collaboration

This sub-section highlights the countries that most benefit from international co-publishing by analysing the difference between the ARCs of their overall publication output and their international co-publications. Since it is easier for a country to increase the number of citations if it is below expectations than for a country that already exhibits scientific impact above the world average, countries with ARCs above and below the world average are considered separately.

- Of those countries with overall below average ARCs, **China** (overall ARC = 0.71; ARC of international co-publications = 1.52), **Croatia** (0.63; 1.32), **Poland** (0.79; 1.34) and **Russia** (0.88; 1.11) reap the most benefit from international collaborations.
- Of those countries that already meet or exceed expectations respecting citation impact, **Malta** (1.01; 1.58), **Italy** (1.20; 1.72) and **Estonia** (1.19; 1.70) show the highest increase between the overall citation rates and ARCs of their international co-publications.

2.1.5 Annual trends for Norway's strategic partners

The RCN has identified Brazil, Canada, China, India, Japan, Russia, South Africa and the US as key scientific partners with which Norway should expand and/or reinforce collaboration in the future. These countries are thus analysed in more detail together with Norway, focusing on yearly trends in their share of world output (Figure 2), international collaboration rate (Figure 3), collaboration rate with Norway (Figure 4), and their scientific impact (Figure 5). This analysis aims to identify which of these countries are currently in a leadership position and which of them are likely to lead in the future, based on each of the above indicators.

Figure 2 shows the yearly world output in Scopus, alongside trends in the countries' share of world output during the period from 2003 to 2012. The United States clearly dominates with a share of almost 28% in 2003. However its share consistently decreased over the entire timeframe, falling to 20% in 2012. China's publications are increasing faster than the world's publications, as can be seen from its share trend. If this trend continued, China should have had overtaken the United States as the nation with the largest yearly scientific production in 2013, based on a linear extrapolation model. Japan's share slowly diminished over the entire period, dropping from 8% to 4.8%. In fact, Japan's share is expected to fall below India's share by 2015 (again based on a linear extrapolation model). Norway's share is stable with the world output, representing 0.4% for 2003 to 2004 and then 0.5% for the following years. Norway's curve is nearly invisible in the figure because it is hidden behind that of South Africa, which presents similar results. Other countries' shares are mainly stable, with the exception

Within the subset of countries identified as key scientific partners with which Norway should expand/reinforce collaboration in the future, **China** stands out the most in terms of the rapidly changing nature of its scientific system.

China should have surpassed the United States as the nation with the largest yearly scientific production in 2013 if the trends shown in this study continued.

Because China's impact is still relatively low, it does not often appear in the report's recommendations by theme (Section 3.2 to 3.16).

However, even though its impact remains relatively low in many areas, this is changing and will continue to do so in the future, which means that **China should definitely be on the radar screen of any nation planning future international collaboration strategies**.

of India, which almost doubled its share over the period. The countries with outputs that are growing faster than the world average are China and India. They will certainly remain and become even more important players in the knowledge-based economy.

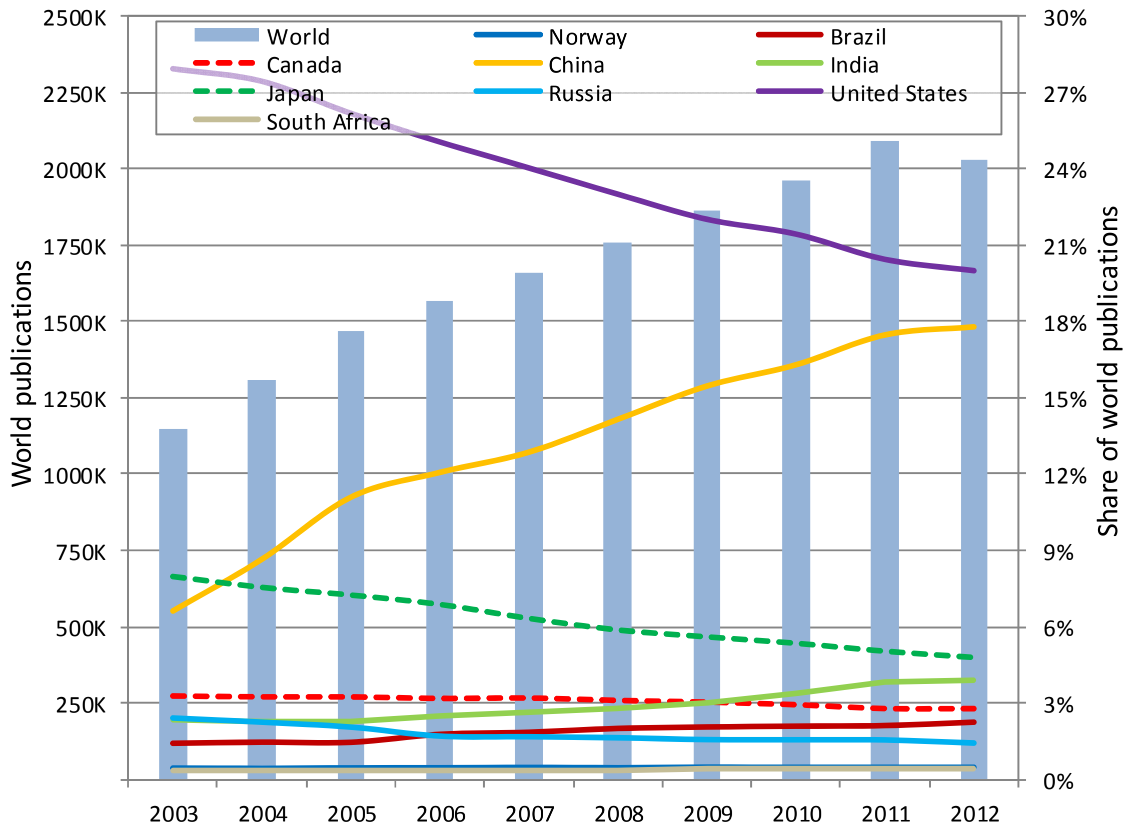


Figure 2 Annual number of worldwide papers and share of world publications of a subset of countries (2003–2012)

Note: The share of world output is based on fractional counting.
Source: Computed by Science-Metrix using Scopus (Elsevier)

Figure 3 presents trends in the international collaboration rate of this subset of countries. Norway has the highest collaboration rate, starting at 16% in 2003 and climbing to 19% in 2012. South Africa follows, starting with a collaboration rate of 15% and topping 16% in 2012. Canada comes in third place with an international collaboration rate ranging from 13% to 16%. The United States increased its collaborations over this time period from 7% to 9%, while Russia saw a decline in its collaboration rate from 2006 to 2011. However, Russia experienced an increase in its international collaboration rate in 2012 to reach 9%, placing it on a similar level to the United States. Although Japan's collaboration rate is low, it is slowly increasing and expected to reach 7% in 2018 (based on a linear extrapolation model). Interestingly, China is the country that collaborates the least, with a collaboration rate around 3% to 4% from 2005 on. Figure 3 indicates which partners it might be easier to collaborate with (i.e., South Africa, Canada, Russia, and the United States). However, since China's output is greater than that of most of these countries, in absolute terms its number of international co-publications surpasses that of most countries in this subset (it is second after the US). Thus, excluding language and cultural barriers, it might not be much more difficult to establish partnerships with China, and this also might become the case for India in the not too distant future.

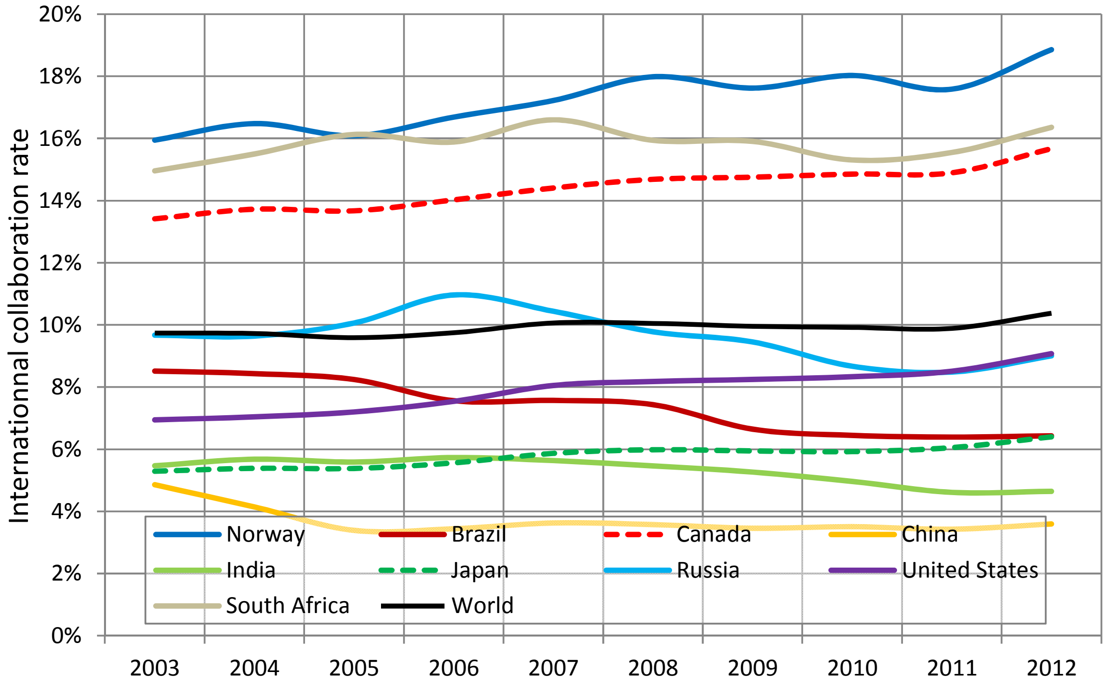


Figure 3 International collaboration rate of selected countries and Norway (2003–2012)

Note: The international collaboration rate is based on fractional counting.
Source: Computed by Science-Metrix using Scopus (Elsevier)

Figure 4 represents the collaboration rate of countries in this subset specifically with Norway. As expected, the countries with low international collaboration rates are those with the lowest collaboration rates with Norway. Although the collaboration rates of Brazil and India with Norway have varied over time, in the long run collaborations are still growing and this growth can be expected to continue.

The country that most frequently co-publishes with Norway is by far South Africa. Although its curve shows high fluctuations, the collaboration rate rose from 0.08% to 0.2% over the 10-year period. The second and third best co-publishers with Norway, with collaboration rates above the world level, are Canada and Russia. Note that their collaboration rates with Norway have also increased over time, showing a stronger growth than the world average in 2012. Collaboration with United States is also positive, although below the world average. If the volume of output is considered as a key criterion for identifying potential partner countries, then Norway might consider strengthening its collaboration with China and India. Both these countries post significant outputs, are experiencing strong growth and currently show low collaboration rates with Norway.

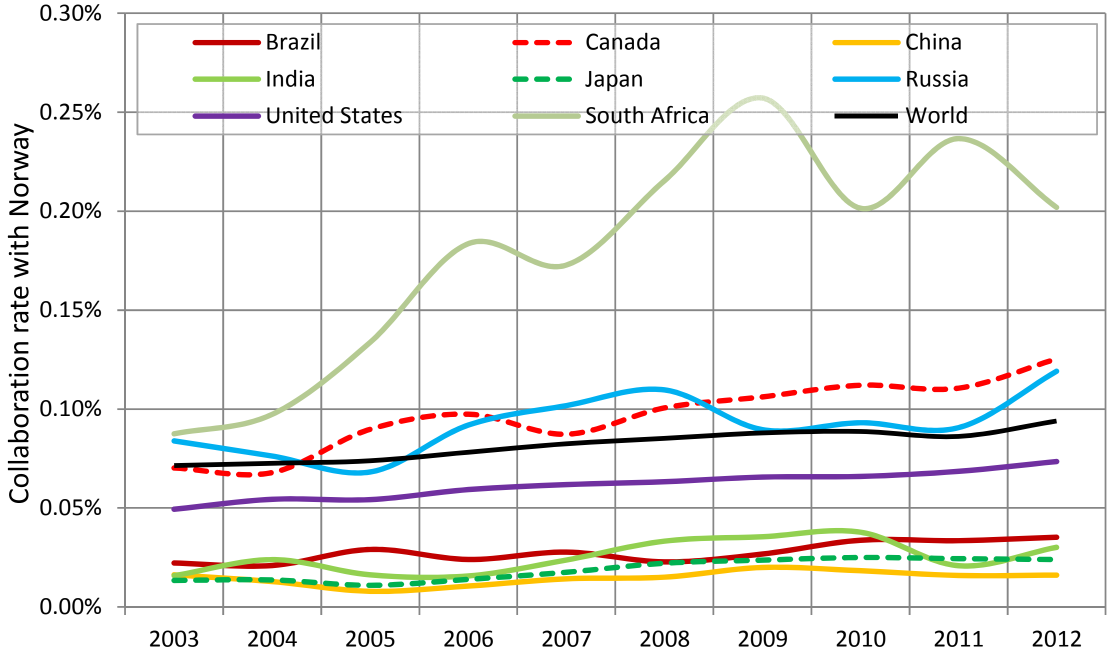


Figure 4 Collaboration rate of selected countries with Norway (2003–2012)

Note: The collaboration rate is based on fractional counting.
Source: Computed by Science-Metrix using Scopus (Elsevier)

Figure 5 presents trends in the impact of the scientific research performed by each country in this subset. One group of countries is distinctively above the world level of impact and another is well below it. South Africa is the only country that shows a progression close to the world level, although its impact is clearly increasing, starting under the world level and reaching an ARC of about 1.15 in 2012. As this performance is likely to continue, South Africa could become a partner of choice when considering scientific impact in the years to come. Norway should definitively continue and perhaps expand its collaboration with the United States and Canada since both these countries produce high impact research. In fact, their impact is actually comparable to Norway's. Together with South Africa, these countries are the only ones in this subset above the world level and they also follow similar trends. As for China and Brazil, their impact came close to 0.8 in 2012. Whereas China's impact has risen steadily since 2005, that of Brazil has remained fairly stable with some yearly fluctuations. China's impact will definitely continue to intensify as its output will grow; for instance its influence on the world average impact will rise, bringing it closer to an ARC score of one.

Although China is still lagging behind in terms of scientific impact, previous analyses by Science-Metrix have shown that its citation impact has exceeded expectations in several research fields, especially in Nanotechnology, and that its citation rates are rapidly increasing in others. Furthermore, based on fractional publication counts (2003–2012), China has already replaced the US as the world's largest producer in some fields; for example, in Energy (Section 3.5) and Nanotechnology & New Materials (Section 3.14). Thus, despite the fact that its impact remains relatively low in many areas compared to that of the traditional leaders (e.g., the US, the UK, Germany and the Netherlands), it is quite clear that this situation will change and that China should be on the radar screen of any nation in planning future international collaboration strategies.

Since Japan's impact is not far from the world average and has steadily increased, rising to 0.9 in 2012, collaboration with Japan could be advantageous for Norway. Even though its collaboration rates (Figure 3 and Figure 4) are low and its publication output is slowly decreasing (Figure 2), it still remains one of the largest within this set of countries. Russia has the lowest impact, although it has slowly increased over time. In fact, Russia's impact is systematically close to or below the world level in each of Norway's 15 strategic themes (see Section 1).

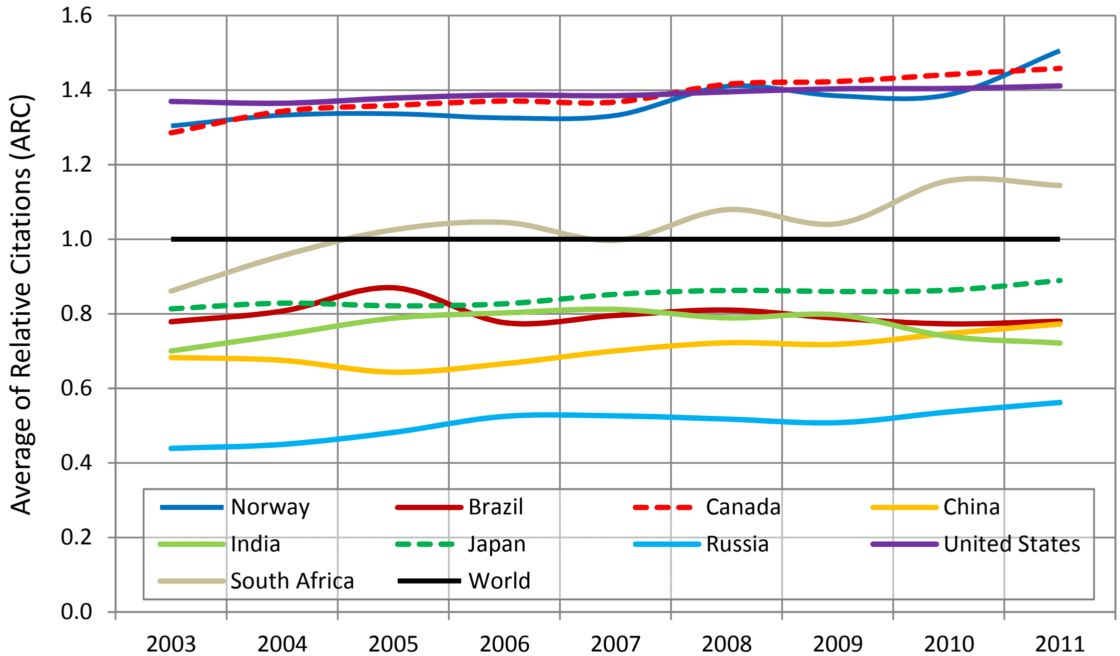


Figure 5 Average of relative citations (ARC) of selected countries and Norway (2003–2012)

Note: The year 2012 is not included in computing the Average of Relative Citations (ARC) due to incomplete citation windows in those years.

Source: Computed by Science-Metrix using Scopus (Elsevier)

2.2 Collaboration Profiles of Selected Countries with Norway in the Sciences in General

This section addresses existing collaborations with Norway. Table II lists the number of co-publications (FULL and FRAC) with Norway for each of the 57 countries and aggregates of the Nordic countries (excluding Norway) and EU member states. The ARC indicates the impact of the countries' and aggregates' papers co-authored with Norwegian collaborators and, when compared to the ARC in Table I, highlights whether partners benefit from collaborating with Norway in terms of citation impact. Co-publications with Norway are provided as shares of a country's overall output including trends and GRs. Furthermore, Table II lists a particular country's affinity for collaborating with Norway and vice versa based on the collaboration affinity indicator, which normalises the number of co-publications by the respective size of the countries as defined by their overall co-publication output (see Section 9.4.9 for a detailed description of this indicator).

As to be expected and as Table II shows, the most papers published in collaboration with Norway are published by the countries with the largest output, as identified in Section 2.1 above, with the exception of China and Japan, which is likely due to isolation by distance and cultural differences.

Based on both full and fractional counting of co-publications, the US (15,756 FULL; 2,434 FRAC), the UK (11,847 FULL; 1,532 FRAC), Sweden (10,033 FULL; 1,436 FRAC) and Germany (8,971 FULL; 985 FRAC) are Norway's most important collaborators. Since this is influenced by these countries' overall output, it is advisable to use indicators normalising for size. The collaboration rate reflects the importance of Norway from the perspective of the collaborating country, as does the collaboration affinity for Norway, which normalises by the expected number of co-publications with Norway. These two indicators (Collaboration Rate and Collaboration Affinity for Norway) thus highlight the importance of Norway for nearby partners, i.e. Iceland (Collaboration Rate = 1.88%; Collaboration Affinity for Norway = *n.c*), Sweden (0.85%; 5.50), Denmark (0.81%; 6.04) and, to a lesser extent Finland (0.38%; 4.03) and Estonia (0.32%; *n.c*), as well as other small European countries such as Luxembourg (0.35%; *n.c*) and Malta (0.28%; *n.c*). Among the Nordic countries, collaborations with Norway declined by 23% for Iceland from 2003–2007 to 2008–2012. However, it should be noted that the collaboration rate with Norway is already high among the Nordic countries. Nevertheless, co-publication rates with Norway still increased for the other three Nordic countries, especially for Sweden (GR of Collaboration Rate = 1.35). The greatest increases within the EU are noted for the Czech Republic (Collaboration Rate = 0.10%; GR=1.69), Hungary (0.09%; 1.68) and Belgium (0.12%; 1.63).

Norway's most important collaborators in terms of the absolute number of co-publication output are the **US**, followed by the **UK**, **Sweden** and **Germany**.

In terms of their collaboration rates and pairwise affinities with Norway, all the **Nordic countries** are noteworthy (in descending order: Iceland, Sweden, Denmark and Finland), as are **Estonia** and **Luxembourg**. This shows the strong influence of **geographic proximity** and **cultural similarity** on the countries' collaboration patterns.

Norway is also an important collaborator for **South Africa, Israel, Russia** and **Canada,** which all have strong affinities for Norway. However, Norway's affinities for these countries are less strong. Although Norway presents very little affinity for collaborating with **China**, this country, **shows a certain affinity for Norway,** co-publishing 19% more with Norwegian researchers than expected.

Among the Nordic countries, **collaboration** between Norway **and Sweden** is increasing, even though it is already high. The greatest increase within the EU is noted with the **Czech Republic**, **Hungary** and **Belgium**.

International **collaboration** with Norway **leads to** a particularly **high ARC** score of 1.76 on average (all countries pooled). All of the 57 selected countries have ARC scores above 2.

Of the traditional leaders in science, those with which collaboration with Norway was most beneficial include **Belgium**, **Switzerland**, **Italy**, **Australia** and **Canada**.

Normalising for the expected co-publication rates with collaborators, Norway's affinity for collaborating countries is particularly high for Iceland (Norway's Collaboration Affinity = 14.97), Denmark (6.28), Sweden (5.80) and Finland (3.91). These figures show that the mutually strongest affinities occur among the Nordic countries, reflecting typical collaboration patterns based on geographic proximity and cultural similarity. Except for Croatia, Norway also shows above-average affinity for EU-28 member states, especially Estonia (3.71), Luxembourg (3.69) and Malta (3.14). Given that Croatia became an EU member as recently as July 2013,[9] this reflects Norway's high affinity for collaborating with EU member states. Outside Europe, collaboration affinities are much lower, with Norway's scores below 1 for 21 of the 28 non-EU member states. Of the seven non-EU members with which Norway co-publishes more than expected, a particular focus on collaborating with South Africa was noted (1.83). South Africa's collaboration rate with Norway (0.19%) is also more than twice the global average of 0.08%.

Norway shows the lowest affinity for China, the Republic of Korea, Iran, Malaysia and Nigeria. Except for China, this lack of affinity is mutual as the Republic of Korea and Iran also co-publish 48% and 36% less than expected with Norway. China, however, shows a certain affinity for Norway, co-publishing 19% more than expected with Norwegian authors. Given China's low collaboration rate overall, Norwegian collaborations still represent only 0.02% of China's output in Scopus, but a GR of 43% indicates that China has increased its share of co-publications with Norwegian colleagues. Outside Europe, Norway is an important collaborator for Israel (Collaboration Affinity for Norway = 1.79), Russia (1.78) and Canada (1.71). However, Norway's affinities for these countries are less strong. In fact, Norway even co-publishes 3% less than expected with Canada.

As shown earlier, collaborating with Norway leads to a particularly high ARC score of 1.76 on average (all countries pooled). As illustrated by the ARC of co-publications in Table II, Norway benefits from collaborating with each of the 57 selected countries. In fact, none of the collaborations with Norway have ARC scores below 2 within this selection. Collaborations with the other Nordic countries lead to a citation impact of 2.16 times the world average. The highest citation impact is obtained by papers involving Norwegian and Argentinean, Colombian and Mexican authors. These high scores might, however, be influenced by a few very large multilateral partnerships given the fairly low number of co-publications involved; extreme relative citation scores have a significant influence on the ARC when the number of co-publications is small. In fact, closer investigation of the data (see companion database) shows that a large proportion of these co-publications appears in fields where it is common to publish in large international research consortia that receive high citation impact due to the large number of authors involved (due to self-citation, see 5.1 for details). It is thus not specifically the collaborations with Argentina, Colombia and Mexico that increase Norway's impact, but the impact of the multilateral research groups to which researchers from these countries belong. Although many other countries are involved in these high impact papers, the countries with a particularly small volume of co-publications with Norway are most affected.

Of those countries that co-published at least 1,000 papers with Norway during the 10-year period, collaborations are most beneficial with Brazil (ARC=4.31), the Czech Republic (4.23) and Poland (3.77). Note however that the above limitations relating to the identification of the countries with which collaboration is most beneficial in terms of potential gain in impact might very well apply again here. Indeed, these countries are not noted for the impact of their total production, which means that the strong scores observed here are potentially greatly affected by the presence of large multilateral partnerships. Partnerships with Norway were the least beneficial with Iran (2.02), Indonesia (2.05) and Nigeria (2.12), although they were still above the average of 1.76 for all international co-publications involving Norway. Of the countries known as traditional leaders in

[9] http://ec.europa.eu/enlargement/countries/detailed-country-information/croatia.

science, Belgium, Switzerland, Italy, Australia and Canada are those where collaboration with Norway was most beneficial.

Table II Collaboration Profiles of Selected Countries with Norway in the Sciences in General (i.e., in Scopus), 2003–2012

	Co-pubs with NO (FULL)						Co-pubs with NO (FRAC)			
Country	FULL	ARC	Coll. Affinity for NO	GR	Coll. Affinity of NO for the CO	GR	FRAC	Coll. Rate	Trend	GR
World	**57,116**	1.76	**n.a.**	**n.a.**	**n.a.**	**n.c.**	**13,926**	**0.08%**		1.16
Nordic	**16,117**	**2.16**	**n.a.**	**n.a.**	**n.a.**	**n.c.**	**2,632**	**0.73%**		**1.23**
Iceland	909	2.92	n.c.	n.c.	14.97	n.c.	82	1.88%		0.77
Denmark (EU-15/28)	6,326	2.63	6.04	n.c.	6.28	n.c.	763	0.81%		1.07
Finland (EU-15/28)	3,604	2.90	4.03	0.67	3.91	n.c.	351	0.38%		1.20
Sweden (EU-15/28)	10,033	2.29	5.50	0.88	5.80	n.c.	1,436	0.85%		1.35
EU-28	39,497	1.93	n.a.	n.c.	n.a.	n.c.	8,052	0.16%		1.24
EU-15	37,872	1.97	n.a.	n.c.	n.a.	n.c.	7,544	0.17%		1.26
Austria	1,976	3.22	1.74	0.93	1.89	n.c.	153	0.16%		1.57
Belgium	2,209	3.58	1.26	0.93	1.51	n.c.	167	0.12%		1.63
France	6,904	2.77	1.30	0.94	1.18	n.c.	669	0.11%		1.21
Germany	8,971	2.72	1.40	1.06	1.14	n.c.	985	0.11%		1.39
Greece	1,511	3.72	1.83	n.c.	1.59	n.c.	87	0.08%		1.21
Ireland	922	3.58	1.79	0.76	1.61	n.c.	62	0.11%		1.18
Italy	5,095	3.27	1.56	0.88	1.12	n.c.	399	0.08%		1.36
Luxembourg	165	2.80	n.c.	n.c.	3.69	n.c.	11	0.35%		1.60
Netherlands	5,834	3.07	2.46	0.92	2.24	n.c.	520	0.20%		1.21
Portugal	1,237	3.37	1.68	n.c.	1.56	n.c.	87	0.11%		1.06
Spain	4,348	3.17	1.55	n.c.	1.15	n.c.	321	0.08%		1.32
United Kingdom	11,847	2.68	1.70	0.95	1.42	n.c.	1,532	0.17%		1.28
Bulgaria	237	3.23	n.c.	n.c.	1.06	n.c.	24	0.11%		1.44
Croatia	302	3.60	n.c.	n.c.	0.96	n.c.	24	0.07%		1.11
Cyprus	68	3.52	n.c.	n.c.	1.04	n.c.	7	0.15%		0.97
Czech Republic	1,260	4.23	1.51	n.c.	1.43	n.c.	92	0.10%		1.69
Estonia	404	3.72	n.c.	n.c.	3.71	n.c.	32	0.32%		0.96
Hungary	756	4.43	1.40	n.c.	1.36	n.c.	49	0.09%		1.68
Latvia	109	4.41	n.c.	n.c.	2.02	n.c.	9	0.17%		0.71
Lithuania	317	2.87	n.c.	n.c.	2.01	n.c.	30	0.17%		0.74
Malta	49	2.91	n.c.	n.c.	3.14	n.c.	4	0.28%		0.82
Poland	1,896	3.77	1.61	n.c.	1.05	n.c.	156	0.07%		1.16
Romania	615	4.19	n.c.	n.c.	1.10	n.c.	33	0.05%		0.48
Slovakia	569	4.60	n.c.	n.c.	1.97	n.c.	29	0.10%		1.10
Slovenia	558	2.88	n.c.	n.c.	2.04	n.c.	18	0.06%		1.50
Argentina	405	6.83	n.c.	n.c.	0.68	n.c.	15	0.02%		1.46
Australia	2,895	3.23	1.36	1.12	0.86	n.c.	342	0.09%		1.52
Brazil	1,041	4.31	0.91	1.04	0.40	n.c.	92	0.03%		1.22
Canada	4,623	3.20	1.71	1.00	0.97	n.c.	507	0.10%		1.33
Chile	398	4.35	n.c.	n.c.	1.03	n.c.	25	0.07%		1.41
China	2,671	2.44	1.19	0.84	0.16	n.c.	360	0.02%		1.43
Colombia	255	6.36	n.c.	n.c.	1.14	n.c.	10	0.05%		0.42
Egypt	116	2.29	n.c.	n.c.	0.23	n.c.	15	0.03%		1.16
India	904	3.23	0.68	1.22	0.23	n.c.	135	0.03%		1.60
Indonesia	82	2.05	n.c.	n.c.	0.67	n.c.	11	0.12%		0.57
Iran	234	2.02	0.64	n.c.	0.18	n.c.	42	0.02%		1.21
Israel	1,123	3.50	1.79	1.29	1.07	n.c.	80	0.07%		1.67
Japan	1,896	3.12	0.77	1.29	0.24	n.c.	194	0.02%		1.71
Malaysia	117	2.91	n.c.	n.c.	0.18	n.c.	16	0.02%		0.55
Mexico	356	6.36	0.47	n.c.	0.40	n.c.	32	0.03%		1.99
New Zealand	657	3.18	n.c.	n.c.	1.02	n.c.	73	0.12%		1.20
Nigeria	48	2.12	n.c.	n.c.	0.18	n.c.	7	0.02%		3.67
Pakistan	90	3.37	n.c.	n.c.	0.25	n.c.	12	0.03%		2.71
Rep. of Korea	541	3.79	0.52	1.01	0.17	n.c.	54	0.01%		1.16
Russia	2,659	2.21	1.78	n.c.	1.06	n.c.	269	0.09%		1.19
Singapore	378	3.50	1.19	n.c.	0.46	n.c.	54	0.06%		1.37
South Africa	1,179	3.04	n.c.	n.c.	1.83	n.c.	124	0.19%		1.58
Switzerland	2,944	3.53	1.37	0.95	1.55	n.c.	234	0.14%		1.44
Taiwan	484	3.95	0.81	1.35	0.23	n.c.	38	0.01%		1.27
Thailand	144	4.28	n.c.	n.c.	0.29	n.c.	18	0.03%		1.65
Turkey	637	3.89	0.96	n.c.	0.37	n.c.	50	0.02%		0.80
United States	15,756	2.37	1.23	0.99	0.52	n.c.	2,434	0.06%		1.20
Viet Nam	97	2.30	n.c.	n.c.	0.93	n.c.	17	0.24%		3.50

Note: n.a. = not applicable; n.c. = not computed. FULL and FRAC respectively mean full and fractional counting; GR = Growth Ratio = $\text{Score}_{2008\text{--}2012}/\text{Score}_{2003\text{–}2007}$. ARC = Average of Relative Citations (based on FULL). Trend = Sparkline showing growth for various indicators (the scale is not the same across countries).

Source: Computed by Science-Metrix using Scopus (Elsevier)

Source: Computed by Science-Metrix using Scopus (Elsevier)

2.3 Collaboration Profiles of Selected Countries with Norway in the Sciences in General by Organisational Sector

This section analyses the collaboration profile of selected countries with Norway by organisational sector. The following three sectors have been selected, based on the codification proposed by the Frascati Manual:[10] Higher Education, Government and Business Enterprise. A fourth category for organisations of another (i.e., Private Non-Profit) or unknown type is presented so that the sum in the share of a country's co-publications with Norway across sectors adds up to at least 100%. Note that the sum of shares across sectors can add up to more than 100% since some addresses were coded to two different sectors (e.g., Unité Mixte de Recherche [partnerships between the CNRS and universities] in France).

For each country or aggregate of countries, Table III presents the total co-publication output with Norway (in FRAC). The share of this output attributable to each of the selected counties' organisations in a given sector is also provided alongside the GR of this share and the yearly trend over the past decade.

The average of the selected countries' shares for each sector clearly indicates that 72% of co-publications with Norway involve organisations from the Higher Education sector in the collaborating country, 19% from Government organisations and 5% from Business Enterprises.

Some countries appear to diverge from this usual pattern. One example is Luxembourg, which posts a share of co-publications with Norway in Higher Education of 42% and of 55.6% for Government organisations. Luxembourg's particular situation was examined in a report Science-Metrix prepared for the European Commission in 2012.[11] The analysis showed a smaller than usual contribution of the Higher Education sector to R&D expenditures (i.e., smaller HERD) in Luxembourg relative to other European countries. Not surprisingly, the study also revealed that Luxembourg systematically has fewer researchers in the Higher Education sector than would be expected given its overall R&D expenditures (all sectors pooled). This situation is changing rapidly as the Luxembourg government has implemented a number of policy actions since 2000 (e.g., creation of a national university in 2003, opening of visas to researchers from new member states). These policies have been effective as Luxembourg's trajectory in terms of HERD and researchers in higher education has closed the gap with expectations based on the general pattern for European countries. This translated into an exponential growth of its scientific output in academic journals in the period from 2000 to 2009. It is also reflected in the extraordinarily high GR (5.96) of Luxembourg's share of co-publications with Norway attributed to its Higher Education sector (Table III). This in turn suggests that departure from the usual co-publication pattern of countries across sectors for Luxembourg is likely to diminish over the years.

[10] OECD (2002), Frascati Manual-*Proposed Standard Practices for Surveys on Research and Experimental Development.* OECD Publication Service, Paris, pp. 53-72.

[11] Campbell, D, Caruso, J, Archambault, E. (2012), *Cross-Cutting Analysis of Scientific Output vs. Other STI Indicators*.

The pattern for Bulgaria and for Russia seems to be similar to that for Luxembourg, with a share of co-publications of around 30% in Higher Education. This result is not that surprising since the Bulgarian Academy of Sciences and the Russian Academy of Sciences, two government organisations, are the major scientific players in both these countries. They are in fact these countries' most collaborative organisations with Norway. Colombia also shows a somewhat similar pattern, with a share equally distributed between Higher Education and Government. Given that only 10 co-publications with Norway are listed for the 10-year period, this pattern could very likely fluctuate in the future.

Within the 57 selected countries, the **Higher Education** sector usually accounts for about 72% of co-publications with Norway, followed by the **Government** and **Business Enterprise** sectors, each with a 19% and 5% share of publications respectively.

Countries with a larger than usual share from the Government sector include **Luxembourg, Bulgaria, Russia, France** and **Argentina**. However, the underlying factors explaining this departure from the usual patterns varies for each country.

Countries with a larger than usual share from the Business Enterprise sector include **Iceland** (Akvaplan-niva), **Israel** (Israel Electric Corporation) and **Malaysia** (petroleum companies such as Petronas and Shell).

The case of France is of particular interest since the sum of its share across sectors amounts to 128%. As explained above, this is because some addresses have been coded to two different sectors in the case of joint ventures and other types of partnerships. In France, this excess across sectors is due to the structure of the French scientific system, which involves a large number of mixed research units between major government organisations (e.g., CNRS, INSERM and INRA) and universities. This explains both the equal distribution of the shares in Higher Education and Government and the sum of shares adding up to more than 100%.

The situation in Argentina is similar to that in France. CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas), a government organisation, is highly involved in joint research units with universities and other partners, and appears frequently in co-publications with Norway.

Considering the share for Business Enterprises, Iceland (share = 20.1), Israel (16.6) and Malaysia (17.4) exhibit shares well above the average across the selected countries. In all these cases, companies are among the respective country's organisations that co-publish the most with Norway. In Iceland, one company in particular collaborates intensely with Norway, i.e., Akvaplan-niva, an organisation active in environmental research and aquaculture. Akvaplan-niva is actually a Norwegian company that also operates in Iceland. Thus, collaboration might substantially involve co-authors from the same company in the two countries. As for Israel, the Israel Electric Corporation appears to collaborate significantly with Norway. In the case of Malaysia, oil companies (Petronas, Shell, etc.) also play an important role in terms of scientific collaboration with Norway.

Table III Collaboration Profiles of Selected Countries with Norway in the Sciences in General (i.e., in Scopus) by Organisational Sector, 2003–2012

		Higher Educ.			Gov.			Bus. Ent.			Other/Unknown
Country	Co-pubs with NO	Share	GR	Trend	Share	GR	Trend	Share	GR	Trend	Share
Nordic	**2,632**	**80%**	**1.03**		**9.1%**	**0.93**		**4.4%**	**0.69**		*7.8%*
Iceland	82	57%	1.02		18.2%	1.19		20.1%	0.68		*9.0%*
Denmark (EU-15/28)	763	82%	1.05		6.9%	1.18		3.4%	0.42		*8.7%*
Finland (EU-15/28)	351	67%	0.95		25.5%	0.90		2.9%	1.25		*10.7%*
Sweden (EU-15/28)	1,436	84%	1.03		5.7%	0.85		4.4%	0.78		*6.5%*
EU-28	**8,052**	**73%**	**1.05**		**18.7%**	**0.90**		**4.3%**	**0.78**		*8.2%*
EU-15	**7,544**	**73%**	**1.06**		**18.5%**	**0.90**		**4.5%**	**0.78**		*8.4%*
Austria	153	72%	1.13		16.0%	0.64		9.0%	1.08		*4.6%*
Belgium	167	81%	1.09		9.4%	0.63		4.2%	0.44		*6.1%*
France	669	55%	1.15		58.3%	1.02		2.5%	0.90		*12.6%*
Germany	985	63%	1.09		26.0%	0.88		6.4%	0.80		*7.6%*
Greece	87	75%	1.04		16.0%	0.72		0.6%	n.c.		*8.2%*
Ireland	62	79%	0.96		12.2%	0.85		1.6%	n.c.		*8.1%*
Italy	399	65%	1.15		25.8%	0.81		3.1%	0.53		*9.7%*
Luxembourg	11	42%	5.96		55.6%	0.54		1.1%	n.c.		*1.3%*
Netherlands	520	75%	1.06		13.0%	0.72		5.0%	0.78		*9.1%*
Portugal	87	82%	1.01		14.6%	0.71		0.2%	n.c.		*5.9%*
Spain	321	72%	1.07		20.9%	0.87		2.8%	1.21		*7.7%*
United Kingdom	1,532	77%	1.06		13.6%	0.85		6.0%	0.82		*8.4%*
Bulgaria	24	31%	1.06		66.2%	1.10		0.1%	n.c.		*2.8%*
Croatia	24	68%	1.04		17.1%	0.58		5.0%	n.c.		*10.3%*
Cyprus	7	71%	0.91		12.1%	n.c.		0.1%	n.c.		*17.3%*
Czech Republic	92	62%	1.32		32.0%	0.66		0.8%	n.c.		*7.4%*
Estonia	32	85%	0.90		7.9%	1.35		2.3%	n.c.		*4.8%*
Hungary	49	56%	1.05		50.0%	1.03		1.8%	n.c.		*4.5%*
Latvia	9	84%	1.12		8.8%	1.69		0.0%	n.c.		*7.2%*
Lithuania	30	87%	0.91		11.2%	1.59		0.2%	n.c.		*1.8%*
Malta	4	97%	n.c.		2.7%	n.c.		0.0%	n.c.		*0.1%*
Poland	156	86%	0.94		7.1%	1.81		1.1%	n.c.		*6.0%*
Romania	33	77%	1.08		14.3%	1.00		1.3%	n.c.		*7.1%*
Slovakia	29	68%	1.07		31.3%	0.62		1.9%	n.c.		*2.6%*
Slovenia	18	67%	1.03		26.3%	0.80		0.5%	n.c.		*6.5%*
Argentina	15	65%	0.87		51.2%	1.67		1.1%	n.c.		*9.3%*
Australia	342	83%	0.99		10.6%	1.20		3.9%	0.99		*5.1%*
Brazil	92	80%	1.09		13.0%	0.60		4.1%	n.c.		*4.1%*
Canada	507	80%	1.06		14.1%	0.76		4.4%	0.97		*4.2%*
Chile	25	84%	1.04		2.0%	n.c.		10.0%	n.c.		*3.7%*
China	360	73%	1.06		20.8%	1.13		3.5%	1.27		*4.8%*
Colombia	10	49%	2.42		43.0%	0.39		4.5%	n.c.		*4.0%*
Egypt	15	62%	1.75		23.0%	n.c.		5.8%	n.c.		*9.5%*
India	135	71%	1.04		12.5%	0.82		7.4%	0.91		*10.4%*
Indonesia	11	74%	1.06		4.6%	n.c.		5.7%	n.c.		*16.5%*
Iran	42	85%	1.45		9.1%	0.28		7.5%	n.c.		*0.3%*
Israel	80	75%	0.80		5.1%	0.65		16.6%	5.15		*2.9%*
Japan	194	73%	1.11		17.8%	0.83		5.1%	1.43		*5.1%*
Malaysia	16	71%	1.60		2.5%	n.c.		17.4%	n.c.		*9.7%*
Mexico	32	67%	1.25		20.3%	0.49		7.9%	n.c.		*5.2%*
New Zealand	73	65%	1.12		22.1%	0.89		8.5%	1.03		*4.5%*
Nigeria	7	84%	0.93		0.8%	n.c.		13.0%	n.c.		*5.2%*
Pakistan	12	67%	1.39		23.2%	4.03		2.1%	n.c.		*11.0%*
Rep. of Korea	54	78%	1.00		6.5%	0.93		9.7%	1.40		*5.9%*
Russia	269	30%	1.32		55.2%	0.95		2.0%	0.97		*13.1%*
Singapore	54	88%	0.97		8.0%	1.45		2.1%	n.c.		*1.8%*
South Africa	124	78%	0.99		20.3%	1.31		1.2%	0.41		*4.1%*
Switzerland	234	65%	1.12		16.4%	0.74		9.2%	0.76		*9.2%*
Taiwan	38	94%	0.99		5.1%	1.01		0.1%	n.c.		*0.7%*
Thailand	18	81%	1.07		8.8%	n.c.		7.5%	n.c.		*2.9%*
Turkey	50	94%	1.01		4.2%	1.02		0.3%	n.c.		*1.9%*
United States	2,434	73%	1.04		10.7%	0.91		7.6%	0.93		*11.9%*
Viet Nam	17	70%	1.39		25.1%	0.66		3.1%	n.c.		*1.8%*

Note: The numbers in this table are based on fractional counting. Other/Unknown include unclassified organisations as well as private non-profit organisations. The growth ratios (GR) are coloured in red when they reflect a decrease (<1) and in green when they indicate an increase (>1). The sum of shares across sectors can add up to more than 100% since some addresses were coded to two different sectors (e.g., Unité Mixte de Recherche [partnerships between the CNRS and universities] in France).

Source: Computed by Science-Metrix using Scopus (Elsevier)

3 Scientific Performance and Collaboration Profiles of Selected Countries with Norway by Strategic Theme

This analysis provides ***strategic information*** to help identify scientific partnerships that could be beneficial to Norway's performance in support of the development of RCN's International Strategy. It is based on a comparative analysis of scientific performance that relies on objective bibliometric indicators that reflect the scientific strengths/weaknesses inherent in:

(a) the study's 58 countries (including Norway) in Scopus overall (i.e. an aggregate of all scientific fields) (Section 3.1), and

(b) the 15 pre-defined strategic themes that are of particular importance to Norway, i.e. Arctic & Antarctic Research (3.2), Biotechnology (3.3), Education (3.4), Energy (3.5), Environment (3.6), Climate Change (3.7), Environmental Technology (3.8), Fisheries & Aquaculture (3.9), Food Sciences (3.10), Health & Care (3.11), Information & Communication Technologies (3.12), Marine & Freshwater Biology (3.13), Maritime Research (3.14), Nanotechnology & New Materials (3.15), and Welfare & Working Life (3.16).

It also analyses Norway's international collaboration patterns with each of the selected countries to identify which of those partnerships appear over- or underexploited to support the provision of ***recommendations*** to the RCN as to potential candidates with which Norway could reinforce partnerships by thematic area.

General approach for the provision of strategic information and recommendations

For each of Norway's strategic themes, publication statistics for Norway and the 57 selected countries and aggregates of the Nordic, EU-15 and EU-28 countries are provided, including the number of papers (FULL and FRAC), the growth ratio (GR) of the output size (FRAC), the specialisation index (SI) and the average of relative citations (ARC) of a country's total production and of its co-publications specifically with Norway.

Although the ARC of both sets of papers can help highlight which country has been most beneficial to Norway, the ARC of co-publications is less reliable because these publications seldom strictly involve the two countries considered (i.e., Norway and its partner). That is why it is difficult to attribute the beneficial effect of the co-publications to the given partner, especially when the partner's production size is small. In these cases, the ARC is more easily affected by the high impact of multilateral co-authorships. For a summary of these metrics, see above Section 1.2. Section 9 (Methods) provides a more detailed description of bibliometric indicators.

These indicators were analysed with a view to ranking a country according to the likelihood that co-authorships between this country's researchers and Norwegian authors would be beneficial to Norway's international standing in the given area. ***Let's first define a beneficial scientific partnership:***

> From Norway's perspective,[12] a beneficial partnership is defined as cooperative research endeavours that have a high potential for increasing the country's research capacity in a given

[12] The information and views set out in this respect are those of the authors and do not necessarily reflect the official opinion of the RCN.

> area (somewhat indicated by the volume of its output and relative specialisation), and most importantly, for increasing its scientific impact (in other words the influence it has on the international scientific community).
>
> Thus, key indicators to account for in quantifying the potential beneficial returns from a partnership with a specific country include the partner's number of papers, SI, GR and ARC.

Approach used to identify Norway's potentially beneficial collaborators

When multiple indicators (i.e., the number of papers, SI, GR and ARC) are used to characterise countries' scientific performance, it is often difficult to determine their position relative to one another without a well-structured ranking mechanism. To make it easier to identify the countries with which collaboration could be beneficial to Norway, Science-Metrix analysts have made use of expert judgement, aided by an in-house tool for dimensionality reduction in the synthesis of complex datasets. This allowed for the identification of countries that stand out when considering all indicators jointly in each individual theme. In particular, emphasis was placed on the scientific impact of a country's total publication output by giving twice as much weight to the ARC compared to the weight granted to each of the other indicators (i.e., the number of papers, SI and GR).

In view of this approach, it is not surprising to see some of the smaller countries (e.g., Cyprus, Luxembourg and Malaysia) among the set of countries identified as Norway's potentially beneficial collaborators. Although these countries are not noted for the volume of their output, they may very well excel in other respects, such as the growth, specialisation and impact of their production in specific areas. Similarly, some of the larger producers of scientific papers (e.g., Germany and China) may not be identified here as potentially beneficial collaborators if they do not perform well in the other dimensions, especially as concerns their impact, since this indicator was given a larger weight. ***Nevertheless, these larger countries can still represent important partners since collaboration opportunities with them are more diverse due to a potentially larger pool of high impact research groups than in smaller countries that have a higher ARC***. Our goal was to identify potential partners throughout the full range of country sizes.

Sections 3.2 to 3.16 present these results, with a comprehensive discussion for each strategic theme. A summary of the main recommendations is provided in a text box in each section.

Collaboration patterns for the provision of recommendations

Collaboration rates with Norway, together with a country's collaboration affinity for Norway (for NO) and of Norway for a country (of NO), are provided. These collaboration affinity indicators determine whether partnerships are over- or underexploited from the perspective of both Norway and the collaborator. The collaboration rate helps assess Norway's importance as a co-publication partner from the collaborating country's perspective, which is particularly useful in cases where the pairwise collaboration affinities could not be computed (this occurred in many themes).

Science-Metrix' final recommendations respecting the countries with which Norway could reinforce partnerships are based on this information and on the above-described analysis of scientific performance. ***The rationale underlying these recommendations is as follows:***

> Countries that scored high based on the above approach to the analysis of scientific performance are tagged as potentially beneficial collaborators. Of these, countries with which Norway does not yet collaborate preferentially/frequently are labelled as suitable candidates for future intensification of partnerships.

For example, although Sweden often stands out as a beneficial collaborator for Norway, it might not be necessary to further expand and/or strengthen collaboration with this partner since Norway already collaborates above expectations with Sweden in many themes. This explains why Sweden does not often appear in the recommendations set out in Sections 3.2 to 3.16. Recommendations for expanding and/or strengthening collaborations are summarized in the text box for each section.

Scientific performance at the micro-level (i.e. organisations)

Sections 3.2 to 3.16 also present the highest performing organisations in each scientific theme for the countries identified as potentially beneficial collaborators for Norway. These recommendations are presented in the text box in each section.

Specifically, one or two of the highest performing organisations for each country tagged as a potentially beneficial collaborator have been highlighted, except where no institutions stood out. Since one of the study's goals was to highlight organisations of interest within the countries identified as potential partners with which Norway could strengthen collaboration, and because these potential partners had to cover the full spectrum of country sizes (see above explanation), ***the organisations that are highlighted in this study are not necessarily the world's top performing organisations***. The reader is referred to the companion databooks provided with the report for a more comprehensive description and performance analysis of organisations for all 58 countries. These databooks also contain information on each nation's collaboration pattern with Norway.

Note that it was not possible to extend the analysis to the level of researchers. In most cases, the data were too sparse. It should also be noted that organisations' performance was calculated based on the 2010 to 2012 period only. Since the growth rate of publications is somewhat irrelevant for such a brief period, it was not considered in assessing the organisations' performance. Similarly, the ARC, which is a measure of impact based on the number of citations an article received after its publication, could not be used because of the very short citation windows of papers published in 2011 and 2012. Instead, the ARIF, an indirect measure of impact, was used as it is not affected by this limitation. In short, the most performing organisations were analysed considering the number of publications (in fractional counting), the specialisation index (SI) and the ARIF.

Limitations

Science-Metrix' recommendations rely exclusively on an analysis of bibliometric data characterising the scientific performance and collaboration pattern with Norway of the selected countries and their organisations. There is obviously a much wider set of parameters that need to be accounted for in targeting specific countries that a nation should focus more on when developing an international science strategy. For example, there may be active developments in specific countries relating to funding policies in specific sectors, as well as regulations that may hinder or facilitate the development of beneficial partnerships. Since this study did not take such alternative factors into account, ***Science-Metrix's selection should not be viewed as a definitive statement of the countries or organisations with which a country should expand and/or strengthen collaboration by thematic area***.

Norway's strengths and weaknesses across its strategic themes

The following sections make considerable use of *positional analysis graphs* (see example below), where SI and ARC scores are transformed to obtain a symmetrical distribution of possible scores around the world level (i.e., the origin in the Cartesian coordinate system). Thus, the strengths of an entity are to be found in the top right quadrant (high level of specialisation, high level of impact). The third dimension is obtained by making the size of data points in the graph proportional to the number of publications produced by the corresponding entities; the colours of data points in the graph can be customized, for example, to differentiate entities.

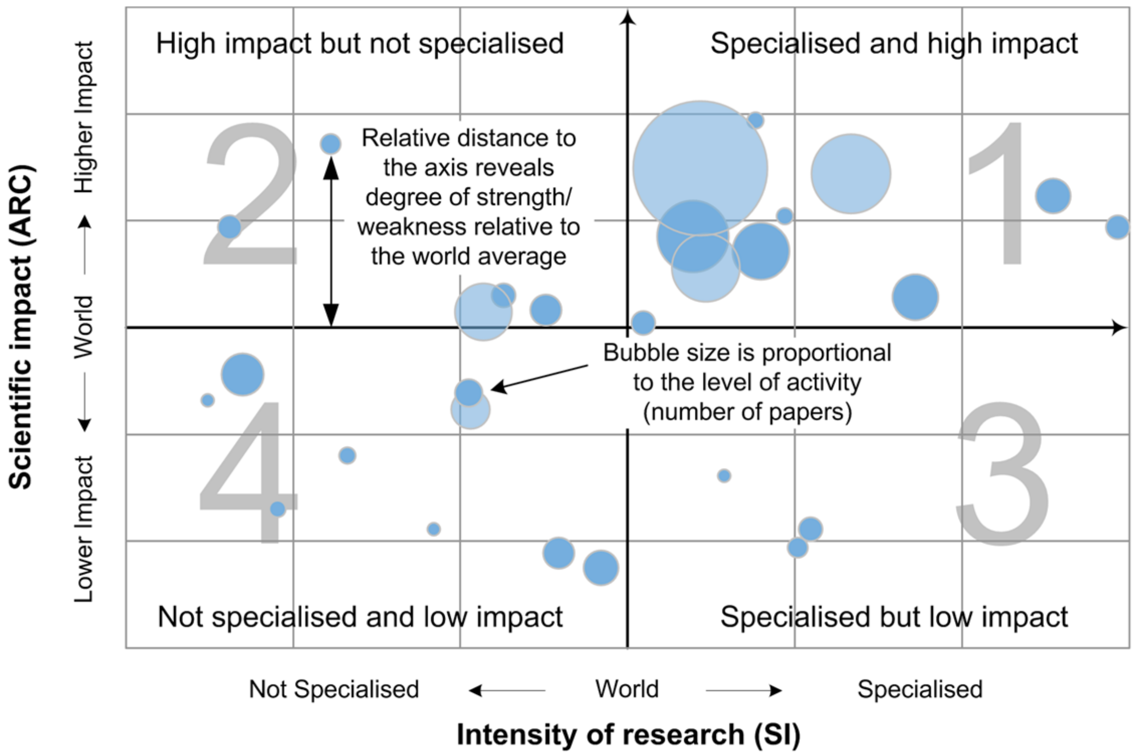


Figure 6 Example of Positional Analysis

Note: The size of bubbles represents the volume of the scientific output based on the number of publications.

To introduce this analysis, Figure 7 below summarises trends in Norway's performance across the 15 selected research themes. This positional analysis synthesises information on the specialisation (SI; as represented by the position on the *x*-axis), impact (ARC; as represented by the position on the *y*-axis) and volume of Norway's scientific output (as represented by the size of bubbles; indicates the number of publications in fractional counting) in each theme in the 2003–2007 and 2008–2012 periods. Note that Norway's main strengths are to be found in the upper right quadrant (i.e., highly specialised with high impact). Areas in which Norway is not specialised but has a large output combined with a high impact also constitute key strengths.

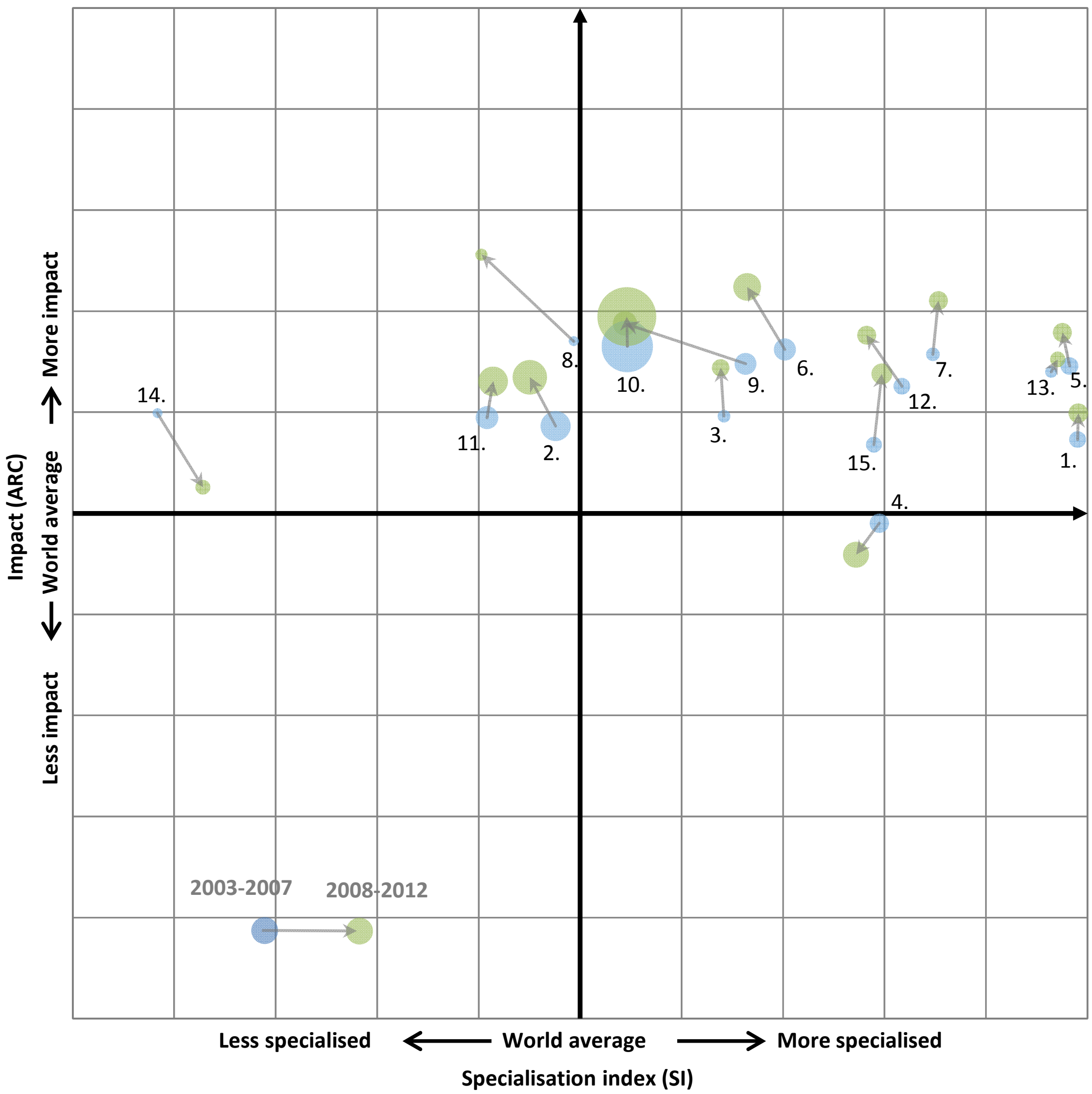
Norway's greatest strengths in 2008–2012 lie in the strategic themes of Climate Change, Fisheries & Aquaculture, Maritime Research, Marine & Freshwater Biology and Environment. Although Norway is less specialised in Health & Care, it is the theme where its output is largest and its impact is also high. Other themes appearing in the top right quadrant – i.e., areas in which Norway is specialised with an impact higher than the world level – include Welfare & Working Life, Arctic & Antarctic Research, Education and Food Sciences. With an impact nearly always above the world level, Norway is generally specialised in areas of the Life Sciences and the Social

Sciences & Humanities, whereas it is not specialised in areas of the Applied Sciences. Exceptions to this include Energy, in which Norway is specialised but has an impact below the world level, as well as Maritime Research, in which Norway is highly specialised with an impact well above the world level.

In terms of trends, Norway's scientific impact improved in all themes except Energy and Nanotechnology & New Materials, which is the theme in which Norway is the least specialised. Nonetheless, its SI in this theme increased from the 2003–2007 to 2008–2012 periods. As will be seen later in Section 3.15, Norway's performance in Nanotechnology & New Materials could benefit greatly from China's large output, strong growth and high impact in this theme (other Asian countries are also of interest here). In terms of specialisation, Norway showed the largest decreases in Food Sciences and Environmental Technologies.

As shown in Figure 7, Norway's **key strengths** are in **Climate Change, Fisheries & Aquaculture, Arctic & Antarctic Research, Marine & Freshwater Biology and Environment.** Norway's highest output of scientific papers is in Health & care, Biotechnologies, ICT and Environment. Norway's scientific impact is above the world average for all strategic themes except for Maritime Research, where it is slightly below the world average. Norway's impact is the highest for Climate Change, Environment, Environmental Technologies and Health & Care.

For all the themes, the scientific impact increased between 2003–2007 and 2008–2012, with the exception of Nanotechnology & New Materials. Arctic & Antarctic Research and Fisheries & Aquaculture are Norway's prime areas of specialisation. Interestingly its international collaboration rate is highest in these two areas (see later in this section).



Theme Legend

1 - Arctic & Antarctic	6 - Environment	11 - Inform. & Comm. Tech.
2 - Biotechnology	7 - Climate Change	12 - Marine & Freshwater Biol.
3 - Education	8 - Environment Technology	13 - Maritime Research
4 - Energy	9 - Food Research	14 - Nanotech & New Materials
5 - Fisheries & Aquaculture	10 - Health & Care	15 - Welfare &Working Life

Figure 7 Positional Analysis of Norway in each of the 15 Selected Research Themes, 2003–2012

Note: The size of bubbles represent the volume of scientific output based on the number of publications in fractional counting. Blue bubbles represent papers published during the first (2003–2007) and green bubbles those published during the second (2008–2012) five-year period.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Positional analysis graphs in the synthesis of information on the performance of countries by theme

Positional analysis graphs (Figure 8 to Figure 22) such as that presented above (Figure 7) have been used to synthesise some of the huge amount of data presented in the core tables (Table V to Table XIX) on the scientific performance of the selected countries by theme. In these figures, performance is shown by combining the specialisation (as represented by the position on the x-axis; indicates the SI), impact (as represented by the position on the y-axis; indicates the ARC) and volume of each country's scientific output (as represented by the size of bubbles; indicates the number of publications in full counting) in the 2003 to 2012 period. Note that the strongest performers are usually positioned in the upper right quadrant (i.e., highly specialised with high impact).

However, a country that would combine a slightly smaller SI and ARC than another country (i.e., not positioned as far to the right and top of the graph) might be considered as a stronger performer if its output volume is much larger (as indicated by the size of the bubble). The colour of bubbles in these graphs illustrates the collaboration rate of selected countries with Norway (based on fractional counting); the colour gradient ranges from yellow (i.e., the smallest score across countries in a given theme) to red (i.e., the largest score across countries in a given theme).

A country's position is comparable across positional analysis graphs such that it is possible to compare the position of a given country across themes to identify its strengths based on specialisation and impact (note that the colour and size of a country's bubble cannot be compared across graphs; the actual numbers as presented in the graphs' companion tables must be used). In the sciences in general (Section 3.1), it was not possible to produce a positional analysis graph since the specialisation index (SI) is not applicable in this case. In fact, all countries would have an SI tied with the world level since sciences in general is the reference used in computing the SI by theme (i.e., 100% of a country's output is in the sciences in general as is the case for the world as a whole [see Section 9.4.4]).

Note that the countries highlighted in the ***blue boxes*** in Sections 3.2 to 3.16 might be slightly different from the countries at the farthest right and top of the positional analysis graphs since dimensions other than their raw performance were considered in these analyses to identify scientific partnerships that could be beneficial to Norway (e.g., growth of output, impact of collaboration with Norway, propensity to collaborate with Norway; see the companion table in each section for information on the other dimensions).

3.1 Profiles of Selected Countries in the Sciences in General

Table IV shows the statistics for the publication and co-publication output and impact of Norway and the 57 selected countries, as well as aggregates of the Nordic countries and EU-15 and EU-28 member states in the sciences in general from 2003 to 2012. It thus represents a summary of Table I (compare Section 2.1) and Table II (2.2) presented above and provides guidance for the more specific analyses of Norway's strategic themes set out below.

Table IV indicates that Norway's co-publications are the most numerous with the US, the UK and Sweden (FULL or FRAC). Based on its collaboration affinity, Norway focuses its international collaboration on geographically close partners, i.e. Iceland, Denmark, Sweden, Finland and Estonia, a trend that is frequently observed in international co-authorship. Collaborations are most beneficial to Norway (and to collaborators) with Argentina, Colombia and Mexico, where co-published papers are cited more than six times above the world average. A closer investigation of the data shows that a large proportion of Norway's co-publications with Argentina (43%) and Colombia (62%) are in the field of Physics and Astronomy (data not presented, but contained in the accompanying database), where papers are frequently published by large international consortia often involving hundreds of authors from multiple countries. As a result, papers authored by such multilateral partnerships often receive very high citation impact, due, at least in part, to self-citation of the many authors. It is thus not specifically the collaborations with Argentina and Colombia that increase Norway's impact, but the impact of the multilateral research group to which Argentinean and Colombian researchers belong. Over one-third of Mexico's co-publications with Norway are tied to the strategic theme of Health & Care (compare Section 3.11), which obtained an impressive ARC of 10.09.

Strategic partners for improving the scientific impact of Norway's output in the sciences in general include Singapore, Iceland, Switzerland, Denmark, the Netherlands, Belgium, the UK, Canada, the US and Australia. Among them, those with which Norwegian researchers collaborate less than expected, include **Singapore**, **Canada**, the **US** and **Australia**.

Among the 15 countries for which Norway shows affinity scores below 0.5 (i.e., it cooperates over 50% less than expected), co-publications with Mexico, Brazil and Thailand receive the highest impact. However, the high scores are based on a small number of co-publications that might include multilateral partners, given that overall these countries are cited below the world average. From Norway's perspective, it might thus be more advantageous to increase collaborations with Singapore, since it is the only one of these 15 countries whose total output is clearly cited above the world average, as reflected by its ARC of 1.50.

In fact, Singapore has the fifth highest overall ARC among the 58 countries, ranking behind Iceland (ARC = 1.72), Switzerland (1.66), Denmark (1.62) and the Netherlands (1.59). Norway already shows very strong affinities for Iceland and Denmark and, to a lesser extent, for the Netherlands. However, although already above expectations, collaborations with Switzerland could be further increased. Norway's affinity for collaborating with Belgium and the UK is similar to that for Switzerland and collaborations with the two former countries could be increased since their performance is noteworthy when statistics on output volume, growth and impact are combined. Output volume is also a key factor to consider since Norway's absolute impact (e.g., absolute number of normalised citations) would greatly benefit from the more numerous collaborations it could have with larger countries exhibiting high impact.

Perhaps the countries with which Norway's researchers could most easily intensify collaboration are those for which its affinity is below expectations. Of the 20 countries identified as at least 20% above the world level, Norway collaborates below expectations with Singapore (ARC = 1.50; ARC of co-publications with Norway = 3.50), Canada (1.39; 3.20), the US (1.39; 2.37) and Australia (1.37; 3.23). These countries not only perform well on impact, but also when output volume, growth and impact are considered jointly. Thus, increasing the number of co-publications with these countries would likely enhance the impact of Norway's research output.

Table IV Scientific Performance & Collaboration Profiles of Selected Countries with Norway in the Sciences in General (i.e., Scopus) (2003–2012)

	Papers				Co-Publications with Norway					Coll. Affinity	
Country	**FULL**	**FRAC**	**GR**	**ARC**	**FULL**	**ARC**	**FRAC**	**Coll. Rate**	**GR**	**for NO**	**of NO**
World	**16,847,218**	**16,847,218**	**1.36**	**1.00**	**57,116**	**1.76**	**13,926**	**0.08%**	**1.16**	**n.a.**	**n.a.**
Nordic	**593,955**	**439,236**	**1.21**	**1.40**	**16,117**	**2.16**	**2,632**	**0.73%**	**1.23**	**n.a.**	**n.a.**
Norway	113,861	78,352	1.41	1.38	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	8,026	4,368	1.62	1.72	909	2.92	82	1.88%	0.77	n.c.	14.97
Denmark (EU-15/28)	140,885	94,600	1.29	1.62	6,326	2.63	763	0.81%	1.07	6.04	6.28
Finland (EU-15/28)	128,781	93,433	1.15	1.36	3,604	2.90	351	0.38%	1.20	4.03	3.91
Sweden (EU-15/28)	244,533	168,484	1.11	1.46	10,033	2.29	1,436	0.85%	1.35	5.50	5.80
EU-28	**5,703,922**	**5,019,625**	**1.25**	**1.12**	**39,497**	**1.93**	**8,052**	**0.16%**	**1.24**	**n.a.**	**n.a.**
EU-15	**5,143,797**	**4,443,620**	**1.22**	**1.19**	**37,872**	**1.97**	**7,544**	**0.17%**	**1.26**	**n.a.**	**n.a.**
Austria	146,590	98,462	1.25	1.32	1,976	3.22	153	0.16%	1.57	1.74	1.89
Belgium	206,638	139,243	1.23	1.48	2,209	3.58	167	0.12%	1.63	1.26	1.51
France	847,869	629,489	1.17	1.17	6,904	2.77	669	0.11%	1.21	1.30	1.18
Germany	1,144,662	863,122	1.18	1.26	8,971	2.72	985	0.11%	1.39	1.40	1.14
Greece	132,896	103,998	1.32	1.13	1,511	3.72	87	0.08%	1.21	1.83	1.59
Ireland	78,989	55,359	1.53	1.35	922	3.58	62	0.11%	1.18	1.79	1.61
Italy	655,430	516,217	1.24	1.20	5,095	3.27	399	0.08%	1.36	1.56	1.12
Luxembourg	5,867	3,073	2.93	1.30	165	2.80	11	0.35%	1.60	n.c.	3.69
Netherlands	370,455	261,568	1.25	1.59	5,834	3.07	520	0.20%	1.21	2.46	2.24
Portugal	110,283	80,473	1.78	1.17	1,237	3.37	87	0.11%	1.06	1.68	1.56
Spain	541,176	425,318	1.40	1.17	4,348	3.17	321	0.08%	1.32	1.55	1.15
United Kingdom	1,218,794	910,783	1.15	1.41	11,847	2.68	1,532	0.17%	1.28	1.70	1.42
Bulgaria	30,453	21,187	1.27	0.71	237	3.23	24	0.11%	1.44	n.c.	1.06
Croatia	43,103	35,932	1.53	0.63	302	3.60	24	0.07%	1.11	n.c.	0.96
Cyprus	8,615	4,963	2.34	1.30	68	3.52	7	0.15%	0.97	n.c.	1.04
Czech Republic	122,799	95,138	1.46	0.85	1,260	4.23	92	0.10%	1.69	1.51	1.43
Estonia	14,557	10,146	1.70	1.19	404	3.72	32	0.32%	0.96	n.c.	3.71
Hungary	77,053	55,750	1.19	0.93	756	4.43	49	0.09%	1.68	1.40	1.36
Latvia	7,104	5,160	2.43	0.75	109	4.41	9	0.17%	0.71	n.c.	2.02
Lithuania	21,261	17,161	1.67	0.81	317	2.87	30	0.17%	0.74	n.c.	2.01
Malta	2,009	1,367	2.32	1.01	49	2.91	4	0.28%	0.82	n.c.	3.14
Poland	256,289	210,620	1.28	0.71	1,896	3.77	156	0.07%	1.16	1.61	1.05
Romania	77,302	62,025	2.86	0.66	615	4.19	33	0.05%	0.48	n.c.	1.10
Slovakia	39,389	28,565	1.38	0.74	569	4.60	29	0.10%	1.10	n.c.	1.97
Slovenia	37,293	27,992	1.47	1.00	558	2.88	18	0.06%	1.50	n.c.	2.04
Argentina	82,306	62,111	1.43	0.94	405	6.83	15	0.02%	1.46	n.c.	0.68
Australia	482,418	366,285	1.38	1.37	2,895	3.23	342	0.09%	1.52	1.36	0.86
Brazil	368,125	319,827	1.77	0.79	1,041	4.31	92	0.03%	1.22	0.91	0.40
Canada	684,860	513,863	1.23	1.39	4,623	3.20	507	0.10%	1.33	1.71	0.97
Chile	53,173	35,878	1.64	0.99	398	4.35	25	0.07%	1.41	n.c.	1.03
China	2,507,201	2,336,110	2.10	0.71	2,671	2.44	360	0.02%	1.43	1.19	0.16
Colombia	30,445	20,895	2.81	0.81	255	6.36	10	0.05%	0.42	n.c.	1.14
Egypt	68,496	52,583	1.80	0.77	116	2.29	15	0.03%	1.16	n.c.	0.23
India	553,505	502,068	1.93	0.76	904	3.23	135	0.03%	1.60	0.68	0.23
Indonesia	16,285	9,073	2.82	0.88	82	2.05	11	0.12%	0.57	n.c.	0.67
Iran	187,295	170,357	3.45	0.84	234	2.02	42	0.02%	1.21	0.64	0.18
Israel	146,416	110,389	1.07	1.34	1,123	3.50	80	0.07%	1.67	1.79	1.07
Japan	1,155,461	1,024,120	1.01	0.85	1,896	3.12	194	0.02%	1.71	0.77	0.24
Malaysia	88,775	73,357	4.58	0.74	117	2.91	16	0.02%	0.55	n.c.	0.18
Mexico	125,404	96,798	1.38	0.79	356	6.36	32	0.03%	1.99	0.47	0.40
New Zealand	89,356	63,600	1.35	1.27	657	3.18	73	0.12%	1.20	n.c.	1.02
Nigeria	35,735	31,536	1.98	0.44	48	2.12	7	0.02%	3.67	n.c.	0.18
Pakistan	49,053	40,494	2.51	0.70	90	3.37	12	0.03%	2.71	n.c.	0.25
Rep. of Korea	465,398	401,017	1.57	0.98	541	3.79	54	0.01%	1.16	0.52	0.17
Russia	357,384	291,606	1.06	0.51	2,659	2.21	269	0.09%	1.19	1.78	1.06
Singapore	115,418	85,533	1.28	1.50	378	3.50	54	0.06%	1.37	1.19	0.46
South Africa	89,157	66,078	1.55	1.05	1,179	3.04	124	0.19%	1.58	n.c.	1.83
Switzerland	268,519	167,790	1.22	1.66	2,944	3.53	234	0.14%	1.44	1.37	1.55
Taiwan	302,901	271,289	1.53	1.08	484	3.95	38	0.01%	1.27	0.81	0.23
Thailand	68,736	52,621	2.01	0.91	144	4.28	18	0.03%	1.65	n.c.	0.29
Turkey	244,381	221,320	1.49	0.81	637	3.89	50	0.02%	0.80	0.96	0.37
United States	4,580,396	3,921,016	1.11	1.39	15,756	2.37	2,434	0.06%	1.20	1.23	0.52
Viet Nam	13,870	7,324	2.74	1.04	97	2.30	17	0.24%	3.50	n.c.	0.93

Note: n.a. = not applicable; n.c. = not computed. FULL and FRAC respectively mean no. of papers or co-publications based on full and fractional counting; GR = Growth Ratio (based on FRAC for publications and on the share of a country's bilateral collaborations with Norway computed fractionally) = $Score_{2008–2012}/Score_{2003–2007}$; ARC = Average of Relative Citations (based on FULL).

Source: Computed by Science-Metrix using Scopus (Elsevier)

From the collaborators' perspective, the collaboration rate is highest and far above the world average of 0.08% for Iceland (1.88%), Sweden (0.85%) and Denmark (0.81%). Outside Europe, collaboration rates are highest for Vietnam (0.24%) and Indonesia (0.12%). Sixteen of 33 countries for which the collaboration affinity could be computed co-publish more than 50% above expectations with Norway. For half of these countries, the affinity is mutual as Norway's affinity scores for these countries are above 1.5 as well. Of these, collaborations with Greece (ARC of co-publications with Norway = 3.72), Ireland (3.58) and Portugal (3.37) have the highest citation impact. Given that Israel, Russia, Canada, the UK, Poland, Italy, Spain and the Czech Republic focus much more on collaborating with Norway than vice versa, the affinity is less mutual. For these countries, co-publishing with Norwegian colleagues increases impact, especially for the Czech Republic (ARC=0.85; ARC of co-publications with Norway = 4.23), Poland (0.71; 3.77) and Israel (1.34; 3.50).

Although the ARC always increases for co-publications with Norway compared to the overall ARC, Sweden, the US, Denmark, Indonesia, Iran, Iceland and Vietnam gain the least from collaborating with Norway. In the cases of Iceland, Denmark and Sweden this is mainly due to their overall high ARCs and high number of co-publications with Norway, which means that a large share of their overall outputs and ARCs consist of Norwegian co-publications. The number of co-publications with Norway of Indonesia, Vietnam and Iran is too low to draw any general conclusions about the overall benefits of collaborations.

3.2 Profiles of Selected Countries in Arctic & Antarctic Research

Table V addresses output and collaboration patterns, Norway's level of specialisation, and the selected countries and country aggregates in Arctic & Antarctic Research, one of 15 strategic themes identified as highly relevant to Norway, as evidenced by Norway's level of specialisation. An SI of 10.32 shows that Norway produces more than 10 times as many papers within the Arctic & Antarctic Research theme than expected given the overall output. In fact, of the 15 strategic themes analysed, Arctic & Antarctic Research is that in which Norway is most specialised, surpassed only by Iceland (SI=14.05), the country for which Norway shows the highest affinity (4.89). Denmark (SI=4.07), New Zealand (3.58) and Russia (3.37) follow with respect to level of specialisation, producing more than three times as much as expected given their overall scientific output.

Overall, the Arctic & Antarctic strategic theme constitutes a relatively small research area, comprising 76,116 papers published between 2003 and 2012. In terms of absolute output, the US is the largest producer of research papers in this area (23,981 FULL; 17,666 FRAC), participating in more than twice as many papers as the UK (9,983; 5,995) and Canada (9,782; 7,011). Germany (7,381; 4,326), Russia (5,820; 4,436) and Norway (5,731; 3,654) follow in fourth to sixth place respectively in terms of number of papers (FULL). Norway loses two ranks to Japan (4,115) and China (3,774) when fractional publication counts are considered. Latvia and Cyprus show the largest growth, increasing their outputs by more than 13 and 5 times from 2003–2007 to 2008–2012 respectively. However, because of their low output they cannot be considered important actors in Arctic & Antarctic Research.

Of the 30 largest producers among the 57 countries analysed, the highest increases in output from the first to the second five-year period were observed for China (GR=2.36), India (1.93) and Brazil (1.63). Norway increased its output by 34% from 2003–2007 to 2008–2012, which constitutes growth above the world (23%) and Nordic average (22%). Norway's Arctic & Antarctic papers are on average cited 19% above the world level, which is very close to the ARC of the Nordic countries as a whole (1.20), and places Norway 23rd among the 57 selected countries. The highest ARC (3.68) is obtained by Colombia, which published as few as 49 papers during the 10-year period. This is most likely a result of Colombian authors' participation in multilaterally authored papers. In spite of its high impact, Colombia cannot be regarded as an important actor in Arctic & Antarctic Research, as is emphasised by its low SI (0.16). Switzerland, as the 14th largest producer of papers and a country specialised (SI = 1.47) in this strategic theme, scores the second highest ARC (1.77), followed by the Netherlands (1.59), Belgium (1.53), the UK (1.50), France (1.39), Sweden (1.39) and Denmark (1.38), which all receive at least 38% more citations than average.

Almost two-thirds (3,460 of 5,731) of Norway's Arctic & Antarctic Research papers are co-published as international collaborations. In absolute terms, Norway co-publishes most frequently with the US, the UK and Germany. Normalising for expected collaborations, Norway's affinity is greatest for Iceland (4.89), Estonia (3.59), Ireland (2.76), Sweden (2.68), Denmark (2.65) and Finland (2.63). With the exception of Ireland, this affinity mirrors typical regional proximity to the Nordic countries. Iceland is the most beneficial of these important partners for Norway since collaboration with this country leads to an ARC of 2.20. Even higher ARCs are obtained for co-publications with Portugal (2.59), Switzerland (2.56), South Africa (2.46), Belgium (2.41), Spain (2.34) and France (2.28). However, it should be noted that ARCs for Portugal, South Africa and Belgium are based on small numbers. As well, ARCs could only be computed for co-publications with 24 collaborators, because the others did not meet the threshold of 31 co-publications.

Based on their overall performance in Arctic & Antarctic Research (see Figure 8), strategic partners for improving the scientific impact of Norwegian publication output include Iceland, Canada, Switzerland, Denmark, the UK, the US and New Zealand. Of these, Norway's collaborations with **Canada**, the **US** and **New Zealand** are below expectations and could thus be further intensified.

At the micro-level for the above countries, organisations that stand out in terms of output, specialisation and impact in this thematic include: **University of Iceland** (Iceland), **Laval University** (Canada), **University of Bern** (Switzerland), **University of Aarhus and University of Copenhagen** (Denmark), **University of Southampton and University of Bristol** (UK), the **NASA** and **Caltech** (US) and **Victoria University of Wellington** (New Zealand).

On the whole, Norway benefits from collaborations with all the selected countries since all computed ARCs exceed the world average of 1.41 of Norway's papers with at least one international partner. Even though they are still cited more than 50% above the world level, papers co-authored with colleagues from Russia (ARC of co-publications with Norway = 1.35; overall ARC = 0.53), New Zealand (1.45; 1.28) and Poland (1.48; 0.66) obtain the lowest ARCs, but they are beneficial to the collaborator.

Given that Norway collaborates less than expected with 23 of 49 countries for which the collaboration affinity score could be computed, Norway could consider intensifying its scientific relationships with these countries. Of these countries, France (ARC=1.39), Mexico (1.36), the US (1.35) and Australia (1.33) are cited more than 1.3 times the world average, making them candidates for future beneficial collaborations in Arctic & Antarctic Research. It would also be advisable to further increase the number of co-publications with Switzerland (ARC = 1.77; ARC of co-publications with Norway = 2.56), Belgium (1.53; 2.41) and the UK (1.50; 1.93) because of their high citation rates and affinity scores below 1.30, which leave room for increasing bilateral co-operations.

Table V Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Arctic & Antarctic (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**76,116**	**76,116**	**1.23**	**1.00**	**1.00**	**3,460**	**1.41**	**855**	**1.18%**	**1.17**	**n.a.**	**n.a.**
Nordic	**11,810**	**8,071**	**1.22**	**4.07**	**1.19**	**1,022**	**1.62**	**166**	**3.76%**	**1.24**	**n.a.**	**n.a.**
Norway	5,731	3,654	1.34	10.32	1.20	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	606	277	0.96	14.05	1.33	147	2.20	17	6.02%	1.39	n.c.	4.89
Denmark (EU-15/28)	3,012	1,738	1.11	4.07	1.38	482	1.82	65	3.75%	1.28	n.c.	2.65
Finland (EU-15/28)	1,656	1,034	1.12	2.45	1.10	244	1.80	29	2.77%	1.66	n.c.	2.63
Sweden (EU-15/28)	2,699	1,369	1.21	1.80	1.39	432	1.69	55	4.04%	1.01	n.c.	2.68
EU-28	**31,613**	**24,519**	**1.17**	**1.08**	**1.18**	**2,380**	**1.54**	**481**	**1.96%**	**1.23**	**n.a.**	**n.a.**
EU-15	**30,020**	**22,839**	**1.15**	**1.14**	**1.22**	**2,316**	**1.54**	**456**	**2.00%**	**1.25**	**n.a.**	**n.a.**
Austria	810	419	1.56	0.94	1.27	73	1.70	7	1.74%	0.45	n.c.	1.75
Belgium	1,089	534	1.21	0.85	1.53	75	2.41	6	1.05%	1.25	n.c.	1.29
France	5,037	2,876	1.18	1.01	1.39	319	2.28	34	1.17%	1.21	0.76	0.98
Germany	7,381	4,326	1.10	1.11	1.35	598	1.79	75	1.74%	1.49	0.89	1.20
Greece	224	144	1.17	0.31	1.02	23	n.c.	2	1.38%	n.c.	n.c.	2.34
Ireland	352	145	1.31	0.58	1.26	45	1.74	3	2.26%	0.65	n.c.	2.76
Italy	3,125	2,057	1.05	0.88	1.00	140	2.19	15	0.73%	2.05	0.63	0.74
Luxembourg	24	6	2.37	0.40	n.c.	3	n.c.	0	0.68%	n.c.	n.c.	n.c.
Netherlands	1,995	1,015	1.16	0.86	1.59	221	2.12	22	2.17%	1.10	1.11	1.93
Portugal	367	187	1.32	0.51	1.22	37	2.59	4	2.29%	0.99	n.c.	2.16
Spain	1,741	993	1.38	0.52	1.18	120	2.34	13	1.33%	0.97	n.c.	1.22
United Kingdom	9,983	5,995	1.15	1.46	1.50	862	1.93	125	2.09%	1.24	1.16	1.23
Bulgaria	115	75	2.26	0.79	0.82	8	n.c.	1	1.48%	n.c.	n.c.	1.72
Croatia	42	31	1.22	0.19	0.60	3	n.c.	0	1.46%	n.c.	n.c.	2.01
Cyprus	14	3	5.06	0.14	n.c.	1	n.c.	0	0.07%	n.c.	n.c.	n.c.
Czech Republic	344	213	1.64	0.49	0.97	20	n.c.	1	0.66%	n.c.	n.c.	1.26
Estonia	194	93	1.91	2.02	1.10	30	n.c.	2	2.55%	0.55	n.c.	3.59
Hungary	121	64	1.67	0.26	1.16	4	n.c.	0	0.23%	n.c.	n.c.	0.81
Latvia	26	12	13.89	0.53	n.c.	2	n.c.	0	0.19%	n.c.	n.c.	n.c.
Lithuania	67	43	1.38	0.56	0.57	5	n.c.	0	0.68%	n.c.	n.c.	1.98
Poland	1,368	1,011	1.30	1.06	0.66	114	1.48	18	1.80%	0.89	n.c.	1.52
Romania	103	54	3.09	0.19	0.84	6	n.c.	0	0.10%	n.c.	n.c.	1.46
Slovakia	54	26	2.17	0.20	0.66	3	n.c.	0	0.68%	n.c.	n.c.	1.51
Slovenia	85	54	1.13	0.43	0.73	7	n.c.	1	1.13%	n.c.	n.c.	2.12
Argentina	1,084	768	1.38	2.74	0.87	8	n.c.	0	0.06%	n.c.	n.c.	0.14
Australia	3,940	2,406	1.17	1.45	1.33	135	1.96	13	0.54%	1.30	0.58	0.55
Brazil	757	545	1.63	0.38	0.92	14	n.c.	2	0.42%	n.c.	n.c.	0.36
Canada	9,782	7,011	1.27	3.02	1.27	524	2.18	61	0.87%	1.33	1.11	0.77
Chile	724	399	1.55	2.46	1.27	9	n.c.	1	0.15%	n.c.	n.c.	0.25
China	4,643	3,774	2.36	0.36	0.76	75	1.90	9	0.25%	0.48	0.64	0.25
Colombia	49	15	1.60	0.16	3.68	4	n.c.	0	0.33%	n.c.	n.c.	2.25
Egypt	44	28	2.00	0.12	0.37	1	n.c.	0	0.00%	n.c.	n.c.	0.63
India	996	848	1.93	0.37	0.64	14	n.c.	2	0.19%	n.c.	n.c.	0.27
Indonesia	40	14	1.30	0.35	1.35	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Iran	109	85	3.03	0.11	0.65	3	n.c.	0	0.24%	n.c.	n.c.	0.69
Israel	171	89	1.15	0.18	1.21	5	n.c.	0	0.15%	n.c.	n.c.	0.69
Japan	5,255	4,115	1.01	0.89	0.77	184	1.99	22	0.53%	1.35	0.87	0.54
Malaysia	127	86	4.89	0.26	0.77	3	n.c.	0	0.23%	n.c.	n.c.	0.58
Mexico	246	119	1.35	0.27	1.36	10	n.c.	0	0.34%	n.c.	n.c.	0.92
New Zealand	1,793	1,027	1.30	3.57	1.28	60	1.45	4	0.41%	2.59	0.52	0.59
Nigeria	20	12	1.50	0.09	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	35	22	2.94	0.12	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Rep. of Korea	1,701	1,356	1.46	0.75	0.43	24	n.c.	3	0.20%	n.c.	n.c.	0.25
Russia	5,820	4,436	1.19	3.37	0.53	379	1.35	65	1.46%	1.27	1.65	0.99
Singapore	141	82	1.99	0.21	0.83	5	n.c.	2	2.05%	n.c.	n.c.	0.86
South Africa	755	449	1.21	1.50	1.23	47	2.46	5	1.06%	0.79	n.c.	1.22
Switzerland	2,170	1,115	1.42	1.47	1.77	160	2.56	18	1.65%	1.54	0.91	1.27
Taiwan	521	395	1.47	0.32	0.55	2	n.c.	0	0.00%	n.c.	n.c.	0.08
Thailand	55	30	1.59	0.12	0.22	3	n.c.	0	1.02%	n.c.	n.c.	1.48
Turkey	159	113	1.45	0.11	0.77	4	n.c.	0	0.13%	n.c.	n.c.	0.60
United States	23,981	17,666	1.12	1.00	1.35	988	1.79	145	0.82%	1.16	0.79	0.53
Viet Nam	14	6	0.70	0.17	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.

Note: *Ibid*.
Source: Computed by Science-Metrix using Scopus (Elsevier)

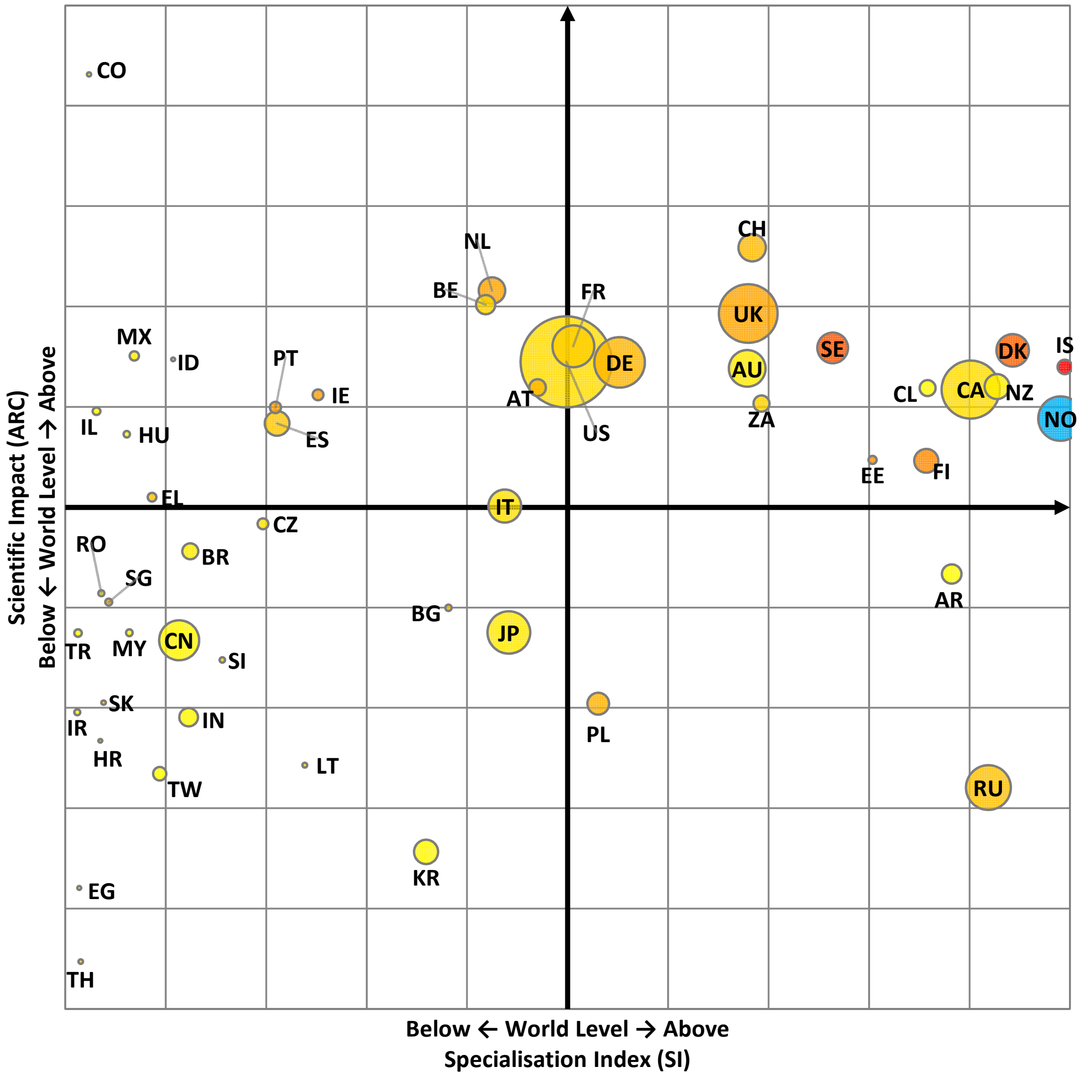


Figure 8 Positional analysis of selected countries in Arctic & Antarctic Research with the mapping of their collaboration rate with Norway, 2003–2012

Note: The bubbles are coloured from yellow to red in ascending order based on the collaboration rate with Norway (based on FRAC). The bubble size is proportional to the country's output (based on FULL counting). The colour intensity and bubble size of countries are not comparable across themes although their position on the grid is. The SI and ARC were transformed in the graph so that the values are symmetrically distributed around the world level.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Considering countries' overall performance, calculated with the composite indicator that takes into account publication output, growth, specialisation and with a special emphasis on impact, Norway, Iceland, Canada, Switzerland, Denmark, the UK, the US and New Zealand[13] are the most important actors in Arctic & Antarctic Research. Norway should increase its co-publications with

[13] Colombia is excluded from this list because of its low number of publications, which is most likely due to participation in multilateral collaborations.

Canada, the US and New Zealand, given that it currently co-publishes between 23% and 47% less than expected with these countries. Canada (SI=3.02) and New Zealand (3.58) especially show high levels of specialisation in this area of research, as well as citation rates around 50% above the world average, which indicates that increased collaboration with them could be beneficial to Norway. Because both show collaboration rates with Norway below the world average of 1.18% and Norway's affinity scores are low, there is room for intensifying collaborations. Canada already shows a slight affinity for Norway, providing a good basis for Norway to increase its co-publications with this country. Although Norway already shows above average affinity scores for Switzerland (ARC = 2.06; SI = 1.47) and the UK (1.75; 1.48), further intensification of these partnerships should be considered because of these countries' high ARCs and considerable specialisation and output in this research area.

Other countries that play an important role in Arctic & Antarctic Research include Russia, France, the Netherlands and Belgium. While Norway can consider them as valuable partners in this strategic theme, they are not highlighted here as priority countries. As seen in Figure 8, Russia, although highly specialised in this theme, still has a very low impact and, considering its low growth ratio (GR=1.19), this impact is not likely to rise rapidly in the near future. Nevertheless, given the country's geographical location and interest in the Arctic zone, Russia could be an extremely attractive partner for Norway. The impact of the other countries is notable but their output and specialisation do not position them as priority countries for collaboration.

3.3 Profiles of Selected Countries in Biotechnology

This section provides an overview of publication and collaboration patterns in Biotechnology for Norway and the selected countries. As Table VI shows, in terms of output, the US, China, Japan, Germany, the UK, France and Italy lead in this strategic theme. Norway ranks 32nd, based on both full and fractional publication counts. Malaysia (GR = 4.33) and Iran (GR = 3.97) show the highest growth and rank 37th and 22nd respectively (FRAC). Overall, this research area increased its output by one-third from the first to second period under study and Norway has shown similar growth. Although specialised in the field, only Luxembourg (SI = 1.33; GR = 3.38) and Thailand (1.26; 2.17) show higher SIs. Denmark (1.24; 1.22) also remains behind global growth. Biotechnology is definitely not one of Norway's areas of specialisation; in fact, Norwegian researchers publish 7% fewer papers in this area than expected (SI=0.93). However, Norway's Biotechnology papers are cited 45% above the world average and the other Nordic countries also receive very high impact scores, i.e. Iceland (ARC = 2.09; ranking 1st), Denmark (1.48; 4th) and Sweden (1.36; 10th). Accordingly, it might be worthwhile for Norway to focus on this strategic theme, especially in collaboration with the other Nordic countries.

Biotechnology is a major strategic theme, comprising almost 2.7 million papers published globally during the 10-year period from 2003 to 2012. Norway publishes 59% of its papers in collaboration with at least one international partner, a rate slightly higher than the average of 50% in the sciences in general (Section 3.1). Considering absolute co-publication output based on full and fractional publication counts, Norway's 10 most important partners in Biotechnology are the US (number of co-publications with Norway FULL = 3,130; FRAC = 402), the UK (2,101; 228), Sweden (1,952; 247), Germany (1,714; 179), France (1,270; 120), Denmark (1,245; 134), the Netherlands (1,056; 87), Italy (910; 68), Spain (828; 67) and Canada (802; 79), signalling a European and North-American alignment with Norway in Biotechnology.

Norway benefits from co-publishing with international partners in terms of impact (ARC of Norwegian co-publications = 1.50), especially with Nordic collaborators (1.70). In fact, co-published papers with any of the selected countries receive at least 1.75 times as many citations as the average Biotechnology paper, except for co-publications with China, which obtain 6% fewer citations than an average Norwegian co-publication and 44% more than the world average. Note that ARCs could not be computed for co-publications with 11 countries. Of those countries with which Norway does not yet collaborate frequently, Singapore (ARC=1.37) and Luxembourg (1.35) have a particularly high overall citation impact, with ARCs more than 30% above the world level. Of these two countries, only Luxembourg is highly specialised, as is reflected by its high SI of 1.33. Note that this is the highest SI among the 58 selected countries, which, compared to other fields, indicates that the analysed countries are not particularly specialised in the strategic theme of Biotechnology.

Based on overall performance (see Figure 9), Iceland, Luxembourg, the US, Denmark, Switzerland, the Netherlands, Ireland, Belgium and Germany can be identified as strategic partners to improve Norway's scientific impact in Biotechnology. Collaborations with **Ireland** and **Switzerland** should be particularly intensified.

Among these countries, organisations that stand out in terms of scientific performance in Biotechnology include: **DeCODE Genetics** (Iceland), **Public research Center for Health** (Luxembourg), **NIH** and **Harvard University** (US), **University of Copenhagen** (Denmark), **University of Zurich** and **University of Lausanne** (Switzerland), **Erasmus MC** and **WUR** (the Netherlands), **University College of Dublin** (Ireland), **KU Leuven and Ghent University** (Belgium) and **Max Planck Society** (Germany).

Based on the countries' overall performance, including publication output, growth, specialisation and particularly impact, the most important actors in Biotechnology are Iceland, Luxembourg, the US, Denmark, Switzerland, the Netherlands, Ireland, Belgium and Germany. Since all of these countries have relative citation rates above Norway's ARC of 1.26, it would be advisable for Norwegian Biotechnology researchers to aim to increase the number of co-publications with them, particularly with Ireland and Switzerland because of their combinations of considerable output, high ARC and specialisation. Collaborations should also be further intensified with Iceland, the Netherlands and Denmark due to their high citation impact.

Table VI Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Biotechnology (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	**FULL**	**FRAC**	**GR**	**SI**	**ARC**	**FULL**	**ARC**	**FRAC**	**Coll. Rate**	**GR**	**for NO**	**of NO**
World	**2,673,484**	**2,673,484**	**1.32**	**1.00**	**1.00**	**10,589**	**1.50**	**2258**	**0.08%**	**1.17**	**n.a.**	**n.a.**
Nordic	**110,893**	**77,286**	**1.12**	**1.11**	**1.32**	**3,133**	**1.70**	**446**	**0.68%**	**1.32**	**n.a.**	**n.a.**
Norway	18,059	11,501	1.31	0.93	1.26	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	1,499	699	1.55	1.01	2.09	179	2.96	12	1.79%	0.64	n.c.	n.c.
Denmark (EU-15/28)	29,511	18,568	1.22	1.24	1.48	1,245	1.80	134	0.72%	1.23	6.06	n.c.
Finland (EU-15/28)	23,215	15,736	1.05	1.06	1.29	659	2.39	52	0.33%	1.31	n.c.	n.c.
Sweden (EU-15/28)	48,113	30,781	1.03	1.15	1.36	1,952	1.75	247	0.80%	1.41	5.66	n.c.
EU-28	**957,410**	**825,548**	**1.21**	**1.04**	**1.13**	**7,665**	**1.59**	**1,394**	**0.17%**	**1.27**	**n.a.**	**n.a.**
EU-15	**874,911**	**739,969**	**1.18**	**1.05**	**1.18**	**7,288**	**1.62**	**1,294**	**0.17%**	**1.29**	**n.a.**	**n.a.**
Austria	28,682	18,280	1.23	1.17	1.27	358	2.05	28	0.16%	1.59	1.83	n.c.
Belgium	37,803	24,133	1.22	1.09	1.48	469	2.61	32	0.13%	1.51	1.50	n.c.
France	141,287	100,541	1.12	1.01	1.20	1,270	2.16	120	0.12%	1.03	1.31	n.c.
Germany	208,949	152,512	1.15	1.11	1.27	1,714	2.10	179	0.12%	1.37	1.52	n.c.
Greece	21,198	16,068	1.32	0.97	1.01	277	2.34	15	0.09%	1.29	n.c.	n.c.
Ireland	15,034	9,934	1.54	1.13	1.45	237	2.62	12	0.12%	1.02	2.84	n.c.
Italy	118,863	92,322	1.26	1.13	1.13	910	2.60	68	0.07%	1.35	1.67	n.c.
Luxembourg	1,328	647	3.38	1.33	1.35	62	2.09	6	0.88%	1.03	n.c.	n.c.
Netherlands	66,845	44,305	1.20	1.07	1.53	1,056	2.48	87	0.20%	1.44	2.48	n.c.
Portugal	20,591	14,671	1.77	1.15	1.08	227	1.96	20	0.14%	0.99	2.06	n.c.
Spain	95,485	72,906	1.36	1.08	1.13	828	2.41	67	0.09%	1.48	1.74	n.c.
United Kingdom	189,557	128,563	1.08	0.89	1.43	2,101	2.11	228	0.18%	1.35	1.70	n.c.
Bulgaria	5,157	3,725	1.27	1.11	0.57	38	2.77	3	0.08%	0.92	n.c.	n.c.
Croatia	5,739	4,390	1.52	0.77	0.76	77	3.97	6	0.14%	1.58	n.c.	n.c.
Cyprus	1,026	540	1.94	0.69	0.90	6	n.c.	0	0.08%	n.c.	n.c.	n.c.
Czech Republic	21,255	16,083	1.44	1.07	0.87	238	2.12	22	0.13%	1.36	2.25	n.c.
Estonia	2,210	1,330	1.84	0.83	1.27	91	2.94	4	0.32%	1.32	n.c.	n.c.
Hungary	13,679	9,382	1.13	1.06	0.91	129	2.38	11	0.12%	2.13	n.c.	n.c.
Latvia	928	629	2.13	0.77	0.85	33	n.c.	2	0.26%	0.26	n.c.	n.c.
Lithuania	2,211	1,567	1.66	0.58	0.78	55	1.77	4	0.28%	1.13	n.c.	n.c.
Malta	217	121	2.02	0.56	1.04	12	n.c.	3	2.69%	n.c.	n.c.	n.c.
Poland	41,135	33,628	1.39	1.01	0.66	358	2.14	26	0.08%	1.23	n.c.	n.c.
Romania	7,602	5,950	3.56	0.60	0.58	57	2.42	3	0.04%	0.14	n.c.	n.c.
Slovakia	6,317	4,359	1.27	0.96	0.76	111	2.20	10	0.24%	1.01	n.c.	n.c.
Slovenia	5,375	3,874	1.63	0.87	0.93	65	2.20	5	0.13%	1.17	n.c.	n.c.
Argentina	14,948	11,033	1.55	1.12	0.92	42	2.14	1	0.01%	1.06	n.c.	n.c.
Australia	72,252	50,644	1.26	0.87	1.35	507	2.76	39	0.08%	1.42	1.39	n.c.
Brazil	62,978	53,876	1.81	1.06	0.78	154	3.20	13	0.02%	1.89	n.c.	n.c.
Canada	111,256	78,829	1.22	0.97	1.32	802	2.60	79	0.10%	1.21	1.77	n.c.
Chile	7,892	5,384	1.52	0.95	0.88	47	2.85	3	0.06%	3.04	n.c.	n.c.
China	365,294	331,818	1.96	0.90	0.61	367	1.44	46	0.01%	1.94	1.17	n.c.
Colombia	5,022	3,201	2.40	0.97	0.82	21	n.c.	2	0.05%	n.c.	n.c.	n.c.
Egypt	11,889	8,444	2.62	1.01	0.68	15	n.c.	2	0.02%	n.c.	n.c.	n.c.
India	96,026	87,405	2.21	1.10	0.69	123	2.11	20	0.02%	1.18	0.76	n.c.
Indonesia	2,551	1,168	3.01	0.81	0.84	4	n.c.	1	0.09%	n.c.	n.c.	n.c.
Iran	22,947	20,305	3.97	0.75	0.64	28	n.c.	4	0.02%	n.c.	n.c.	n.c.
Israel	26,214	18,825	1.06	1.07	1.27	205	2.00	23	0.12%	1.37	1.87	n.c.
Japan	220,662	191,582	0.97	1.18	0.86	347	2.07	32	0.02%	1.61	0.79	n.c.
Malaysia	11,069	8,893	4.33	0.76	0.69	17	n.c.	2	0.02%	n.c.	n.c.	n.c.
Mexico	20,124	15,238	1.49	0.99	0.78	59	3.02	4	0.02%	1.39	n.c.	n.c.
New Zealand	13,417	8,805	1.28	0.87	1.26	130	1.98	13	0.15%	0.99	1.98	n.c.
Nigeria	6,801	5,761	1.91	1.15	0.47	7	n.c.	1	0.01%	n.c.	n.c.	n.c.
Pakistan	7,959	6,429	3.14	1.00	0.71	10	n.c.	1	0.02%	n.c.	n.c.	n.c.
Rep. of Korea	89,069	77,248	1.38	1.21	0.81	108	2.23	7	9.31E-05	1.74	n.c.	n.c.
Russia	30,243	23,833	1.09	0.52	0.50	195	1.91	17	0.07%	1.16	n.c.	n.c.
Singapore	18,505	12,794	1.38	0.94	1.37	89	4.46	7	0.05%	8.55	n.c.	n.c.
South Africa	11,674	7,943	1.57	0.76	1.08	107	2.24	12	0.16%	0.94	n.c.	n.c.
Switzerland	49,385	28,670	1.16	1.08	1.58	450	2.67	30	0.10%	1.51	1.46	n.c.
Taiwan	42,806	37,502	1.50	0.87	0.95	69	3.69	4	0.01%	1.44	1.13	n.c.
Thailand	14,784	10,514	2.17	1.26	0.90	43	1.96	6	0.06%	2.01	n.c.	n.c.
Turkey	30,604	26,586	1.58	0.76	0.72	96	1.94	9	0.03%	0.91	n.c.	n.c.
United States	797,828	657,365	1.12	1.06	1.39	3,130	1.94	402	0.06%	1.15	1.23	n.c.
Viet Nam	2,418	999	3.22	0.86	1.05	16	n.c.	2	0.21%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

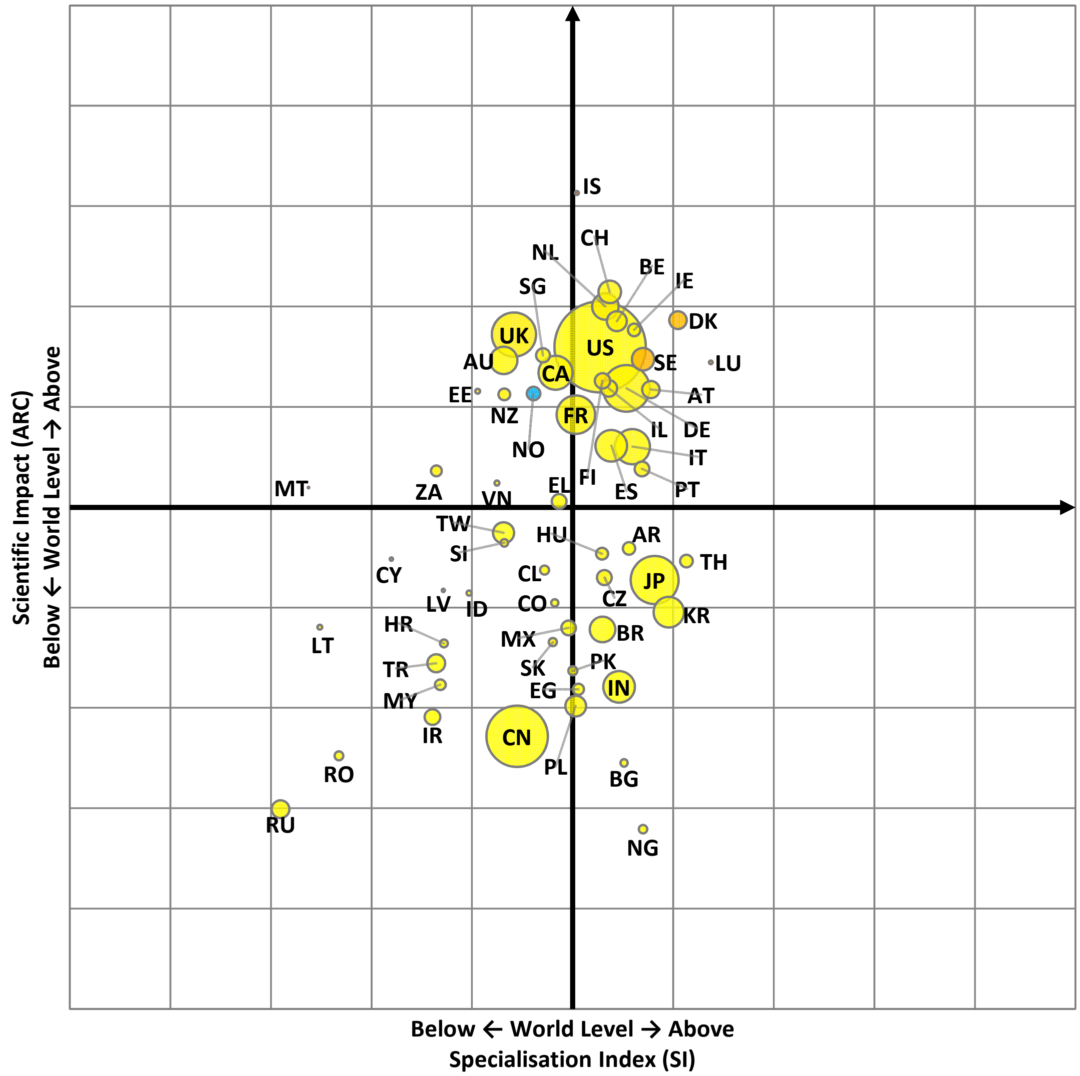


Figure 9 Positional analysis of selected countries in Biotechnology with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.4 Profiles of Selected Countries in Education

Table VII presents the strategic theme of Education. The number of papers during the 2003 to 2012 period is provided in full and fractional publication count including GR, SI and ARC for Norway, the 57 selected countries, and Nordic and EU country aggregates. Statistics for collaborations with Norway are also provided. Education is a medium-sized strategic theme comprising 414,231 publications from 2003 to 2012. Although Norway is specialised in this theme (SI = 1.34), it collaborates much less internationally than it does in other strategic themes (34% compared to 50% in Scopus), which is typical for social science fields. Compared to natural sciences and technology research, Education is more nationally than internationally oriented.

With 3,252 papers, Norway is the 25th (FULL; 26th FRAC) producer of Education output among the 58 analysed countries and is considered to be fairly specialised, producing 34% more Education papers than expected. The US clearly leads the field, having produced 38% (FRAC) of the worldwide output in this theme, which represents 65% more than expected given the total number of US papers (SI = 1.65). Small countries such as Cyprus (SI = 5.60), Malta (3.57), Malaysia (2.46), Nigeria (2.43) and New Zealand (2.27) are the most specialised in Education research. Among these, Malaysia also shows an extraordinary GR of 8.48.

Overall, the theme increased its output by 81% worldwide from the first to the second five-year period. Norway's growth is slightly above the world average (GR = 1.87) and on a par with the other Nordic countries (1.86). The Benelux represents a region of high impact in Education research, the highest ARC scores being obtained by papers with authors from the Netherlands (1.87), Belgium (1.66) and Luxembourg (1.58). Outside Europe, Singapore (ARC = 1.51) receives high citation rates. Among the Nordic countries, Finland (1.44) scores the highest ARC, while Sweden's output in Education research is also cited at 40% above the world average. On the whole, the ARC of the Nordic countries (1.32) is above the world level. With 1.29, Norway remains slightly below the Nordic average and ranks 13th among the 58 selected countries.

Although international co-publications represent only one-third of its output in Education, Norway benefits from collaborating internationally in terms of impact. The 1,108 Norwegian papers published with at least one international partner are, on average, cited 60% above the world level. In absolute terms, Norway most frequently co-operates with the US (number of co-publications with Norway FULL = 267), Sweden (219) and the UK (175), based on both full and fractional publication counts. Collaborations with Finland (ARC of co-publications with Norway = 2.34), the US (2.19), the Netherlands (2.08), Italy (1.95), Canada (1.89), Germany (1.89), Sweden (1.79), Australia (1.74), China (1.67) and Denmark (1.63) receive a citation impact above expectations of 1.60 for all international co-publications including Norway. The UK (1.40), Spain (1.24) and South Africa (1.10) are cited less often than the average Norwegian international co-publications but remain above the world average. Note that the ARC for co-publications with other countries could not be computed owing to small numbers.

Based on their overall performance in Education (see Figure 10), strategic partners for improving the scientific impact of Norwegian publication output include Belgium, Luxembourg, the Netherlands, the UK, Cyprus, Canada, Australia, Taiwan and the US. Norway's collaborations with these countries are low and should especially be intensified with **Canada**, **Cyprus** and **Luxembourg**, due to their high specialisation and impact.

At the micro-level, organisations that stand out in Education in these strategic countries are: **Ghent University** (Belgium), **Utrecht University** (the Netherlands), **University of Nottingham** and **University of Oxford** (UK), **Near East University** (Cyprus), **University of Toronto** (Canada), **Queensland University of Technology** (Australia), **National Central University** (Taiwan) and **University of Michigan** and **University of Texas at Austin** (US).

Of the countries with the highest ARC, i.e. the Netherlands, Belgium, Luxembourg and Singapore, Norway co-publishes frequently only with the Netherlands. Intensifying collaborations with Belgium, Luxembourg and Singapore could thus benefit Norway's impact in Education research. However, only Luxembourg is specialised in this strategic theme. Among the 21 countries more specialised in this research area than Norway, only the UK, Cyprus and Australia have a higher impact. Thus, only these three countries should be considered as candidates for increasing collaborations. Even though Cyprus' overall publication output in this theme (876 FULL) is comparably small, its high SI (5.60) makes it an important actor in Education research. This importance is underscored by the large international conferences on this topic held in Cyprus. Two examples are the 2009 World Conference on Educational Sciences, where close to 500 peer-reviewed papers[14] were presented by international authors, and the 2012 International Conference on Educational Research (CY-ICER), with almost 400 accepted papers.[15] The companion database, which contains statistics on the level of organisations and authors, can help develop collaboration strategies in Education research to target those institutions and/or researchers in Cyprus, the UK and Australia with whom partnership would be most beneficial to Norway.

Based on overall performance including publication output, growth, specialisation and especially impact, Belgium, Luxembourg, the Netherlands, the UK, Cyprus, Canada, Australia, Taiwan and the US are the most important actors in Education. Of those countries with a high impact and specialisation, Norway collaborates the most with the UK (175 FULL; 38 FRAC) and Australia (105; 20), but less frequently with Canada (66; 10), Cyprus (4; 1) and Luxembourg (2; 0.1), which suggests that it would be advisable for Norway to intensify collaborations with the latter countries. As well, a further increase in the number of co-publications with the Netherlands (ARC = 1.87; number of co-publications with Norway = 103 FULL; 15 FRAC; ARC of co-publications with Norway = 2.08) could be beneficial to Norway due to that country's high ARC.

[14] Uzunboylu, H. and Cavus, N. (2009). Message from the Guest Editors. *Procedia Social and Behavioral Sciences*, 1(1), 2.

[15] Uzunboylu, H., Hursen, Ç., Sakalli, M., and Kanbul, S. (2012). Message from the Guest Editors. *Procedia Social and Behavioral Sciences*, 47(1), 2.

Table VII Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Education (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**414,231**	**414,231**	**1.81**	**1.00**	**1.00**	**1,108**	**1.60**	**304**	**0.07%**	**1.37**	**n.a.**	**n.a.**
Nordic	**12,942**	**10,878**	**1.86**	**1.01**	**1.32**	**344**	**1.90**	**68**	**0.81%**	**1.26**	**n.a.**	**n.a.**
Norway	3,252	2,574	1.87	1.34	1.29	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	249	179	2.12	1.67	1.27	16	n.c.	1	0.52%	n.c.	n.c.	n.c.
Denmark (EU-15/28)	1,948	1,504	2.07	0.65	1.28	96	1.63	12	0.81%	0.98	n.c.	n.c.
Finland (EU-15/28)	3,506	2,897	1.77	1.26	1.44	94	2.34	13	0.46%	1.22	n.c.	n.c.
Sweden (EU-15/28)	4,685	3,724	1.84	0.90	1.40	219	1.79	41	1.10%	1.37	n.c.	n.c.
EU-28	**112,751**	**103,829**	**1.85**	**0.84**	**1.14**	**687**	**1.84**	**168**	**0.16%**	**1.45**	**n.a.**	**n.a.**
EU-15	**100,680**	**91,617**	**1.76**	**0.84**	**1.22**	**673**	**1.86**	**162**	**0.18%**	**1.49**	**n.a.**	**n.a.**
Austria	1,988	1,506	1.85	0.62	1.09	22	n.c.	2	0.15%	n.c.	n.c.	n.c.
Belgium	3,164	2,435	1.77	0.71	1.66	29	n.c.	2	0.09%	n.c.	n.c.	n.c.
France	7,504	6,165	1.56	0.40	0.83	43	n.c.	4	0.06%	1.37	n.c.	n.c.
Germany	13,612	11,308	1.61	0.53	1.21	86	1.89	15	0.13%	4.98	n.c.	n.c.
Greece	3,800	3,304	2.05	1.29	1.02	21	n.c.	2	0.07%	n.c.	n.c.	n.c.
Ireland	2,415	1,957	2.07	1.44	1.11	25	n.c.	3	0.15%	n.c.	n.c.	n.c.
Italy	6,886	5,863	1.66	0.46	1.04	47	1.95	4	0.06%	0.82	n.c.	n.c.
Luxembourg	137	85	9.12	1.13	1.58	2	n.c.	0	0.07%	n.c.	n.c.	n.c.
Netherlands	7,931	6,215	1.67	0.97	1.87	103	2.08	15	0.24%	1.55	n.c.	n.c.
Portugal	2,711	2,207	3.24	1.12	0.76	31	n.c.	3	0.13%	6.44	n.c.	n.c.
Spain	12,905	11,452	2.68	1.10	0.89	60	1.39	8	0.07%	2.65	n.c.	n.c.
United Kingdom	35,977	30,994	1.52	1.38	1.43	175	1.57	38	0.12%	1.12	1.33	n.c.
Bulgaria	556	461	2.87	0.88	0.24	2	n.c.	0	0.02%	n.c.	n.c.	n.c.
Croatia	1,539	1,397	2.29	1.58	0.47	6	n.c.	0	0.03%	n.c.	n.c.	n.c.
Cyprus	876	683	2.98	5.60	1.34	4	n.c.	1	0.09%	n.c.	n.c.	n.c.
Czech Republic	1,419	1,229	2.24	0.53	0.43	9	n.c.	0	0.04%	n.c.	n.c.	n.c.
Estonia	522	416	2.77	1.67	0.69	6	n.c.	0	0.09%	n.c.	n.c.	n.c.
Hungary	1,132	935	1.94	0.68	0.71	15	n.c.	1	0.09%	n.c.	n.c.	n.c.
Latvia	230	194	6.33	1.53	0.56	6	n.c.	1	0.40%	n.c.	n.c.	n.c.
Lithuania	693	615	4.24	1.46	0.54	6	n.c.	0	0.05%	n.c.	n.c.	n.c.
Malta	156	120	2.85	3.57	0.74	1	n.c.	0	1.23E-05	n.c.	n.c.	n.c.
Poland	2,750	2,473	1.63	0.48	0.39	12	n.c.	1	0.05%	n.c.	n.c.	n.c.
Romania	2,024	1,818	9.16	1.19	0.51	7	n.c.	0	0.02%	n.c.	n.c.	n.c.
Slovakia	824	706	2.87	1.00	0.77	5	n.c.	0	0.01%	n.c.	n.c.	n.c.
Slovenia	1,311	1,166	2.63	1.69	0.56	2	n.c.	0	3.96E-06	n.c.	n.c.	n.c.
Argentina	1,231	1,041	2.00	0.68	0.41	1	n.c.	0	7.02E-07	n.c.	n.c.	n.c.
Australia	19,571	16,936	1.87	1.88	1.32	105	1.74	20	0.12%	1.29	n.c.	n.c.
Brazil	10,804	10,122	2.61	1.29	0.48	18	n.c.	2	0.02%	n.c.	n.c.	n.c.
Canada	19,091	15,916	1.65	1.26	1.33	66	1.89	10	0.07%	1.42	1.17	n.c.
Chile	1,674	1,401	3.03	1.59	0.78	5	n.c.	1	0.04%	n.c.	n.c.	n.c.
China	24,252	22,399	4.22	0.39	0.59	39	1.67	5	0.02%	0.84	n.c.	n.c.
Colombia	1,159	929	3.75	1.81	0.49	3	n.c.	0	2.68E-05	n.c.	n.c.	n.c.
Egypt	673	502	3.36	0.39	0.61	3	n.c.	1	0.10%	n.c.	n.c.	n.c.
India	5,416	4,892	3.21	0.40	0.53	10	n.c.	1	0.02%	n.c.	n.c.	n.c.
Indonesia	442	309	4.37	1.38	0.58	3	n.c.	1	0.27%	n.c.	n.c.	n.c.
Iran	4,648	4,358	7.66	1.04	0.49	9	n.c.	1	0.02%	n.c.	n.c.	n.c.
Israel	4,308	3,695	1.35	1.36	1.27	22	n.c.	3	0.08%	n.c.	n.c.	n.c.
Japan	9,489	8,531	1.47	0.34	0.57	16	n.c.	1	9.77E-05	n.c.	n.c.	n.c.
Malaysia	4,804	4,430	8.48	2.46	0.56	6	n.c.	1	0.02%	n.c.	n.c.	n.c.
Mexico	3,059	2,613	2.04	1.10	0.48	2	n.c.	0	2.31E-06	n.c.	n.c.	n.c.
New Zealand	4,357	3,544	1.77	2.27	1.16	16	n.c.	4	0.10%	n.c.	n.c.	n.c.
Nigeria	2,019	1,882	2.85	2.43	0.33	2	n.c.	0	0.01%	n.c.	n.c.	n.c.
Pakistan	1,304	1,172	3.78	1.18	0.40	1	n.c.	0	0.03%	n.c.	n.c.	n.c.
Rep. of Korea	4,047	3,288	2.29	0.33	1.11	10	n.c.	1	0.02%	n.c.	n.c.	n.c.
Russia	1,442	1,227	1.52	0.17	0.29	19	n.c.	3	0.25%	n.c.	n.c.	n.c.
Singapore	2,520	2,005	2.09	0.95	1.51	4	n.c.	1	0.03%	n.c.	n.c.	n.c.
South Africa	4,512	3,903	2.28	2.40	0.70	48	1.10	9	0.22%	1.30	n.c.	n.c.
Switzerland	3,042	2,132	1.78	0.52	1.42	29	n.c.	3	0.13%	n.c.	n.c.	n.c.
Taiwan	7,933	7,284	2.75	1.09	1.41	22	n.c.	5	0.06%	n.c.	n.c.	n.c.
Thailand	1,867	1,564	3.14	1.21	0.54	2	n.c.	0	0.01%	n.c.	n.c.	n.c.
Turkey	10,127	9,564	4.04	1.76	0.71	13	n.c.	2	0.02%	n.c.	n.c.	n.c.
United States	169,715	159,320	1.36	1.65	1.15	267	2.19	44	0.03%	1.62	0.97	n.c.
Viet Nam	244	156	2.97	0.87	0.63	2	n.c.	0	0.16%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

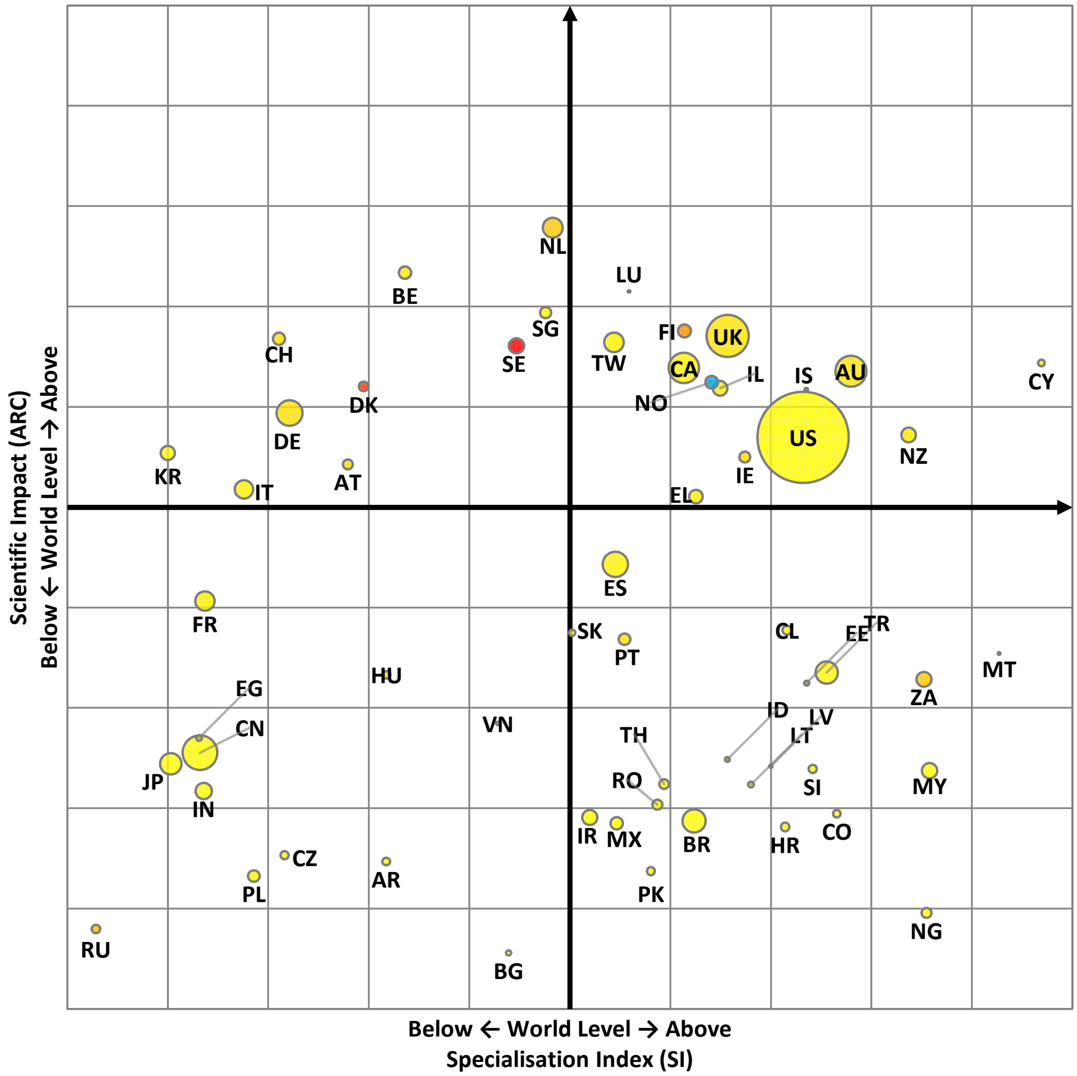


Figure 10 Positional analysis of selected countries in Education with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.5 Profiles of Selected Countries in Energy

Table VIII lists publication and collaboration indicators in Energy research for Norway, the 57 selected countries, and aggregates of Nordic countries and EU-15 and EU-28 member states from 2003 to 2012. In terms of output, the US, China, Japan, the UK, Germany, Canada and India lead the field in Energy research. Interestingly, the Republic of Korea follows as the eighth largest producer of Energy papers, ranking four positions higher than in the sciences in general (Section 3.1), as is emphasised by its high SI of 1.31. Of the 15 largest producers, only China is more specialised in Energy research, producing 55% more papers in this area than expected given its size. Together with Taiwan (number of publications FRAC = 12,027; GR = 2.58), Korea (20,427; 2.51) and India (22,003; 2.40), China (140,301; 2.38) show the highest growth among the 15 top-ranking Energy research nations.

Overall, the strategic theme of Energy research shows extraordinary growth, with global output increasing by 87% from the first to the second period analysed. This growth is primarily caused and sustained by non-EU and non-Nordic countries. The output of both the EU-28 (GR = 1.78) and the Nordic countries (1.71) declines relatively to the world and highest output. Among the countries with considerable output (i.e. at least 500 papers) and those with the 15 highest GRs, only Romania (GR=3.88) and Portugal (2.65) are EU member states. Malaysia, Iran and Colombia have grown much faster, with GRs of 5.41, 4.26 and 4.25 respectively. With GRs of 1.92 and 1.82, Denmark and Norway are the fastest growing Nordic countries, which puts them in 31st and 37th place respectively among the 58 selected countries, highlighting the strong average growth of this strategic theme. Based on full counts, Sweden (7,886 FULL; 5,737 FRAC) has a slightly larger output than Norway and ranks 19th among the 58 analysed countries. Based on fractional publication counts, Norway (5,742 FRAC; 7,722 FULL) is the largest producer of Energy research papers among the Nordic countries. It is also far more specialised than any other Nordic or EU country, producing 89% more papers than expected. This output underscores the importance of Energy research for Norway as the world's second largest exporter of natural gas and Europe's largest oil producer.[16] Only Indonesia and Malaysia, both leading producers of natural gas,[17] are more specialised in Energy research. Indonesia has also been the world's largest exporter of coal since 2011.[18] Norway is trailed by Estonia, Nigeria, Iran and China, which constitute the fourth to seventh most specialised countries among the 58 selected. All of these countries are major producers or hold large reserves of oil, gas or coal, except for Estonia, which according to the US Energy Information Administration is however "one of the few producers of oil shale."[19] Papers authored by researchers in Singapore, Denmark and Switzerland have the highest citation impact. Among the countries publishing more than 30% of Energy output than expected, only the Republic of Korea is highly cited. Together with its high output and growth, it represents a potential partner for future collaborations.

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[16] http://www.eia.gov/countries/country-data.cfm?fips=NO

[17] http://www.eia.gov/countries/

[18] http://www.eia.gov/countries/country-data.cfm?fips=ID

[19] http://www.eia.gov/countries/country-data.cfm?fips=EN

Norway publishes 43% of its Energy publication output with at least one researcher from another country, which is slightly below the overall share of international co-publications. The impact of internationally co-authored papers by Norway is only 12% above the world average and, contrary to other strategic themes, its Energy publication output does not increase Norway's overall impact. The major collaborators in terms of number of co-publications are the US (991 FULL; 208 FRAC), the UK (581; 106) and Germany (370; 56). The citation impact of co-publications with German colleagues is particularly high, scoring an ARC of 1.64, which makes Germany a candidate for further increased partnerships. Of the 25 countries for which an ARC of co-publications could be computed, Norway benefits most from collaborating with Belgium (ARC of co-publications with Norway = 2.21), Portugal (2.16), Poland (1.87), the Netherlands (1.74), Canada (1.67), Greece (1.66), Germany (1.64), Australia (1.62) and Italy (1.61). Given their large outputs, collaborations with Germany and Canada are most advisable. Publications co-authored with researchers from the US (0.91) and Iran (0.88), however, diminish Norway's citation impact in Energy research.

Considering overall performance in Energy (see Figure 11), Singapore, Denmark, Malaysia, the Republic of Korea, Switzerland, Canada and Taiwan can be identified as potential strategic partners to improve Norway's scientific impact. Norway's collaborations with these countries are low and should especially be intensified with **Singapore** and **the Republic of Korea**.

Analysis at the micro-level shows that the best performing institutions in Energy in these strategic nations are: **Nanyang Technological University** and **National University of Singapore** (Singapore), **DTU** and **Aalborg University** (Denmark), **University of Malaya** (Malaysia), **KAIST** (Korea), **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **National Research Council** (Canada) and **National Cheng Kung University** and **National Chiao Tung University** (Taiwan).

Considering overall performance, including publication output, growth, specialisation, and especially impact, Singapore, Denmark, Malaysia, the Republic of Korea (0.01%), Switzerland (0.29%) and Taiwan (0.00%) are the most important actors in Energy of the 58 countries analysed. All of these except Denmark (Collaboration Rate = 1.04%) and Switzerland (0.29%) allocate less than 0.05% of their overall output in Energy research to co-publications with Norway, which is far below the global average of 0.14%. Malaysia is comparable to Norway in terms of output, specialisation and impact. Norway should increase its number of co-publications with Singapore (4 FULL; 1 FRAC) because of this country's extraordinarily high ARC (2.62), as well as with the Republic of Korea (20 FULL; 3 FRAC) because of a combination of high specialisation (SI=1.31) and impact (ARC=1.57). Current collaborations with Denmark (243 FULL; 44 FRAC) should also be enhanced.

Table VIII Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Energy (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**653,356**	**653,356**	**1.87**	**1.00**	**1.00**	**3,317**	**1.12**	**887**	**0.14%**	**0.97**	**n.a.**	**n.a.**
Nordic	**24,342**	**18,727**	**1.71**	**1.10**	**1.43**	**564**	**1.42**	**113**	**0.87%**	**1.11**	**n.a.**	**n.a.**
Norway	7,722	5,742	1.82	1.89	0.95	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	280	165	1.54	0.97	0.74	15	n.c.	2	1.22%	n.c.	n.c.	n.c.
Denmark (EU-15/28)	5,961	4,268	1.92	1.16	2.06	243	1.49	44	1.04%	0.80	n.c.	n.c.
Finland (EU-15/28)	3,673	2,815	1.63	0.78	1.25	118	1.58	17	0.59%	1.60	n.c.	n.c.
Sweden (EU-15/28)	7,886	5,737	1.51	0.88	1.58	279	1.43	50	0.87%	1.34	n.c.	n.c.
EU-28	**167,823**	**146,662**	**1.78**	**0.75**	**1.25**	**1,937**	**1.30**	**440**	**0.30%**	**1.02**	**n.a.**	**n.a.**
EU-15	**150,112**	**128,366**	**1.74**	**0.74**	**1.32**	**1,867**	**1.31**	**419**	**0.33%**	**1.04**	**n.a.**	**n.a.**
Austria	4,226	2,911	1.81	0.76	1.50	48	1.30	5	0.18%	3.02	n.c.	n.c.
Belgium	4,988	3,436	1.78	0.64	1.42	76	2.21	9	0.25%	0.87	n.c.	n.c.
France	23,004	16,751	1.59	0.69	1.24	305	1.20	42	0.25%	0.83	n.c.	n.c.
Germany	31,077	23,713	1.71	0.71	1.31	370	1.64	56	0.23%	1.23	1.40	n.c.
Greece	4,934	4,047	1.66	1.00	1.49	87	1.66	8	0.20%	0.88	n.c.	n.c.
Ireland	1,954	1,370	2.33	0.64	1.58	45	1.53	4	0.32%	0.40	n.c.	n.c.
Italy	18,828	15,320	1.85	0.77	1.28	179	1.61	24	0.15%	1.18	n.c.	n.c.
Luxembourg	163	87	3.79	0.73	1.67	1	n.c.	0	0.05%	n.c.	n.c.	n.c.
Netherlands	10,785	7,731	1.61	0.76	1.52	253	1.74	33	0.42%	1.10	n.c.	n.c.
Portugal	4,069	3,198	2.65	1.02	1.29	48	2.16	5	0.15%	4.56	n.c.	n.c.
Spain	16,582	13,197	2.03	0.80	1.58	135	1.36	17	0.13%	1.15	n.c.	n.c.
United Kingdom	32,144	23,786	1.63	0.67	1.33	581	1.23	106	0.44%	1.00	2.05	n.c.
Bulgaria	1,073	755	1.39	0.92	0.76	7	n.c.	0	0.04%	n.c.	n.c.	n.c.
Croatia	1,234	1,054	1.99	0.76	0.57	10	n.c.	1	0.14%	n.c.	n.c.	n.c.
Cyprus	359	204	2.89	1.06	1.72	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Czech Republic	2,862	2,250	2.11	0.61	0.83	34	n.c.	3	0.12%	1.40	n.c.	n.c.
Estonia	878	724	1.85	1.84	0.78	10	n.c.	2	0.24%	n.c.	n.c.	n.c.
Hungary	1,781	1,368	1.94	0.63	0.70	21	n.c.	3	0.19%	n.c.	n.c.	n.c.
Latvia	351	291	4.60	1.46	0.40	3	n.c.	0	0.05%	n.c.	n.c.	n.c.
Lithuania	930	797	2.04	1.20	0.91	11	n.c.	1	0.19%	n.c.	n.c.	n.c.
Malta	78	47	2.26	0.90	0.73	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Poland	7,213	6,160	1.91	0.75	0.77	48	1.87	6	0.10%	0.72	n.c.	n.c.
Romania	3,488	2,936	3.88	1.22	0.59	22	n.c.	3	0.10%	n.c.	n.c.	n.c.
Slovakia	878	661	1.81	0.60	0.59	18	n.c.	1	0.08%	n.c.	n.c.	n.c.
Slovenia	1,339	1,049	1.49	0.97	1.03	21	n.c.	1	0.13%	n.c.	n.c.	n.c.
Argentina	2,359	1,800	1.95	0.75	0.95	22	n.c.	3	0.16%	n.c.	n.c.	n.c.
Australia	14,503	10,657	2.07	0.75	1.44	133	1.62	24	0.22%	1.23	n.c.	n.c.
Brazil	14,354	12,659	2.06	1.02	0.81	47	1.09	6	0.05%	1.52	n.c.	n.c.
Canada	27,897	21,767	1.62	1.09	1.24	215	1.67	36	0.16%	0.93	1.47	n.c.
Chile	1,344	889	1.83	0.64	1.41	13	n.c.	0	0.04%	n.c.	n.c.	n.c.
China	148,480	140,301	2.38	1.55	0.77	148	1.27	30	0.02%	1.21	n.c.	n.c.
Colombia	1,679	1,211	4.25	1.49	0.70	14	n.c.	2	0.18%	n.c.	n.c.	n.c.
Egypt	3,882	3,056	1.78	1.50	0.68	8	n.c.	1	0.02%	n.c.	n.c.	n.c.
India	24,351	22,003	2.40	1.13	1.04	66	1.06	13	0.06%	1.68	n.c.	n.c.
Indonesia	1,360	840	2.79	2.39	0.52	4	n.c.	1	0.10%	n.c.	n.c.	n.c.
Iran	11,590	10,573	4.26	1.60	0.81	44	0.88	9	0.09%	0.49	n.c.	n.c.
Israel	2,190	1,658	1.37	0.39	1.37	18	n.c.	1	0.08%	n.c.	n.c.	n.c.
Japan	40,326	35,950	1.27	0.91	0.99	92	1.49	16	0.05%	2.70	n.c.	n.c.
Malaysia	6,464	5,472	5.41	1.92	0.96	16	n.c.	2	0.04%	n.c.	n.c.	n.c.
Mexico	5,685	4,636	1.49	1.24	0.70	19	n.c.	4	0.08%	n.c.	n.c.	n.c.
New Zealand	2,247	1,615	1.89	0.65	1.32	21	n.c.	3	0.20%	n.c.	n.c.	n.c.
Nigeria	2,383	2,065	2.40	1.69	0.33	16	n.c.	3	0.16%	n.c.	n.c.	n.c.
Pakistan	1,391	1,068	2.82	0.68	0.73	3	n.c.	1	0.08%	n.c.	n.c.	n.c.
Rep. of Korea	23,356	20,427	2.51	1.31	1.33	20	n.c.	3	0.01%	n.c.	n.c.	n.c.
Russia	14,044	12,205	1.20	1.08	0.32	119	1.19	18	0.15%	2.08	n.c.	n.c.
Singapore	4,593	3,555	2.58	1.07	2.21	4	n.c.	1	0.02%	n.c.	n.c.	n.c.
South Africa	3,228	2,477	2.03	0.97	0.99	35	n.c.	4	0.16%	0.99	n.c.	n.c.
Switzerland	7,488	5,046	1.65	0.78	1.93	106	1.06	15	0.29%	1.36	n.c.	n.c.
Taiwan	12,988	12,027	2.58	1.14	1.38	6	n.c.	0	0.00%	n.c.	n.c.	n.c.
Thailand	3,672	2,991	2.39	1.47	1.06	9	n.c.	2	0.06%	n.c.	n.c.	n.c.
Turkey	8,515	7,651	1.99	0.89	1.60	13	n.c.	2	0.03%	n.c.	n.c.	n.c.
United States	150,074	129,073	1.60	0.85	1.17	991	0.91	208	0.16%	0.96	1.52	n.c.
Viet Nam	523	275	2.61	0.97	0.72	2	n.c.	0	0.14%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

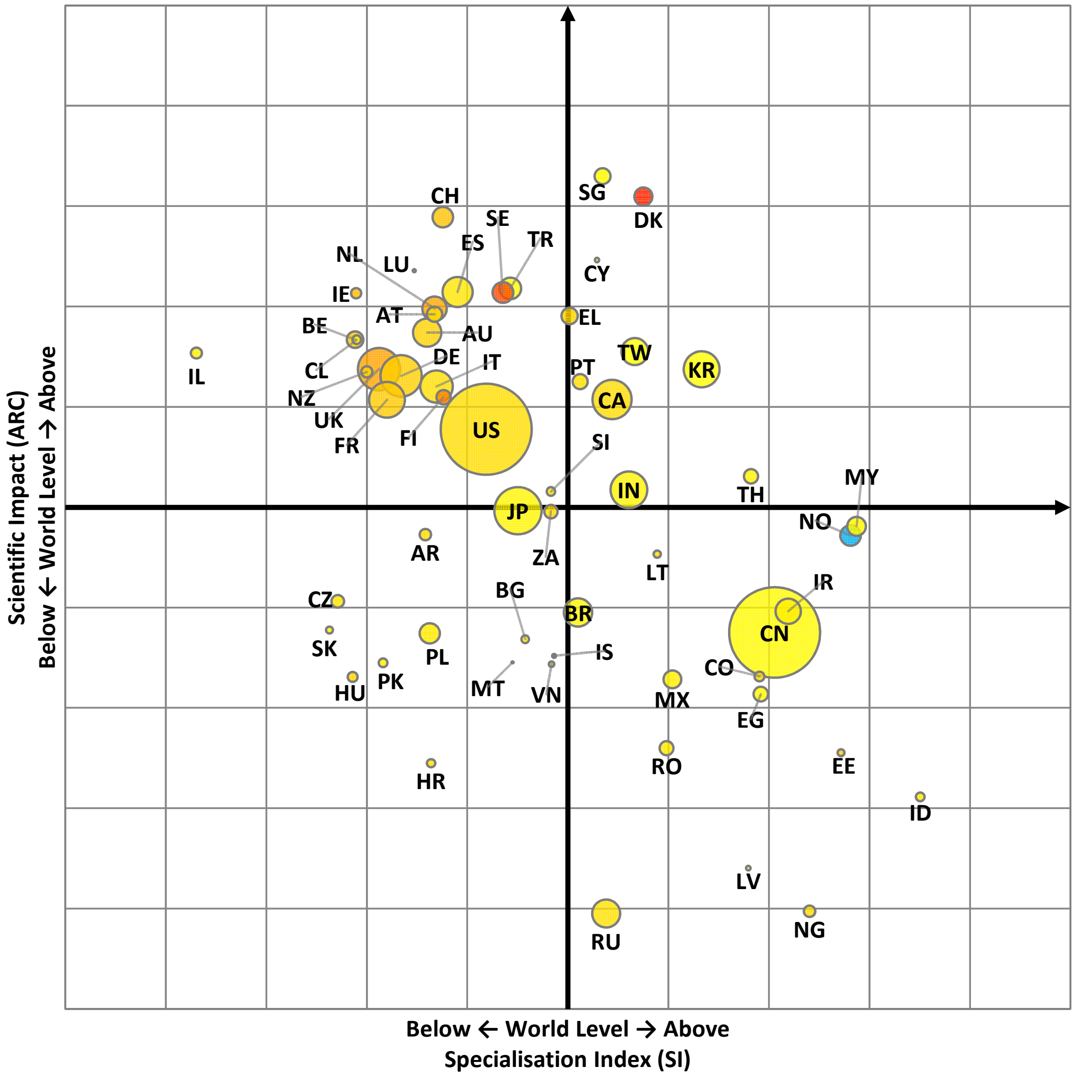


Figure 11 Positional analysis of selected countries in Energy with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.6 Profiles of Selected Countries in Environment

As Table IX illustrates, Environment is an important research area, with more than 1 million papers published worldwide from 2003 to 2012. The US is the largest producer of scientific papers in Environment (265,885 FULL; 222,106 FRAC), followed by China (150,807; 137,824), the UK (78,807; 55,081) Germany (62,554; 44,238) and Canada (52,775; 39,015). Among the 57 selected countries, Norway ranks 24th with 11,218 papers (FULL; 6,959 FRAC).

Norway is specialised in Environment, ranking 10th among selected countries with an SI of 1.46. It increased its output by 58% between the second and the first half of the study period, which represents a growth above the Nordic average (38%) but below the world average (65%). Norway's papers in Environment are on average cited 52% above the world level, which is higher than the ARC for the Nordic countries (1.45) and places it in 6th position among the 58 countries selected.

Romania, Malaysia and Latvia show the largest growth of publications in this strategic theme, increasing their outputs by more than fourfold between the first and the second half of the study period. Considering that Malaysia concentrates 50% more effort on Environment than on other fields in general (SI = 1.52), its growth ratio is the second highest among the selected countries (GR = 5.24). Although actually ranking 32nd in terms of absolute number of publications, Malaysia is likely to become a major player in Environment in the future.

Switzerland exhibits the highest ARC (1.82), followed by Denmark, Singapore, the Netherlands and Iceland (ARCs from 1.82 to 1.59). Denmark and Iceland stand out with SI values of 1.20 and 1.37 respectively.

More than half of Norway's Environment papers are co-published in international collaboration. Norway co-publishes most frequently with the US (1,645 FULL; 230 FRAC), although this collaboration represents only 0.10% (Collaboration Rate) of the total number of US papers in this field, which is lower than the world level of 0.16%. The UK, with 1,625 co-publications (FULL) with Norway in Environment, represents a higher share (0.36%), as does Germany (1,198 FULL; 0.28%). Other countries with notable co-publication output and collaboration rates with Norway in Environment include Sweden (1,127 FULL; 1.14%), Denmark (696 FULL; 1.05%) and Finland (513 FULL; 0.68%). Although Iceland shows by far the greatest share of publications with Norway in Environment (3.570%), its total co-publication output with Norway is low (141 FULL) and could be increased. Of these countries, Denmark (ARC = 1.69), Sweden (1.52) and the UK (1.44) stand out in terms of scientific performance, mainly because of their high citation impact. Denmark (SI = 1.20) and Sweden (1.22) also specialise in this strategic theme, while the UK exhibits a high publication output as previously noted (78,807 papers, FULL). Data also show that the ARC values for the co-publications of Denmark (ARC of co-publications with Norway = 2.40), Sweden (2.33) and Germany (2.53) with Norway are greater than the global ARC performance for these countries, indicating that both partners benefit from this collaboration. Given these performances, Norway should pursue and/or accentuate its collaboration with these countries.

Strategic partners for improving Norway's scientific impact in Environment (see Figure 12) include Switzerland, Denmark, Australia, Portugal, the Netherlands, the UK, Canada, Spain and New Zealand since these countries exhibit high general performance considering all indicators combined. Collaboration with **Australia Portugal, Spain and New Zealand** could be emphasised since it is presently below expectations.

Organisations that stand out in terms of output, specialisation and impact in Environment for these strategic countries include: **ETHZ** (Switzerland), **DTU** and **University of Aarhus** (Denmark), **CSIRO** (Australia), **University of Aveiro** (Portugal), **WUR** (the Netherlands), **University of Leeds** (UK), **University of British Columbia** (Canada) and **Spanish National Research Council** (Spain).

Other countries are noteworthy in terms of general performance in this strategic theme and should be analysed in terms of their relations with Norway. Considering output, growth ratio, SI and ARC together, Switzerland, Australia, Portugal, Estonia, the Netherlands, Spain, New

Zealand, Canada and Belgium rank in the 15 top performing countries[20] in Environment, along with Denmark and Sweden, which have already been mentioned. Switzerland's co-publication output with Norway in Environment amounts to 418 papers (FULL), with a significant collaboration growth ratio of 1.86, signifying that its affinity with Norway is growing. Switzerland's co-publications with Norway exhibit a very high ARC of 3.28, showing that Norway's visibility benefits from this collaboration.

For the same reason, Norway's collaboration with the above 15 top countries could be enhanced as they combine excellent overall scientific performance in Environment with an ARC of co-publications greater than 2.3. Canada (52,755 FULL; Collaboration Affinity for Norway = 2.41) and the Netherlands (24,953; 2.61) are worth mentioning as they have high general output and already show an affinity for collaborating with Norway. Belgium's co-publications with Norway exhibit a high impact (ARC of 3.55) and collaboration with this country could be further strengthened given that its share of publications with Norway is already notable (0.22%), even though absolute output of co-publications is low (292).

As is the case for the great majority of themes, Norway also has a strong affinity for the other Nordic countries in Environment research. As well as with the above-mentioned Nordic countries, Norway should endeavour to continue developing collaborations with Iceland (SI = 1.37; ARC = 1.59) and Finland (1.39; 1.35) in this field since these countries are both specialised in this theme and their impact is far above the world level.

[20] Malaysia and Cyprus are discarded due to their very low co-publication output.

Table IX Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Environment (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	**FULL**	**FRAC**	**GR**	**SI**	**ARC**	**FULL**	**ARC**	**FRAC**	**Coll. Rate**	**GR**	**for NO**	**of NO**
World	**1,026,586**	**1,026,586**	**1.65**	**1.00**	**1.00**	**6,670**	**1.78**	**1,599**	**0.16%**	**1.08**	**n.a.**	**n.a.**
Nordic	**48,598**	**34,670**	**1.38**	**1.30**	**1.45**	**1,932**	**2.20**	**282**	**1.02%**	**1.24**	**n.a.**	**n.a.**
Norway	11,218	6,956	1.58	1.46	1.52	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	776	366	1.28	1.37	1.59	141	2.61	13	3.57%	0.82	n.c.	n.c.
Denmark (EU-15/28)	11,361	6,916	1.52	1.20	1.69	698	2.40	73	1.05%	1.07	n.c.	n.c.
Finland (EU-15/28)	10,971	7,942	1.31	1.39	1.35	513	2.33	54	0.68%	1.19	n.c.	n.c.
Sweden (EU-15/28)	18,780	12,490	1.26	1.22	1.52	1,127	2.33	142	1.14%	1.42	n.c.	n.c.
EU-28	**360,269**	**312,950**	**1.53**	**1.02**	**1.17**	**4,726**	**1.96**	**939**	**0.30%**	**1.15**	**n.a.**	**n.a.**
EU-15	**322,648**	**273,638**	**1.47**	**1.01**	**1.24**	**4,551**	**1.99**	**880**	**0.32%**	**1.17**	**n.a.**	**n.a.**
Austria	9,307	5,939	1.50	0.99	1.32	259	2.65	22	0.37%	1.70	n.c.	n.c.
Belgium	13,411	8,851	1.48	1.04	1.46	292	3.55	20	0.22%	1.09	n.c.	n.c.
France	49,610	34,821	1.44	0.91	1.28	874	2.61	71	0.21%	1.13	n.c.	n.c.
Germany	62,554	44,238	1.38	0.84	1.30	1,198	2.53	124	0.28%	1.36	1.97	n.c.
Greece	9,928	7,897	1.58	1.25	1.18	154	2.72	11	0.14%	1.10	n.c.	n.c.
Ireland	4,827	3,310	1.96	0.98	1.36	108	3.25	7	0.22%	0.47	n.c.	n.c.
Italy	38,571	30,092	1.53	0.96	1.17	525	2.70	43	0.14%	1.33	1.88	n.c.
Luxembourg	464	231	3.17	1.24	1.35	17	n.c.	1	0.26%	n.c.	n.c.	n.c.
Netherlands	24,953	16,103	1.41	1.01	1.61	734	2.71	71	0.44%	1.10	2.61	n.c.
Portugal	10,524	7,833	2.16	1.60	1.29	115	3.03	7	0.09%	1.65	n.c.	n.c.
Spain	39,773	30,894	1.85	1.19	1.34	418	2.63	34	0.11%	0.87	n.c.	n.c.
United Kingdom	78,607	56,081	1.33	1.01	1.44	1,625	2.48	200	0.36%	1.27	2.30	n.c.
Bulgaria	1,977	1,361	1.56	1.05	0.70	41	2.38	1	0.09%	0.96	n.c.	n.c.
Croatia	2,969	2,514	1.74	1.15	0.56	40	n.c.	4	0.17%	2.04	n.c.	n.c.
Cyprus	711	401	2.97	1.33	1.36	7	n.c.	0	0.02%	n.c.	n.c.	n.c.
Czech Republic	7,230	5,670	1.85	0.98	0.94	120	2.86	8	0.15%	4.30	n.c.	n.c.
Estonia	1,825	1,262	1.89	2.04	1.31	100	2.30	9	0.68%	0.78	n.c.	n.c.
Hungary	4,632	3,516	1.71	1.03	0.81	58	1.94	5	0.13%	0.79	n.c.	n.c.
Latvia	570	443	4.25	1.41	0.88	25	n.c.	1	0.18%	n.c.	n.c.	n.c.
Lithuania	1,897	1,594	1.88	1.52	0.94	52	2.45	2	0.16%	0.74	n.c.	n.c.
Malta	179	115	1.58	1.38	1.07	6	n.c.	0	0.14%	n.c.	n.c.	n.c.
Poland	15,081	12,874	1.57	1.00	0.65	221	2.37	20	0.16%	0.95	n.c.	n.c.
Romania	6,607	5,614	6.06	1.49	0.54	62	1.61	4	0.08%	0.27	n.c.	n.c.
Slovakia	2,413	1,771	1.51	1.02	0.74	49	3.33	2	0.10%	3.74	n.c.	n.c.
Slovenia	2,878	2,177	1.61	1.28	0.88	42	2.88	1	0.07%	4.19	n.c.	n.c.
Argentina	6,898	5,341	1.81	1.41	0.98	29	n.c.	2	0.03%	n.c.	n.c.	n.c.
Australia	41,970	31,748	1.75	1.42	1.38	289	3.05	29	0.09%	1.72	n.c.	n.c.
Brazil	26,760	22,849	2.21	1.17	0.84	68	3.27	5	0.02%	1.45	n.c.	n.c.
Canada	52,755	39,015	1.37	1.25	1.31	717	2.75	77	0.20%	1.06	2.41	n.c.
Chile	4,566	2,977	1.66	1.36	1.14	39	n.c.	3	0.10%	1.54	n.c.	n.c.
China	150,807	137,824	2.86	0.97	0.78	338	1.96	53	0.04%	0.68	n.c.	n.c.
Colombia	2,522	1,585	3.46	1.24	0.97	11	n.c.	2	0.15%	n.c.	n.c.	n.c.
Egypt	5,004	3,838	1.83	1.20	0.66	10	n.c.	2	0.04%	n.c.	n.c.	n.c.
India	45,299	41,431	2.02	1.35	0.78	77	1.85	11	0.03%	1.25	n.c.	n.c.
Indonesia	2,213	1,122	2.21	2.03	0.98	16	n.c.	2	0.16%	n.c.	n.c.	n.c.
Iran	12,236	11,032	4.20	1.06	0.77	8	n.c.	1	0.01%	n.c.	n.c.	n.c.
Israel	5,798	4,273	1.30	0.64	1.22	36	4.24	2	0.05%	1.51	n.c.	n.c.
Japan	48,218	40,649	1.20	0.65	0.86	223	2.74	18	0.04%	1.52	n.c.	n.c.
Malaysia	8,193	6,783	5.24	1.52	0.95	13	n.c.	2	0.03%	n.c.	n.c.	n.c.
Mexico	10,670	8,046	1.68	1.36	0.84	39	n.c.	5	0.06%	3.45	n.c.	n.c.
New Zealand	8,724	5,871	1.40	1.52	1.37	111	2.64	11	0.18%	1.84	n.c.	n.c.
Nigeria	4,334	3,773	2.01	1.96	0.40	3	n.c.	0	0.01%	n.c.	n.c.	n.c.
Pakistan	3,509	2,826	2.57	1.15	0.83	7	n.c.	2	0.06%	n.c.	n.c.	n.c.
Rep. of Korea	23,079	19,087	1.89	0.78	1.00	66	2.61	5	0.03%	2.41	n.c.	n.c.
Russia	12,531	9,531	1.10	0.54	0.57	329	1.60	41	0.43%	0.95	n.c.	n.c.
Singapore	4,739	3,518	1.65	0.67	1.67	16	n.c.	2	0.05%	n.c.	n.c.	n.c.
South Africa	9,655	7,141	1.57	1.77	1.06	132	2.42	18	0.25%	1.62	n.c.	n.c.
Switzerland	17,681	10,634	1.49	1.04	1.82	418	3.28	33	0.31%	1.89	2.21	n.c.
Taiwan	14,654	12,836	1.80	0.78	1.02	34	n.c.	5	0.04%	1.12	n.c.	n.c.
Thailand	5,778	4,267	2.24	1.33	0.94	21	n.c.	4	0.09%	n.c.	n.c.	n.c.
Turkey	14,427	12,990	1.72	0.96	1.08	35	n.c.	4	0.03%	0.82	n.c.	n.c.
United States	265,885	222,106	1.29	0.93	1.25	1,645	2.37	230	0.10%	1.33	1.36	n.c.
Viet Nam	1,235	531	2.42	1.19	1.01	15	n.c.	4	0.84%	n.c.	n.c.	n.c.

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

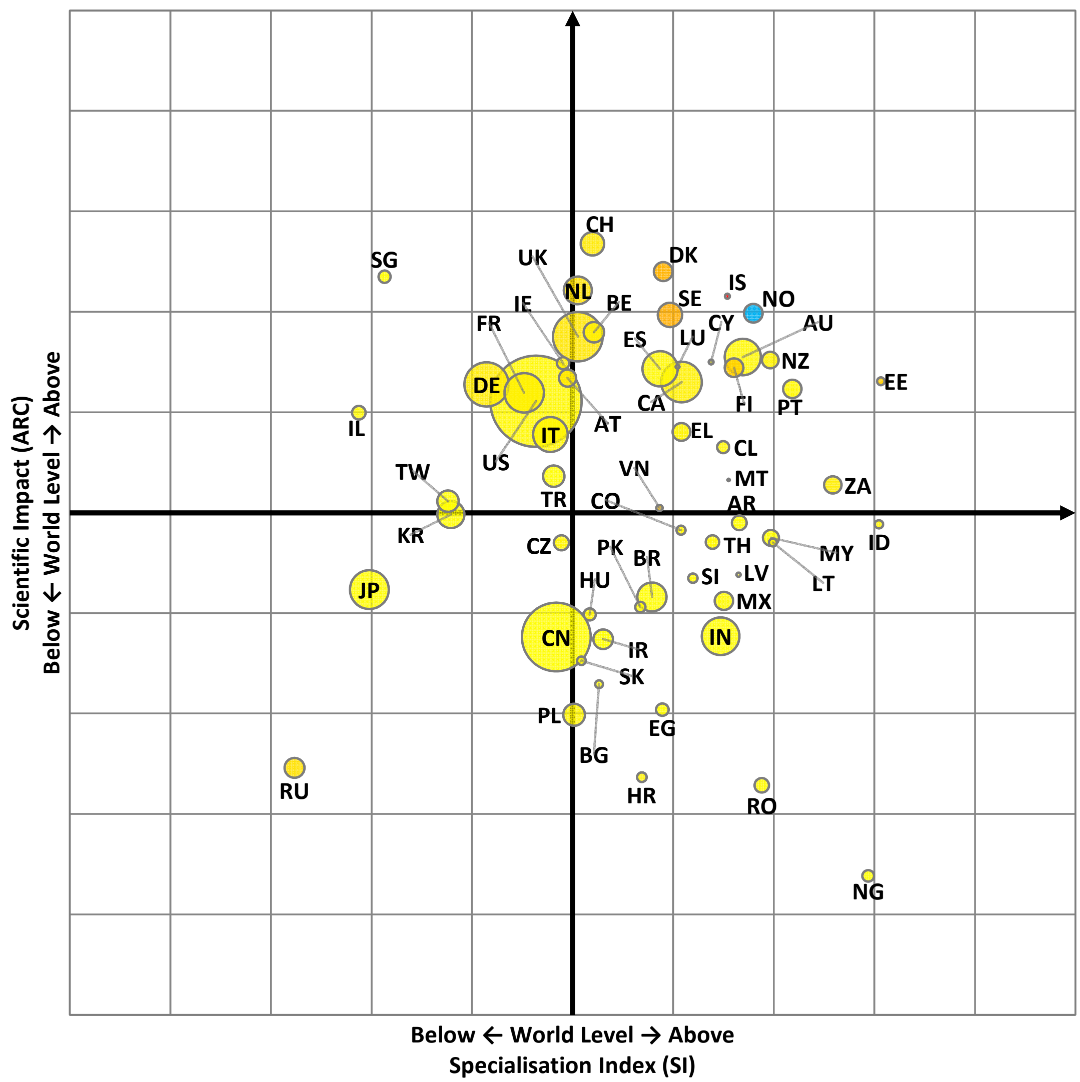


Figure 12 Positional analysis of selected countries in Environment with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.7 Profiles of Selected Countries in Climate Change

As Table X shows, Norway is a major player in Climate Change among the selected countries, ranking 3rd in terms of SI (2.40), and 6th in terms of impact (ARC of 2.13). Norway's output in this thematic amounted to 5,070 papers (FULL; 3,013 FRAC) from 2003 to 2012, with a growth ratio (GR = 1.91) above the world level (1.80). In fact, considering output, GR, SI and ARC in combination, Norway's performance is the best of all the selected countries, followed by that of Switzerland, Australia, Denmark and the UK.

Since very few affinity scores could be computed, the analysis of collaborations with Norway relies mainly on counts and shares of co-publications with Norwegian authors. The US partners the highest number of publications with Norway (924 FULL), followed closely by the UK (921 FULL).

While the co-publication output of the US with Norway represents only 0.18% of the total US output in this theme, the UK's share with Norway represents 0.59%, which is above the world level of 0.28. This is also reflected by the strong affinity that the UK shows for Norway (Collaboration Affinity for Norway = 1.90). Germany (675 FULL; Collaboration Rate = 0.46%), Sweden (546; 1.64%), France (447; 0.34%), Denmark (350; 1.53%) and the Netherlands (350; 0.59%) follow, all presenting shares of publications with Norway higher than the world average. All these countries stand out in terms of general performance (i.e. considering all performance indicators) except for the Netherlands. The data show that Sweden and Denmark are important collaborators with Norway. This cooperation should be encouraged when the high impact of current co-publications with Norway are also taken into account: Swedish-Norwegian co-publications obtained an ARC of 2.08 and Danish-Norwegian papers an ARC of 2.28. These observations also apply to Norway's other Nordic partners, Iceland and Finland. In fact, all the Nordic countries exhibit high general ARC values (from 1.40 to 1.60), high SIs (from 1.45 to 3.04) and high co-publication impact (ARC from 2.08 to 2.42) in Climate Change.

Strategic partners for improving Norway's visibility and impact in Climate Change (see Figure 13) include Switzerland, Australia, Denmark, the UK, the Netherlands, Sweden, Finland, the US, Canada and New Zealand. Collaboration with **Australia, Canada, New Zealand** and the **US** could be further promoted, as it is actually below expectations.

Organisations that stand out in Climate Change for the above nations include: **ETHZ** (Switzerland), **CSIRO** (Australia), **DTU** and **University of Aarhus** (Denmark), **University of Oxford** (UK), **WUR** and **Utrecht University** (the Netherlands), **Stockholm University** (Sweden), **University of Eastern Finland** and **University of Helsinki** (Finland), the **NASA**, **Columbia University**, **US Department of Energy** and **University of California - Berkeley** (US), **University of British Columbia** (Canada) and **University of Otago** (New Zealand).

Another potential partner for Norway to target in this theme is Switzerland owing to its high specialisation (SI=1.45), high impact (ARC=1.68) and affinity for collaborating with Norway (Collaboration Affinity for Norway = 1.89). Co-publications involving Swiss and Norwegian authors also exhibit a very high ARC (3.02). Although Australia is notable for its performance in terms of output, growth, specialisation and impact in Climate Change, the actual share of its collaboration with Norway, relative to other countries, represents only 0.11%. Thus more frequent collaborations with Australia could be accentuated in the coming years. The Netherlands also qualifies as a beneficial collaborator for Norway, mainly because of its high overall impact in Climate Change and the fact that it already tends to collaborate with Norway (Collaboration Affinity for Norway = 1.82; Collaboration Rate = 0.59). Increased collaboration with Estonia and Portugal would also be strategic for Norway, given these countries high general performances. Despite its low co-publications output, Estonia produces a significant share of its publications in collaboration with Norway (0.76%), is highly specialised in Climate Change (SI = 2.56), and has a high growth ratio (GR = 2.20). Portugal exhibits high growth, high citation impact (ARC = 1.38) and a very strong impact for its publications with Norwegian authors (3.48). Other countries of interest, whether for their output, SI, ARC or affinity for collaborating with Norway, include New Zealand, the US, Austria, Canada and Belgium.

Table X Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Climate Change (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	**FULL**	**FRAC**	**GR**	**SI**	**ARC**	**FULL**	**ARC**	**FRAC**	**Coll. Rate**	**GR**	**for NO**	**of NO**
World	**270,112**	**270,112**	**1.80**	**1.00**	**1.00**	**3,154**	**1.73**	**746**	**0.28%**	**1.10**	**n.a.**	**n.a.**
Nordic	**17,641**	**11,852**	**1.63**	**1.68**	**1.43**	**953**	**2.06**	**133**	**1.51%**	**1.10**	**n.a.**	**n.a.**
Norway	5,070	3,013	1.91	2.40	1.49	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	451	213	1.18	3.04	1.40	84	2.42	7	3.28%	0.66	n.c.	n.c.
Denmark (EU-15/28)	4,044	2,238	1.80	1.48	1.60	350	2.28	34	1.53%	0.95	n.c.	n.c.
Finland (EU-15/28)	3,783	2,484	1.50	1.66	1.43	283	2.23	28	1.14%	1.28	n.c.	n.c.
Sweden (EU-15/28)	6,477	3,904	1.48	1.45	1.53	546	2.08	64	1.64%	1.19	n.c.	n.c.
EU-28	**107,042**	**89,590**	**1.72**	**1.11**	**1.17**	**2,312**	**1.89**	**447**	**0.50%**	**1.08**	**n.a.**	**n.a.**
EU-15	**99,320**	**81,358**	**1.69**	**1.14**	**1.22**	**2,261**	**1.91**	**428**	**0.53%**	**1.09**	**n.a.**	**n.a.**
Austria	3,201	1,804	1.90	1.14	1.45	123	2.53	9	0.47%	1.05	n.c.	n.c.
Belgium	3,698	2,132	1.59	0.95	1.45	118	3.50	7	0.35%	0.79	n.c.	n.c.
France	16,357	10,387	1.52	1.03	1.32	447	2.73	36	0.34%	1.10	n.c.	n.c.
Germany	22,730	14,884	1.57	1.08	1.32	675	2.42	69	0.46%	1.21	1.50	n.c.
Greece	2,150	1,575	1.86	0.94	1.14	58	2.94	2	0.15%	2.09	n.c.	n.c.
Ireland	1,406	856	2.33	0.96	1.56	49	4.01	2	0.27%	0.53	n.c.	n.c.
Italy	10,819	7,602	1.70	0.92	1.20	208	3.19	13	0.18%	1.34	1.18	n.c.
Luxembourg	110	48	2.89	0.98	1.42	2	n.c.	0	0.11%	n.c.	n.c.	n.c.
Netherlands	8,682	5,164	1.68	1.23	1.57	350	2.57	30	0.59%	1.06	1.82	n.c.
Portugal	2,359	1,515	2.56	1.17	1.36	47	3.48	3	0.19%	1.33	n.c.	n.c.
Spain	10,826	7,761	2.17	1.14	1.28	200	2.47	19	0.25%	0.75	n.c.	n.c.
United Kingdom	28,419	19,007	1.69	1.30	1.48	921	2.33	111	0.59%	1.17	1.90	n.c.
Bulgaria	415	263	1.66	0.78	0.71	13	n.c.	1	0.19%	n.c.	n.c.	n.c.
Croatia	708	579	2.15	1.00	0.51	12	n.c.	1	0.15%	n.c.	n.c.	n.c.
Cyprus	185	98	3.30	1.23	1.22	5	n.c.	0	0.04%	n.c.	n.c.	n.c.
Czech Republic	1,825	1,334	1.96	0.87	0.91	47	3.26	2	0.15%	8.73	n.c.	n.c.
Estonia	675	417	2.20	2.56	1.34	51	2.64	3	0.76%	0.47	n.c.	n.c.
Hungary	1,292	959	2.07	1.07	0.83	16	n.c.	2	0.19%	n.c.	n.c.	n.c.
Latvia	166	114	3.92	1.38	1.26	9	n.c.	0	0.24%	n.c.	n.c.	n.c.
Lithuania	435	354	2.67	1.29	0.83	10	n.c.	1	0.15%	n.c.	n.c.	n.c.
Malta	42	27	1.69	1.24	0.91	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Poland	3,104	2,415	1.61	0.72	0.69	92	2.57	7	0.30%	0.80	n.c.	n.c.
Romania	1,106	862	5.36	0.87	0.61	25	n.c.	1	0.17%	n.c.	n.c.	n.c.
Slovakia	557	374	1.63	0.82	0.85	16	n.c.	0	0.10%	n.c.	n.c.	n.c.
Slovenia	630	436	1.85	0.97	0.79	15	n.c.	1	0.14%	n.c.	n.c.	n.c.
Argentina	2,481	1,783	1.81	1.79	0.93	19	n.c.	1	0.03%	n.c.	n.c.	n.c.
Australia	15,161	10,977	2.27	1.87	1.36	160	3.38	12	0.11%	2.38	n.c.	n.c.
Brazil	6,421	5,086	2.36	0.99	0.84	37	3.14	2	0.03%	1.40	n.c.	n.c.
Canada	17,173	12,146	1.57	1.47	1.28	346	2.94	30	0.25%	1.60	1.80	n.c.
Chile	1,585	944	1.73	1.64	1.11	22	n.c.	1	0.12%	n.c.	n.c.	n.c.
China	30,288	25,948	2.91	0.69	0.73	187	1.82	27	0.10%	0.93	1.35	n.c.
Colombia	696	392	3.31	1.17	1.18	3	n.c.	0	0.02%	n.c.	n.c.	n.c.
Egypt	689	469	1.91	0.56	0.50	4	n.c.	0	0.04%	n.c.	n.c.	n.c.
India	7,649	6,578	2.46	0.82	0.70	33	n.c.	4	0.06%	2.85	n.c.	n.c.
Indonesia	675	308	2.17	2.12	1.06	6	n.c.	1	0.33%	n.c.	n.c.	n.c.
Iran	2,019	1,750	4.97	0.64	0.61	2	n.c.	1	0.03%	n.c.	n.c.	n.c.
Israel	1,942	1,329	1.29	0.75	1.14	21	n.c.	1	0.11%	n.c.	n.c.	n.c.
Japan	12,464	9,838	1.28	0.60	0.83	142	2.79	8	0.09%	2.36	n.c.	n.c.
Malaysia	1,454	1,130	6.78	0.96	0.96	6	n.c.	1	0.06%	n.c.	n.c.	n.c.
Mexico	2,591	1,817	1.69	1.17	0.78	15	n.c.	1	0.07%	n.c.	n.c.	n.c.
New Zealand	3,377	2,079	1.53	2.04	1.34	59	2.35	4	0.21%	8.48	n.c.	n.c.
Nigeria	537	429	2.66	0.85	0.42	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	585	426	3.52	0.66	0.70	2	n.c.	0	0.01%	n.c.	n.c.	n.c.
Rep. of Korea	4,244	3,224	2.49	0.50	0.88	24	n.c.	1	0.02%	n.c.	n.c.	n.c.
Russia	5,163	3,692	1.13	0.79	0.66	166	1.89	18	0.49%	1.47	n.c.	n.c.
Singapore	812	558	2.66	0.41	1.46	5	n.c.	0	0.03%	n.c.	n.c.	n.c.
South Africa	2,817	1,873	1.71	1.77	1.20	57	2.97	6	0.32%	1.53	n.c.	n.c.
Switzerland	7,073	3,893	1.67	1.45	1.68	254	3.02	21	0.54%	1.87	1.64	n.c.
Taiwan	2,754	2,216	2.67	0.51	0.90	19	n.c.	3	0.15%	n.c.	n.c.	n.c.
Thailand	1,095	734	2.56	0.87	0.94	2	n.c.	0	0.00%	n.c.	n.c.	n.c.
Turkey	2,518	2,156	2.19	0.61	1.00	13	n.c.	2	0.08%	n.c.	n.c.	n.c.
United States	85,026	68,514	1.53	1.09	1.26	924	2.37	125	0.18%	1.23	1.13	n.c.
Viet Nam	265	111	2.20	0.94	0.89	1	n.c.	0	0.30%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

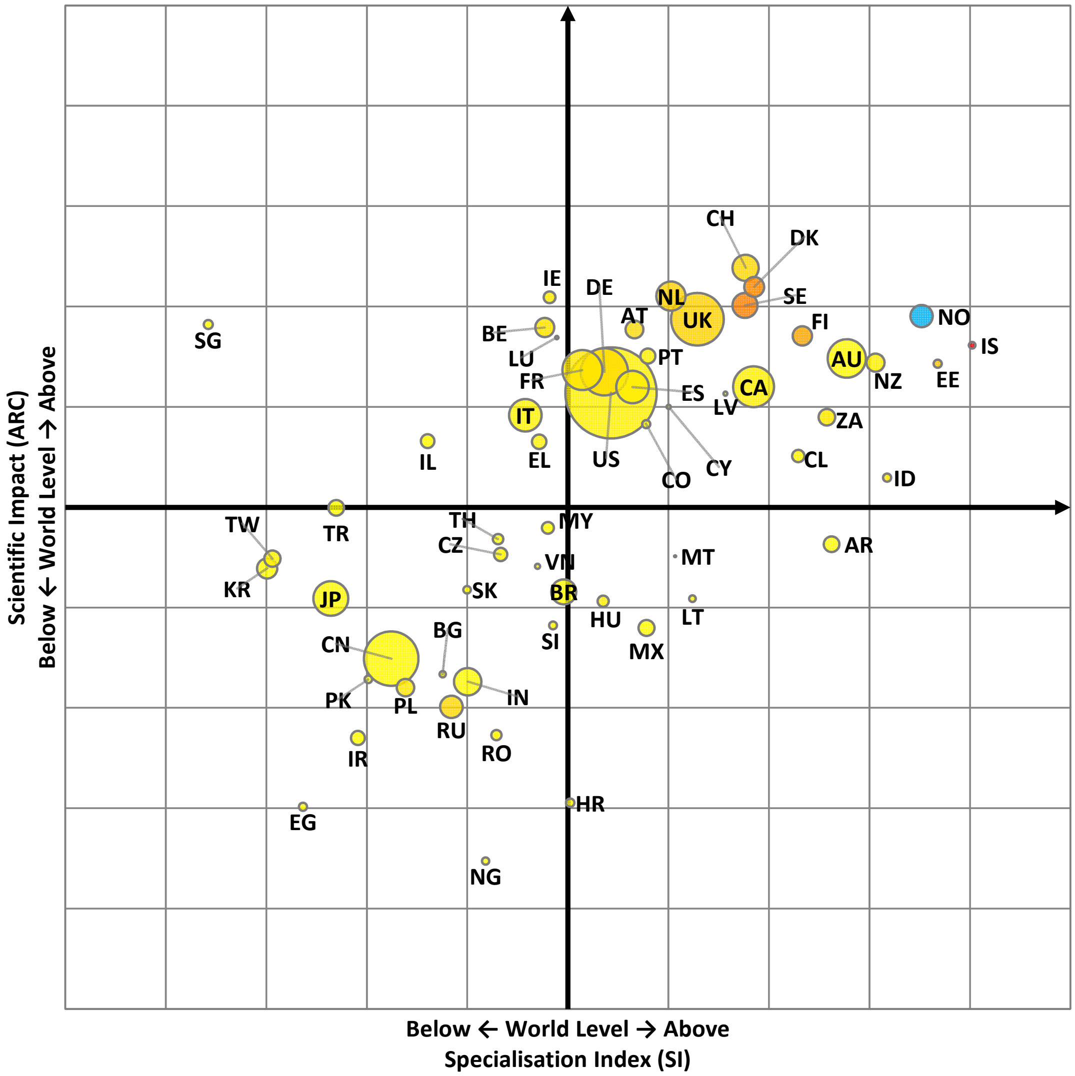


Figure 13 Positional analysis of selected countries in Climate Change with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.8 Profiles of Selected Countries in Environmental Technology

As Table XI indicates, 337,813 scientific papers in Environmental Technology were produced globally from 2003 to 2012. Norway contributed 2,048 publications (FULL; 1,387 FRAC) to this field. Its growth ratio (GR = 1.50) is below the world level (1.74), but above average for the Nordic countries as a whole (GR = 1.32). Norway (SI = 0.88) is less specialised than the other Nordic countries in general (SI = 1.09), although it exhibits a high average of relative citations in Environment (ARC=1.60) and is only second to Denmark (ARC=1.81) among the Nordic countries in this field. This general performance puts Norway in 13th place in relation to the 57 selected countries considering all indicators combined.

Very few affinities between countries could be computed and analysis relies on counts and shares of co-publications with Norway. As usual, the US partners the highest number of publications with Norway (194 FULL), followed closely by the UK (180 FULL). However, the co-publication output with Norway relative to other countries represents only 0.05% of the total US production in this theme, in contrast to 0.19% for the UK. The world share of collaboration with Norway in this strategic theme is as low as 0.08%. Given their strategic importance, Norway should consider increasing collaboration with these countries.

Sweden (179 FULL; Collaboration Rate = 0.77%), Germany (153; 0.18%), the Netherlands (118, 0.32%) and Canada (101; 0.12%) follow as concerns co-publication output with Norway. Of these countries, the Netherlands stands out in terms of general performance (i.e. all indicators included), primarily for its ARC (1.78) and its large share of co-publications with Norway (0.32%). Canada is noteworthy because of its global output (15,207 FULL) and impact (ARC = 1.25) in this field, while also being slightly specialised (SI = 1.15). In addition, Canada already shows a strong affinity for collaborating with Norway (2.53). This cooperation could be reinforced as the two countries significantly increase their scientific impact on their co-publications. As one of the Nordic countries, Sweden already shares a high portion of its co-publications with Norway. Given its overall performance, particularly in terms of general impact (ARC=1.38) and specific co-publication impact (ARC=2.79), collaboration with Sweden should be encouraged.

Strategic partners for improving Norway's impact in Environmental Technology (see Figure 14) include Switzerland, Malaysia, Portugal, Denmark, Spain, Singapore, Australia, Canada and China as these countries are top ranking considering all indicators combined. Collaboration is presently below expectations and effort should be made to build stronger scientific relations with these countries, especially with **Malaysia, Spain, Australia** and **China.**

At the micro-level, the top institutions in Environmental Technologies for these countries are: **ETHZ** (Switzerland), **University of Science** (Malaysia), **New University of Lisbon** and **University of Porto** (Portugal), **DTU** and **Aalborg University** (Denmark), **CSIC** and **University of Santiago de Compostela** (Spain), **Nanyang Technological University** (Singapore), **CSIRO** and **University of Queensland** (Australia), **University of Waterloo** (Canada) and **Tongji University** and **Chinese Academy of Sciences** (China).

Other potential partners for Norway in Environmental Technology include Malaysia, Switzerland, Portugal, Denmark, Spain, Singapore and Australia. These countries are top ranking considering all indicators combined. Malaysia exhibits very high growth (GR = 5.35) and SI (2.07)and its impact is above the world level (ARC = 1.12). Because Malaysia's share of co-publications with Norway is still very low (0.03%), Norway would benefit from reinforcing its collaboration with this country. Switzerland's strength lies mainly in its high impact (ARC=1.97), which reflects on its co-publications impact with Norway (ARC of co-publications with Norway = 2.84). Since Portugal performs well in terms of growth, SI and impact in Environmental Technology, Norway should consider increasing collaborative research with this partner. Denmark has the third best overall impact in this strategic field and its collaboration with Norway is highly beneficial to both countries, as reflected by the highest impact of all the selected countries (ARC = 4.10). Spain and Australia rank among top producers in this area and present ARC values above the world level. Singapore ranks second among the 58 selected countries in terms of impact (ARC=1.82), although its output is still fairly low in this strategic theme.

Finally, China and India are worthy of note for their performance in Environmental Technology. They both combine high output, growth ratio and specialisation index. Although their scientific impact is still close to or below the world level, these countries are likely to become important players in this strategic field in the years to come.

Table XI Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Environmental Technology (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	**FULL**	**FRAC**	**GR**	**SI**	**ARC**	**FULL**	**ARC**	**FRAC**	**Coll. Rate**	**GR**	**for NO**	**of NO**
World	**337,813**	**337,813**	**1.74**	**1.00**	**1.00**	**1,081**	**1.89**	**276**	**0.08%**	**1.06**	**n.a.**	**n.a.**
Nordic	**12,494**	**9,623**	**1.32**	**1.09**	**1.42**	**290**	**2.81**	**50**	**0.61%**	**1.30**	**n.a.**	**n.a.**
Norway	2,048	1,387	1.50	0.88	1.60	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	91	42	1.41	0.49	1.36	11	n.c.	3	5.95%	n.c.	n.c.	n.c.
Denmark (EU-15/28)	3,078	2,082	1.47	1.10	1.81	83	4.10	10	0.48%	1.47	n.c.	n.c.
Finland (EU-15/28)	2,742	2,167	1.41	1.16	1.17	51	1.86	8	0.35%	0.71	n.c.	n.c.
Sweden (EU-15/28)	5,253	3,945	1.15	1.17	1.38	179	2.79	30	0.77%	1.60	n.c.	n.c.
EU-28	**106,151**	**94,542**	**1.52**	**0.94**	**1.19**	**763**	**2.10**	**168**	**0.18%**	**1.11**	**n.a.**	**n.a.**
EU-15	**93,446**	**81,426**	**1.44**	**0.91**	**1.27**	**710**	**2.18**	**152**	**0.19%**	**1.16**	**n.a.**	**n.a.**
Austria	2,729	2,006	1.42	1.02	1.19	32	n.c.	3	0.17%	4.03	n.c.	n.c.
Belgium	4,090	2,964	1.45	1.06	1.46	52	3.78	5	0.15%	1.47	n.c.	n.c.
France	13,623	10,321	1.49	0.82	1.21	100	2.19	11	0.10%	1.17	n.c.	n.c.
Germany	15,916	12,175	1.36	0.70	1.21	153	2.58	22	0.18%	1.21	2.36	n.c.
Greece	3,505	2,989	1.48	1.43	1.25	27	n.c.	4	0.13%	n.c.	n.c.	n.c.
Ireland	1,366	1,033	2.13	0.93	1.43	15	n.c.	1	0.12%	n.c.	n.c.	n.c.
Italy	10,895	9,075	1.55	0.88	1.21	73	1.99	10	0.11%	1.41	n.c.	n.c.
Luxembourg	135	77	3.07	1.25	1.12	5	n.c.	0	0.29%	n.c.	n.c.	n.c.
Netherlands	6,565	4,605	1.23	0.88	1.58	118	2.69	15	0.32%	0.79	n.c.	n.c.
Portugal	3,595	2,880	2.16	1.79	1.37	25	n.c.	2	0.08%	n.c.	n.c.	n.c.
Spain	13,370	11,131	1.78	1.31	1.41	47	2.26	5	0.04%	0.60	n.c.	n.c.
United Kingdom	18,419	13,975	1.21	0.77	1.36	180	2.45	27	0.19%	1.28	2.26	n.c.
Bulgaria	595	441	1.39	1.04	0.69	3	n.c.	0	0.01%	n.c.	n.c.	n.c.
Croatia	854	738	1.56	1.02	0.61	7	n.c.	1	0.14%	n.c.	n.c.	n.c.
Cyprus	258	151	3.06	1.52	1.58	1	n.c.	0	0.01%	n.c.	n.c.	n.c.
Czech Republic	2,057	1,696	1.93	0.89	0.91	18	n.c.	2	0.13%	n.c.	n.c.	n.c.
Estonia	373	296	1.82	1.45	0.91	20	n.c.	3	1.17%	n.c.	n.c.	n.c.
Hungary	1,295	1,048	1.70	0.94	0.74	17	n.c.	2	0.17%	n.c.	n.c.	n.c.
Latvia	218	190	4.68	1.84	0.66	2	n.c.	0	0.01%	n.c.	n.c.	n.c.
Lithuania	533	467	2.23	1.36	1.20	7	n.c.	0	0.09%	n.c.	n.c.	n.c.
Malta	54	40	1.69	1.45	1.13	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Poland	5,045	4,512	1.81	1.07	0.65	37	1.20	5	0.11%	1.35	n.c.	n.c.
Romania	2,467	2,151	6.12	1.73	0.56	10	n.c.	2	0.08%	n.c.	n.c.	n.c.
Slovakia	634	499	1.47	0.87	0.68	9	n.c.	0	0.04%	n.c.	n.c.	n.c.
Slovenia	1,096	887	1.71	1.58	0.94	7	n.c.	0	0.03%	n.c.	n.c.	n.c.
Argentina	1,451	1,207	1.84	0.97	0.87	2	n.c.	0	0.02%	n.c.	n.c.	n.c.
Australia	10,535	8,248	1.74	1.12	1.44	29	n.c.	5	0.06%	n.c.	n.c.	n.c.
Brazil	8,208	7,261	2.13	1.13	0.79	11	n.c.	1	0.02%	n.c.	n.c.	n.c.
Canada	15,207	11,869	1.37	1.15	1.25	101	2.43	14	0.12%	0.80	2.53	n.c.
Chile	1,172	825	1.67	1.15	1.31	5	n.c.	0	0.04%	n.c.	n.c.	n.c.
China	62,260	58,301	3.21	1.24	0.80	56	1.99	11	0.02%	0.99	n.c.	n.c.
Colombia	781	514	3.61	1.23	0.89	1	n.c.	0	0.06%	n.c.	n.c.	n.c.
Egypt	2,248	1,799	1.80	1.71	0.75	4	n.c.	1	0.06%	n.c.	n.c.	n.c.
India	18,791	17,473	2.19	1.74	0.90	17	n.c.	3	0.01%	n.c.	n.c.	n.c.
Indonesia	566	311	3.10	1.71	0.82	3	n.c.	0	0.03%	n.c.	n.c.	n.c.
Iran	5,578	5,130	4.17	1.50	0.92	1	n.c.	0	0.01%	n.c.	n.c.	n.c.
Israel	1,633	1,298	1.44	0.59	1.32	5	n.c.	0	0.02%	n.c.	n.c.	n.c.
Japan	16,585	14,543	1.17	0.71	0.87	24	n.c.	4	0.03%	n.c.	n.c.	n.c.
Malaysia	3,577	3,042	5.35	2.07	1.12	4	n.c.	1	0.03%	n.c.	n.c.	n.c.
Mexico	3,425	2,771	1.77	1.43	0.81	5	n.c.	0	0.01%	n.c.	n.c.	n.c.
New Zealand	1,867	1,345	1.36	1.05	1.48	10	n.c.	1	0.10%	n.c.	n.c.	n.c.
Nigeria	1,503	1,320	2.44	2.09	0.47	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	1,283	1,024	2.87	1.26	0.99	3	n.c.	1	0.07%	n.c.	n.c.	n.c.
Rep. of Korea	10,326	8,795	1.81	1.09	1.06	5	n.c.	1	0.01%	n.c.	n.c.	n.c.
Russia	2,396	1,900	1.06	0.32	0.47	27	n.c.	4	0.19%	n.c.	n.c.	n.c.
Singapore	1,993	1,514	1.65	0.88	1.82	6	n.c.	1	0.07%	n.c.	n.c.	n.c.
South Africa	2,464	1,985	1.42	1.50	0.88	14	n.c.	3	0.16%	n.c.	n.c.	n.c.
Switzerland	4,288	2,898	1.32	0.86	1.97	43	2.84	5	0.16%	1.62	n.c.	n.c.
Taiwan	6,030	5,451	1.69	1.00	1.10	2	n.c.	0	0.00%	n.c.	n.c.	n.c.
Thailand	2,362	1,838	2.40	1.74	1.02	10	n.c.	3	0.14%	n.c.	n.c.	n.c.
Turkey	5,445	4,928	1.67	1.11	1.29	3	n.c.	1	0.01%	n.c.	n.c.	n.c.
United States	72,778	62,771	1.27	0.80	1.12	194	1.78	32	0.05%	1.60	1.31	n.c.
Viet Nam	361	169	2.99	1.15	0.95	3	n.c.	0	0.29%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

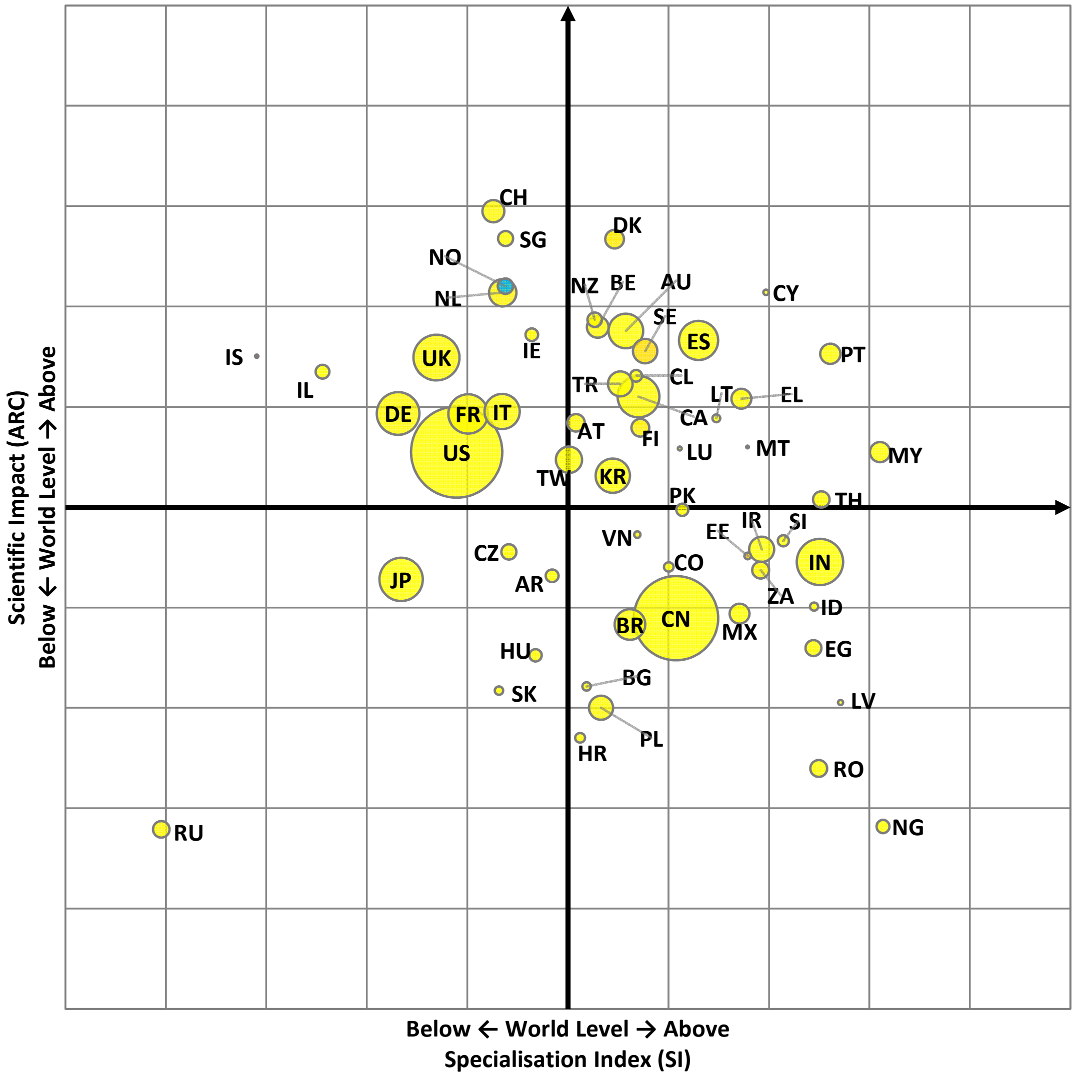


Figure 14 Positional analysis of selected countries in Environmental Technology with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.9 Profiles of Selected Countries in Fisheries & Aquaculture

Table XII examines the strategic theme of Fisheries & Aquaculture, listing the number of papers based on full and fractional publication counts, including GR, SI and ARC for Norway, the 57 selected countries and Nordic and EU country aggregates. Furthermore, statistics for collaborations with Norway are provided. As expected, Norway ranks among the top 10 largest producers of output in Fisheries & Aquaculture and is extremely specialised in this area, producing almost seven times as much output as expected. In fact, among the 15 strategic themes analysed in this study, the only other theme where Norway is more specialised is Arctic & Antarctic Research (Section 3.2). With an SI of 10.94, only Iceland, the country with the highest collaboration rate for Norway, is more specialised in Fisheries & Aquaculture. The largest producers of overall output in Fisheries & Aquaculture are the US (number of publications FULL

= 30,412; FRAC 25,279), Canada (10,285; 7,510), China (9,205; 8,270), Japan (8,449; 7,307), the UK (7,994; 5,101); Australia (6,230; 4,711), Spain (6,158; 4,676), France (6,006; 4,047), Norway (5,216; 3,701) and Brazil (4,412; 3,866), based on full publications. When considering fractional counts, Canada and China as well as Norway and Brazil respectively change places for second and ninth position among the largest producers. Among the top 10, China and Brazil increased their output from 2003–2007 and 2008–2012 by 174% and 137%, respectively.

In comparison to the 34% global growth ratio for Fisheries & Aquaculture, Norway's growth was only 18%, representing a relative decline. Publications co-authored by Latvian researchers receive the highest impact, although Latvia only published 43 papers in this research area over the 10-year period, most likely co-authored with partners from multinational collaborations as indicated by the low number of fractional papers. Denmark (ARC = 1.59), Switzerland (1.58), the Netherlands (1.55), Sweden (1.49), the UK (1.47), Belgium (1.43) and Norway (1.40) are all cited at least 40% more than the average Fisheries & Aquaculture paper.

Slightly more than half of Norwegian papers in Fisheries & Aquaculture are co-published internationally. Norway collaborates most frequently with the UK (number of co-publications with Norway = 599), the US (454) and Canada (435), followed by Nordic partners Denmark (274) and Sweden (266). Citation impact is high and above expectations for all of these collaborations. Overall, international co-publications increase Norway's impact from an ARC of 1.40 for all publications to 1.61 for internationally co-authored papers. However, the most beneficial partnerships from a citation impact perspective are with the Netherlands (ARC of co-publications with Norway = 2.51), Belgium (2.32), Germany (2.20) and France (2.14). Co-publications with Russia (1.47), Ireland (1.39), South Africa (1.39), Finland (1.39) and Iceland (1.34) do not meet expectations. Among the countries with ARCs above 1.40, Norway does not yet collaborate frequently with Switzerland or Belgium. As expected, neither country is specialised in Fisheries & Aquaculture. It would thus be more advisable to further increase collaborations with existing partners with high specialisation and citation rates such as Denmark (SI=1.86; ARC=1.59) and Canada (2.10; 1.36). Both countries already have strong connections to Norway and Canadian researchers co-publish more than twice as many papers with Norwegian colleagues than expected (Coll. Affinity for NO = 2.08).

Norway leads in Fisheries & Aquaculture considering countries' overall performance (see Figure 15), followed by Iceland, Denmark, Canada, Australia, Portugal, Spain, New Zealand and the UK. **Portugal** can be identified as strategic partner to counter Norway's relative decline in output. The strong partnership with **Denmark** should be further intensified to increase citation impact.

Organisations that stand out in this strategic field in the above countries, and with which Norway should consider reinforcing collaboration include: **Matís ltd. - Icelandic Food and Biotech R&D** (Iceland), **DTU** (Denmark), **University of British Columbia** and **Dalhousie University** (Canada), **CSIRO** and **Australian Research Council** (Australia), **University of Aveiro** (Portugal), **Spanish National Research Council** (Spain) and **Imperial College London** (UK).

Based on overall scientific performance in Fisheries & Aquaculture, including publication output, growth, specialisation and particularly impact, Norway clearly leads the field. It is highly specialised and well received in terms of citations. However, because its growth ratio remains far behind worldwide growth in this theme, its global output is declining in relative terms. Iceland, Denmark, Canada, Australia, Portugal and the UK follow in terms of overall performance and

Norway is well connected with all of these countries except Portugal. Although its ARC is lower than that of Norwegian papers, Portugal's growth ratio might be a reason to collaborate with this country. Existing co-publications with Portugal are also cited 2.01 times on average. Among current partnerships, it would be advisable to further increase collaborations with Denmark due its significantly higher ARC.

Table XII Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Fisheries & Aquaculture (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**117,484**	**117,484**	**1.34**	**1.00**	**1.00**	**2,674**	**1.61**	**641**	**0.56%**	**1.00**	**n.a.**	**n.a.**
Nordic	**9,822**	**7,326**	**1.13**	**2.39**	**1.37**	**704**	**1.74**	**115**	**3.18%**	**1.22**	**n.a.**	**n.a.**
Norway	5,216	3,701	1.18	6.77	1.40	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	553	333	1.56	10.94	1.15	149	1.34	19	5.73%	0.87	n.c.	n.c.
Denmark (EU-15/28)	2,017	1,225	1.14	1.86	1.59	274	2.00	38	3.11%	1.47	n.c.	n.c.
Finland (EU-15/28)	1,195	880	0.88	1.35	1.10	114	1.39	19	2.10%	1.20	n.c.	n.c.
Sweden (EU-15/28)	1,933	1,187	1.10	1.01	1.49	266	2.02	39	3.32%	1.07	n.c.	n.c.
EU-28	**37,256**	**31,241**	**1.20**	**0.89**	**1.20**	**1,720**	**1.73**	**360**	**1.15%**	**1.02**	**n.a.**	**n.a.**
EU-15	**34,082**	**27,904**	**1.16**	**0.90**	**1.25**	**1,675**	**1.75**	**346**	**1.24%**	**1.06**	**n.a.**	**n.a.**
Austria	547	296	1.14	0.43	1.14	57	1.91	8	2.55%	0.83	n.c.	n.c.
Belgium	1,435	900	1.07	0.93	1.43	61	2.32	8	0.93%	1.37	n.c.	n.c.
France	6,006	4,047	1.17	0.92	1.29	219	2.14	27	0.67%	1.47	n.c.	n.c.
Germany	4,171	2,632	1.10	0.44	1.36	188	2.20	21	0.80%	1.21	n.c.	n.c.
Greece	1,120	818	1.08	1.13	1.22	34	n.c.	4	0.44%	0.81	n.c.	n.c.
Ireland	841	529	1.25	1.37	1.15	91	1.39	8	1.56%	0.74	n.c.	n.c.
Italy	3,603	2,770	1.17	0.77	1.13	125	1.66	17	0.60%	0.93	n.c.	n.c.
Luxembourg	12	7	2.51	0.33	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Netherlands	1,906	1,146	1.15	0.63	1.55	161	2.51	19	1.70%	2.06	n.c.	n.c.
Portugal	2,369	1,691	1.55	3.01	1.20	78	2.01	11	0.66%	0.81	n.c.	n.c.
Spain	6,158	4,676	1.31	1.58	1.23	196	2.06	26	0.56%	1.06	n.c.	n.c.
United Kingdom	7,994	5,101	1.04	0.80	1.47	599	1.80	100	1.97%	0.90	n.c.	n.c.
Bulgaria	138	82	2.19	0.56	0.73	2	n.c.	0	0.11%	n.c.	n.c.	n.c.
Croatia	556	470	1.34	1.88	0.65	7	n.c.	2	0.39%	n.c.	n.c.	n.c.
Cyprus	17	6	3.12	0.17	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Czech Republic	986	751	1.64	1.13	1.07	24	n.c.	3	0.42%	n.c.	n.c.	n.c.
Estonia	152	90	1.22	1.27	1.25	15	n.c.	2	2.00%	n.c.	n.c.	n.c.
Hungary	363	261	1.12	0.67	1.09	2	n.c.	0	0.16%	n.c.	n.c.	n.c.
Latvia	43	17	1.24	0.47	2.29	2	n.c.	1	3.77%	n.c.	n.c.	n.c.
Lithuania	123	84	2.67	0.70	0.98	12	n.c.	2	2.25%	n.c.	n.c.	n.c.
Malta	34	9	2.13	0.99	n.c.	1	n.c.	0	0.01%	n.c.	n.c.	n.c.
Poland	1,452	1,198	1.57	0.82	0.67	29	n.c.	4	0.36%	n.c.	n.c.	n.c.
Romania	254	210	10.15	0.48	0.66	2	n.c.	0	0.02%	n.c.	n.c.	n.c.
Slovakia	103	57	0.94	0.28	1.17	2	n.c.	0	0.05%	n.c.	n.c.	n.c.
Slovenia	177	102	1.53	0.52	1.04	4	n.c.	0	0.13%	n.c.	n.c.	n.c.
Argentina	1,076	861	1.74	1.99	0.90	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Australia	6,230	4,711	1.30	1.84	1.32	134	1.84	19	0.40%	1.71	n.c.	n.c.
Brazil	4,412	3,866	2.37	1.73	0.86	16	n.c.	1	0.04%	n.c.	n.c.	n.c.
Canada	10,285	7,510	1.08	2.10	1.36	435	2.04	67	0.90%	1.02	2.08	n.c.
Chile	1,422	1,027	1.58	4.11	0.90	46	1.51	6	0.63%	1.89	n.c.	n.c.
China	9,205	8,270	2.74	0.51	0.91	58	1.52	10	0.12%	2.28	n.c.	n.c.
Colombia	272	170	2.19	1.17	0.78	7	n.c.	2	0.90%	n.c.	n.c.	n.c.
Egypt	612	449	2.21	1.22	0.69	1	n.c.	1	0.11%	n.c.	n.c.	n.c.
India	4,028	3,690	1.89	1.05	0.67	28	n.c.	4	0.11%	n.c.	n.c.	n.c.
Indonesia	321	129	2.05	2.03	0.84	1	n.c.	0	0.02%	n.c.	n.c.	n.c.
Iran	1,217	1,063	6.18	0.89	0.54	8	n.c.	2	0.16%	n.c.	n.c.	n.c.
Israel	620	440	0.76	0.57	1.09	11	n.c.	1	0.18%	n.c.	n.c.	n.c.
Japan	8,449	7,307	1.01	1.02	0.69	63	1.88	9	0.12%	2.61	n.c.	n.c.
Malaysia	1,058	755	3.93	1.48	0.87	9	n.c.	2	0.22%	n.c.	n.c.	n.c.
Mexico	2,408	1,898	1.45	2.81	0.77	12	n.c.	0	0.02%	n.c.	n.c.	n.c.
New Zealand	1,623	1,084	1.23	2.44	1.25	46	1.69	6	0.59%	1.25	n.c.	n.c.
Nigeria	580	527	2.65	2.40	0.43	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	290	232	2.57	0.82	0.73	1	n.c.	0	0.02%	n.c.	n.c.	n.c.
Rep. of Korea	2,221	1,832	2.20	0.66	0.93	12	n.c.	2	0.09%	n.c.	n.c.	n.c.
Russia	1,955	1,616	1.54	0.79	0.41	86	1.47	15	0.90%	1.16	n.c.	n.c.
Singapore	368	242	1.11	0.41	1.09	3	n.c.	0	0.10%	n.c.	n.c.	n.c.
South Africa	1,224	871	1.40	1.89	1.18	56	1.39	9	1.00%	1.15	n.c.	n.c.
Switzerland	808	411	1.31	0.35	1.58	29	n.c.	2	0.49%	n.c.	n.c.	n.c.
Taiwan	1,588	1,399	1.33	0.74	0.96	11	n.c.	1	0.10%	n.c.	n.c.	n.c.
Thailand	1,663	1,258	1.85	3.43	0.69	15	n.c.	2	0.16%	n.c.	n.c.	n.c.
Turkey	1,887	1,709	1.92	1.11	0.75	11	n.c.	1	0.08%	n.c.	n.c.	n.c.
United States	30,412	25,279	1.05	0.92	1.15	454	1.84	72	0.29%	1.15	0.89	n.c.
Viet Nam	462	184	2.27	3.60	0.98	25	n.c.	6	3.30%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

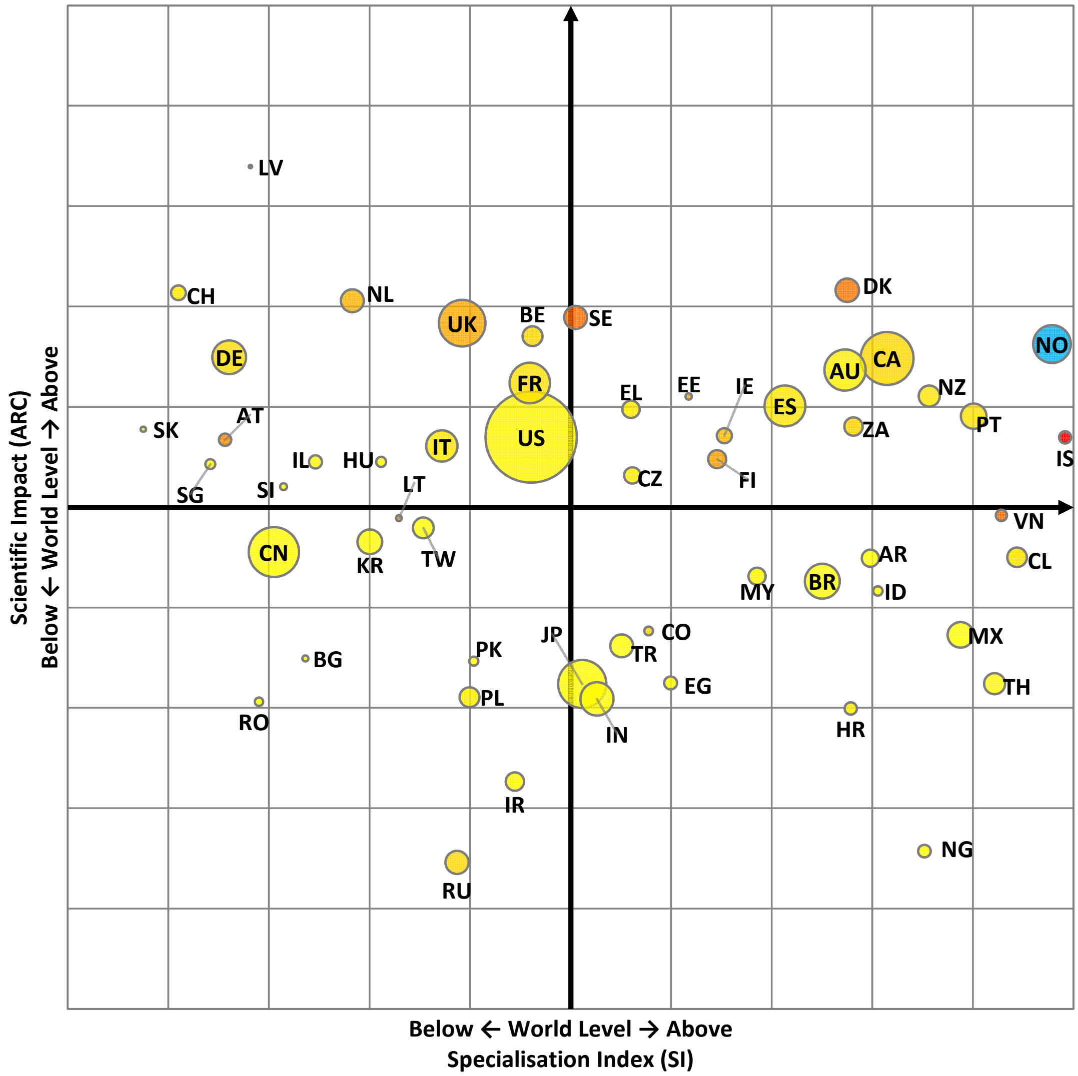


Figure 15 Positional analysis of selected countries in Fisheries & Aquaculture with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.10 Profiles of Selected Countries in Food Sciences

Norway published more than 5,500 publications (FULL, 33rd) in Food Sciences from 2003 to 2012. Although it is specialised in this theme (SI 1.21) and has a high scientific impact (ARC 1.43), its output (GR = 1.22) is growing less rapidly than at the theme level (1.50).

Norway's main collaborators in co-publications are the US (914 FULL; ARC 1.34), the UK (887 FULL; ARC 1.52), Sweden (682 FULL; ARC 1.56), Denmark (618 FULL; ARC 1.60), France (517 FULL; ARC 1.34), Germany (508 FULL; ARC 1.32) and the Netherlands (489 FULL; ARC 1.68). All these countries are strong performers in this theme, having a high scientific impact. In fact, judging by the number of co-publications, China in 15th position is Norway's only top collaborator with an ARC score below the world level (ARC = 0.83 for 133 co-publications FULL).

This is highly indicative of the quality of Norway's collaborators and the appropriateness of the current focus of its collaborations. In addition to the above-mentioned countries, other leaders with which Norway frequently collaborates include Switzerland (ARC = 1.66), Finland (1.47), Belgium (1.43), Australia (1.37), Spain (1.33) and Canada (1.32). Norway should continue to focus on these countries as they are leaders in Food Sciences. Among all the above-mentioned countries, only the US (0.08%) has a share of publications in collaboration with Norway that is below the world level of 0.11%. However, the US still exhibits an affinity for Norway (1.14), indicating that, based on its collaboration patterns, the US collaborates more than expected with Norway, but still collaborates less than most other countries all things being equal. Norway would benefit from strengthening its partnership with the US since it is the clear leader in output and produces high impact papers. Scores of affinity for Norway could only be computed for five other countries, which all present a strong affinity for collaborating with Norway: the Netherlands (Collaboration Affinity for Norway = 2.77), the UK (2.08), Canada (1.96), Italy (1.84) and Germany (1.45).

Strategic partners for improving the scientific impact of Norway's output in Food Sciences (see Figure 16) include the Netherlands, Ireland, Denmark, Switzerland, Spain, Luxembourg, the UK, Australia, the US, Belgium, New Zealand and Singapore. Among those listed above, the **US** and **Singapore** have a share of co-publications with Norway below the world level.

Organisations that stand out based on output, specialisation or impact in Food Science for these strategic countries include: **WUR** (the Netherlands), **University College Dublin** (Ireland), **University of Aarhus** (Denmark), **Spanish National Research Council** (Spain), **CSIRO** (Australia), **US Department of Agriculture and University of California – Davis** (US), **Ghent University** (Belgium) and **Massey University** (New Zealand).

Given its impact (ARC = 1.51), Ireland should also be considered. Even though Ireland's share of publications with Norway (0.13%) stands slightly above the world level, this share represents only 92 co-publications (fewer than 10 per year) and Norway would benefit from increasing collaborations with this country.

Three of the countries that very rarely collaborate with Norway are of particular interest: Singapore (Collaboration Rate = 0.02%), Luxembourg and Malaysia. For the first two — Singapore and Luxembourg — the output is relatively small compared to other countries and neither are specialized (SI = 0.30 and 0.74, respectively). However, they perform high impact science as expressed by their ARC (1.51 and 1.45, respectively). With fewer than 10 co-publications in the 10-year period, Norway does not actually collaborate with these countries. Accordingly, strong gains could be made in terms of both output and impact if Norway were to develop partnerships with these countries. As Luxembourg's output is relatively low, bibliometrics would be needed to identify institutions and/or researchers with which collaborations would be most beneficial for Norway. The case of Malaysia is different; Norway should consider it in its strategic plan not particularly because of its output but rather because of its strong growth. Malaysia published about 8,500 publications in this theme, which is close to the same amount as Norway, but is experiencing a tremendous annual increase in output as expressed by its growth ratio (GR = 4.88). While Malaysia's impact is slightly below the world level (ARC = 0.92), such growth could represent an excellent opportunity in the future when Malaysia's impact begins to increase. Added to this is the fact that it is quite difficult to maintain high impact with a rapidly growing output.

Thus, Malaysia's performance should be closely observed in the near future to assess the advantages of undertaking targeted collaborations with high impact institutions in this country.

Finally, co-publications with China, which were fairly rare over the 10-year period (133 FULL), rank 5th in terms of impact (ARC of co-publications with Norway = 3.23), behind co-publications with the Czech Republic (5.00), Poland (4.03), Slovakia (3.54) and Switzerland (3.28). While China's impact on its own is low (ARC=0.83), it ranks 2nd in output with 122,000 publications and experienced tremendous growth (GR = 2.41) over the period under study. Given that China's impact is on the rise in most scientific areas, and based on the high impact of Norway-China co-publications, it would be wise to include China in Norway's collaboration strategy in Food Science, at least in some form since it is bound to become one of the future leaders in this theme.

Table XIII Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Food (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**1,032,258**	**1,032,258**	**1.50**	**1.00**	**1.00**	**4,543**	**1.66**	**1,083**	**0.11%**	**0.95**	**n.a.**	**n.a.**
Nordic	**40,101**	**29,585**	**1.11**	**1.10**	**1.46**	**1,296**	**2.05**	**203**	**0.85%**	**1.13**	**n.a.**	**n.a.**
Norway	8,524	5,833	1.22	1.21	1.42	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	679	376	1.63	1.40	1.24	124	1.54	13	3.43%	1.37	n.c.	n.c.
Denmark (EU-15/28)	12,687	8,541	1.09	1.47	1.60	618	2.42	73	0.85%	0.97	n.c.	n.c.
Finland (EU-15/28)	8,181	6,028	1.12	1.05	1.47	296	2.64	32	0.54%	1.00	n.c.	n.c.
Sweden (EU-15/28)	13,455	8,808	1.06	0.85	1.56	682	2.42	85	0.96%	1.28	n.c.	n.c.
EU-28	**342,519**	**298,536**	**1.31**	**0.97**	**1.19**	**2,951**	**1.82**	**585**	**0.20%**	**1.01**	**n.a.**	**n.a.**
EU-15	**298,136**	**252,879**	**1.24**	**0.93**	**1.28**	**2,800**	**1.86**	**541**	**0.21%**	**1.04**	**n.a.**	**n.a.**
Austria	7,574	4,754	1.25	0.79	1.38	105	2.98	11	0.23%	1.15	n.c.	n.c.
Belgium	14,791	10,329	1.24	1.21	1.43	163	2.62	15	0.15%	1.30	n.c.	n.c.
France	44,451	31,278	1.17	0.81	1.34	517	2.72	48	0.15%	1.12	n.c.	n.c.
Germany	53,625	38,855	1.14	0.73	1.32	508	2.69	51	0.13%	1.07	1.45	n.c.
Greece	8,702	7,056	1.38	1.11	1.19	127	3.07	3	0.04%	0.53	n.c.	n.c.
Ireland	7,089	5,134	1.52	1.51	1.51	92	2.31	7	0.13%	0.69	n.c.	n.c.
Italy	39,163	31,489	1.43	1.00	1.15	320	2.85	19	0.06%	1.25	1.84	n.c.
Luxembourg	288	139	4.08	0.74	1.45	9	n.c.	0	0.17%	n.c.	n.c.	n.c.
Netherlands	22,855	15,127	1.15	0.94	1.68	489	2.65	50	0.33%	1.02	2.77	n.c.
Portugal	8,333	6,192	1.94	1.26	1.26	84	3.02	8	0.12%	1.47	n.c.	n.c.
Spain	46,497	37,548	1.46	1.44	1.33	349	2.69	27	0.07%	1.61	n.c.	n.c.
United Kingdom	60,471	41,601	1.08	0.75	1.52	887	2.45	113	0.27%	1.11	2.08	n.c.
Bulgaria	2,462	1,930	1.73	1.49	0.58	17	n.c.	1	0.07%	n.c.	n.c.	n.c.
Croatia	3,719	3,176	1.73	1.44	0.59	30	n.c.	2	0.07%	1.69	n.c.	n.c.
Cyprus	366	180	2.97	0.59	1.11	5	n.c.	0	0.02%	n.c.	n.c.	n.c.
Czech Republic	10,221	8,592	1.95	1.47	0.83	85	5.00	7	0.09%	1.59	n.c.	n.c.
Estonia	1,131	827	1.95	1.33	1.16	42	1.86	4	0.49%	0.78	n.c.	n.c.
Hungary	6,832	5,385	1.29	1.58	0.73	34	n.c.	4	0.07%	2.63	n.c.	n.c.
Latvia	487	374	4.24	1.18	0.72	13	n.c.	1	0.19%	n.c.	n.c.	n.c.
Lithuania	1,747	1,472	2.50	1.40	0.68	26	n.c.	3	0.18%	n.c.	n.c.	n.c.
Malta	61	39	1.19	0.46	1.10	3	n.c.	0	0.19%	n.c.	n.c.	n.c.
Poland	18,488	16,212	1.61	1.26	0.68	123	4.03	14	0.09%	0.94	n.c.	n.c.
Romania	3,501	2,947	5.46	0.78	0.53	18	n.c.	2	0.08%	n.c.	n.c.	n.c.
Slovakia	3,167	2,424	1.36	1.38	0.72	36	3.54	4	0.15%	0.87	n.c.	n.c.
Slovenia	2,665	2,099	1.86	1.22	0.91	22	n.c.	2	0.08%	n.c.	n.c.	n.c.
Argentina	11,622	9,433	1.63	2.48	0.93	11	n.c.	1	0.01%	n.c.	n.c.	n.c.
Australia	37,003	27,829	1.27	1.24	1.37	218	3.00	33	0.12%	1.36	n.c.	n.c.
Brazil	57,155	52,233	2.33	2.67	0.74	35	n.c.	4	0.01%	3.31	n.c.	n.c.
Canada	43,298	32,387	1.17	1.03	1.32	315	2.64	47	0.15%	1.38	1.96	n.c.
Chile	5,090	3,647	1.93	1.66	0.92	32	n.c.	3	0.08%	1.59	n.c.	n.c.
China	121,644	110,856	2.41	0.77	0.83	133	3.23	21	0.02%	1.02	n.c.	n.c.
Colombia	3,585	2,365	3.33	1.85	0.85	14	n.c.	3	0.11%	n.c.	n.c.	n.c.
Egypt	7,360	5,541	2.89	1.72	0.76	12	n.c.	2	0.04%	n.c.	n.c.	n.c.
India	61,185	57,106	1.83	1.86	0.65	54	1.52	9	0.02%	1.26	n.c.	n.c.
Indonesia	2,401	1,184	2.40	2.13	0.95	8	n.c.	1	0.08%	n.c.	n.c.	n.c.
Iran	19,044	17,205	4.29	1.65	0.71	18	n.c.	2	0.01%	n.c.	n.c.	n.c.
Israel	6,974	5,144	1.09	0.76	1.32	27	n.c.	3	0.06%	n.c.	n.c.	n.c.
Japan	54,534	46,878	1.06	0.75	0.88	102	2.42	12	0.03%	0.85	n.c.	n.c.
Malaysia	8,475	7,220	4.88	1.61	0.92	10	n.c.	2	0.03%	n.c.	n.c.	n.c.
Mexico	14,045	10,718	1.69	1.81	0.82	37	1.32	5	0.05%	1.18	n.c.	n.c.
New Zealand	11,622	8,475	1.19	2.17	1.32	94	3.20	13	0.15%	0.96	n.c.	n.c.
Nigeria	9,913	8,753	1.80	4.53	0.39	6	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	8,569	7,362	2.84	2.97	0.84	10	n.c.	2	0.02%	n.c.	n.c.	n.c.
Rep. of Korea	25,381	21,607	2.25	0.88	0.87	22	n.c.	2	0.01%	n.c.	n.c.	n.c.
Russia	9,661	7,808	1.04	0.44	0.50	84	2.49	12	0.15%	1.21	n.c.	n.c.
Singapore	2,432	1,577	1.30	0.30	1.51	5	n.c.	0	0.02%	n.c.	n.c.	n.c.
South Africa	10,376	7,748	1.48	1.91	0.96	87	2.24	12	0.15%	1.17	n.c.	n.c.
Switzerland	13,717	8,439	1.19	0.82	1.66	143	3.28	10	0.12%	1.86	n.c.	n.c.
Taiwan	11,157	9,959	1.61	0.60	0.98	8	n.c.	1	0.01%	n.c.	n.c.	n.c.
Thailand	9,660	7,428	2.34	2.30	0.89	25	n.c.	4	0.05%	n.c.	n.c.	n.c.
Turkey	21,931	20,163	1.67	1.49	0.84	16	n.c.	2	0.01%	n.c.	n.c.	n.c.
United States	226,571	187,417	1.12	0.78	1.34	914	2.13	152	0.08%	0.95	1.14	n.c.
Viet Nam	1,986	824	2.02	1.84	1.14	27	n.c.	5	0.64%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

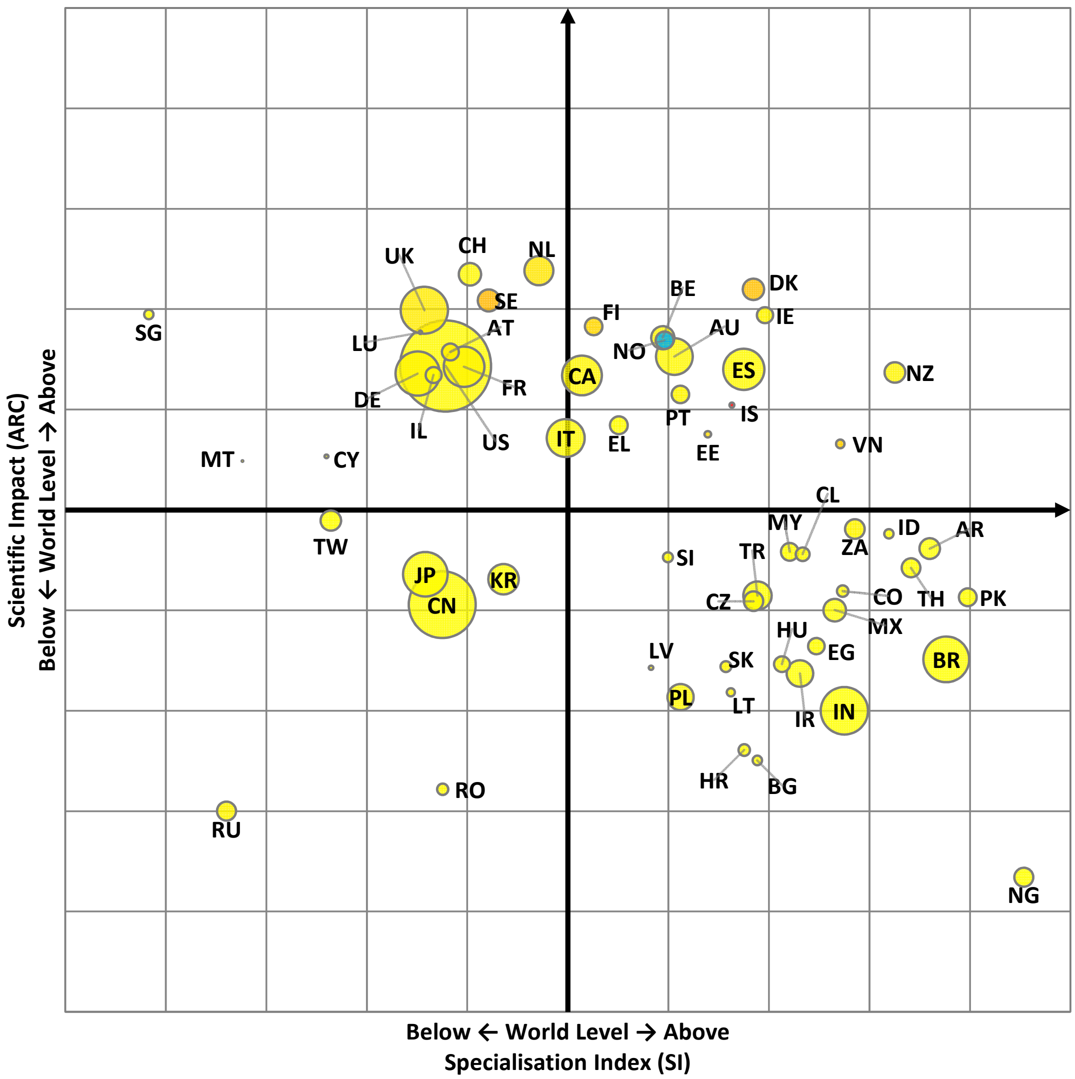


Figure 16 Positional analysis of selected countries in Food Sciences with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.11 Profiles of Selected Countries in Health & Care

Norway published close to 48,000 publications in Health & Care (FULL, 28th), which is by far the largest theme in this study. Norway is slightly specialized in this area (SI = 1.10), with an output growing approximately at the same rate (GR = 1.31) as that of the world rate (1.26) and a scientific impact close to the other leaders in the theme (ARC = 1.46, 8th).

At 6,800 (FULL), the US has the highest number of co-publications with Norway, although this number is relatively low compared to those of other countries with far smaller outputs in the theme. In fact, Sweden co-published 5,800 publications with Norway based on an output of 116,000 papers in Health & Care overall, which represents approximately one-twentieth of the US output. This difference is clearly highlighted by these countries' affinity index for Norway, the US showing a slight affinity (Collaboration Affinity for Norway = 1.08) while Sweden has a strong affinity (6.56). The United Kingdom ranks third in terms of co-publications (5,300 FULL) and also has positive affinity for Norway (1.54), while Denmark, in fourth place (3,600 FULL), has the strongest affinity for Norway of the entire selection (6.69). Of the 26 countries for which an affinity for Norway could be computed, 18 show preferential collaboration patterns with Norway, with the Nordic countries unsurprisingly topping the list, followed by the Netherlands (2.40), Ireland (2.38) and Austria (1.94).

Overall, leaders in Health & Care are all specialised in this theme and have a high scientific impact. These leaders include the Netherlands, the US, the Nordic countries (Sweden, Denmark, Iceland and Finland), Switzerland, Canada, the UK, Belgium, Australia and Ireland. All these countries share another common trait, i.e., they all exhibit a positive affinity for collaborating with Norway. From Norway's perspective, the affinity is mutual, except for three countries with which Norway collaborates less than expected according to the affinity index: the US (0.46), Canada (0.80) and Australia (0.90). While Norway should consider increasing its collaborations with all the above countries, significant gains could be made by focusing on the US, Canada and Australia, as these partnerships appear to be underexploited. This is particularly true for the US, which has by far the highest output in the theme and with which Norway collaborates 54% less than expected. Collaborations with the remaining leaders for which Norway exhibits a strong affinity could also result in solid benefits for Norway. However, these collaborations might be more difficult to put in place given Norway's current involvement with these countries. This is especially the case for the Nordic countries, in particular Iceland, with which Norway collaborates 16 times more than expected. Nevertheless, strengthening partnerships with these countries would help solidify Norway's position as a world leader in this theme. Collaborations with Iceland could be particularly beneficial since it achieves the highest ARC among the selection (1.88).

Strategic partners for improving the scientific impact of Norway's output in Health & Care (see Figure 17) include the Netherlands, the US, Denmark, Iceland, Switzerland, Canada, the UK, Belgium, Sweden, Australia, Ireland and Singapore. Of these, Norway collaborates less than expected with the **US**, **Singapore**, **Canada** and **Australia**. Given the strong growth of its output, its high scientific impact and the mutual affinity between both countries, **Luxembourg** should also be considered for increased collaborations.

At the micro-level, Norway should consider the following organisations (among many others) that stand out in Health & Care in the above countries: **Academic Medical Centre** and **Erasmus MC** (the Netherlands), **Brigham and Women's Hospital** and **National Institutes of Health** (US), **Copenhagen University Hospital** (Denmark), **DeCODE Genetics** (Iceland), **University Hospital of Zürich** (Switzerland), **University Health Network** (Canada), **Medical Research Council** (UK), **UZ Leuven** (Belgium), **Karolinska Institute** and **Karolinska University Hospital** (Sweden), **University of Melbourne** and **University of Sydney** (Australia), **Trinity College Dublin** (Ireland) and **Singapore National Eye Center** (Singapore).

Luxembourg is an interesting case for Norway in Health & Care because it dedicates a much larger part of its output to collaborations with Norway (0.64%) than the world on average (0.07%), ranking fourth between Denmark (0.74%) and Finland (0.37%) for this indicator. This strong relation is reciprocal, as expressed by Norway's 7.03 affinity score for Luxembourg. Although

Luxembourg's output is relatively small (2,100 FULL), it has grown at a much higher rate (GR=2.13) than the world level (1.26) and the country has a relatively strong impact in this research area (ARC = 1.28). While more investigation might be needed to identify institutions and/or researchers that Norway could collaborate with given the low volume of output in the theme in Luxembourg, strengthening this partnership could prove beneficial to both countries, especially from Luxembourg's perspective.

Table XIV Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Health & Care (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**6,552,871**	**6,552,871**	**1.26**	**1.00**	**1.00**	**23,051**	**1.99**	**4,824**	**0.07%**	**1.26**	**n.a.**	**n.a.**
Nordic	**264,030**	**200,166**	**1.14**	**1.17**	**1.44**	**8,620**	**2.36**	**1,264**	**0.76%**	**1.30**	**n.a.**	**n.a.**
Norway	47,942	33,418	1.31	1.10	1.46	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	3,560	1,933	1.49	1.14	1.88	492	3.66	28	1.44%	0.82	n.c.	16.51
Denmark (EU-15/28)	69,504	48,013	1.25	1.30	1.60	3,619	2.86	355	0.74%	1.12	6.69	6.82
Finland (EU-15/28)	50,043	35,873	1.05	0.99	1.51	1,910	3.48	132	0.37%	1.29	5.16	4.95
Sweden (EU-15/28)	116,137	80,929	1.06	1.23	1.52	5,817	2.45	750	0.93%	1.41	6.56	6.66
EU-28	**2,425,050**	**2,172,053**	**1.16**	**1.11**	**1.07**	**16,821**	**2.17**	**2,949**	**0.14%**	**1.34**	**n.a.**	**n.a.**
EU-15	**2,231,741**	**1,974,671**	**1.15**	**1.14**	**1.12**	**16,251**	**2.22**	**2,800**	**0.14%**	**1.35**	**n.a.**	**n.a.**
Austria	63,233	42,866	1.07	1.12	1.36	900	3.85	45	0.11%	1.93	1.94	1.86
Belgium	91,454	61,623	1.17	1.14	1.57	1,246	4.41	65	0.11%	1.78	1.44	1.80
France	323,892	255,324	1.07	1.04	1.10	2,416	3.61	141	0.06%	1.12	1.24	1.02
Germany	474,696	374,509	1.10	1.12	1.22	3,550	3.51	291	0.08%	1.67	1.51	1.04
Greece	55,393	44,466	1.31	1.10	1.02	712	4.34	16	0.04%	1.20	n.c.	1.67
Ireland	33,495	23,634	1.61	1.10	1.36	512	4.49	19	0.08%	1.13	2.38	1.96
Italy	294,916	240,589	1.18	1.20	1.19	2,256	4.34	118	0.05%	1.34	1.66	1.05
Luxembourg	2,089	983	2.13	0.82	1.28	125	2.92	6	0.64%	1.36	n.c.	7.03
Netherlands	186,736	136,847	1.26	1.35	1.62	2,808	3.70	203	0.15%	1.40	2.40	2.03
Portugal	33,153	24,196	1.93	0.77	1.10	526	4.22	31	0.13%	1.11	n.c.	2.03
Spain	212,721	175,092	1.28	1.06	1.00	1,803	4.31	78	0.04%	1.34	1.67	1.15
United Kingdom	561,851	429,727	1.10	1.21	1.40	5,284	3.33	551	0.13%	1.41	1.54	1.31
Bulgaria	8,527	6,480	1.04	0.79	0.60	77	5.73	3	0.05%	0.83	n.c.	1.11
Croatia	18,377	16,028	1.37	1.15	0.53	159	2.96	11	0.07%	1.35	n.c.	1.09
Cyprus	2,013	1,074	2.58	0.56	1.08	27	n.c.	1	0.05%	n.c.	n.c.	1.57
Czech Republic	43,454	35,560	1.23	0.96	0.73	485	6.03	27	0.08%	1.37	n.c.	1.44
Estonia	3,940	2,381	1.38	0.60	1.30	189	4.97	8	0.32%	0.80	n.c.	5.75
Hungary	28,806	21,003	1.12	0.97	0.97	359	5.35	17	0.08%	3.27	n.c.	1.59
Latvia	1,549	950	2.14	0.47	1.12	54	5.50	3	0.28%	0.89	n.c.	4.06
Lithuania	4,850	3,559	1.06	0.53	0.82	156	4.42	11	0.30%	0.81	n.c.	3.88
Malta	933	599	2.53	1.13	1.18	33	3.29	0	0.02%	5.64	n.c.	4.05
Poland	92,043	79,453	1.16	0.97	0.61	749	5.23	45	0.06%	1.20	n.c.	1.07
Romania	15,785	12,899	2.94	0.53	0.61	148	4.81	6	0.04%	0.84	n.c.	1.17
Slovakia	12,689	9,526	1.16	0.86	0.66	202	4.55	12	0.13%	0.94	n.c.	1.98
Slovenia	10,538	7,871	1.52	0.72	0.86	184	2.25	6	0.08%	0.71	n.c.	2.16
Argentina	30,753	23,598	1.35	0.98	0.95	130	9.63	3	0.01%	0.97	n.c.	0.54
Australia	203,687	156,640	1.36	1.10	1.38	1,353	3.96	124	0.08%	1.65	1.45	0.90
Brazil	161,128	143,010	1.80	1.15	0.77	418	5.61	35	0.02%	1.48	0.93	0.35
Canada	293,304	220,539	1.25	1.10	1.46	1,719	4.38	145	0.07%	1.34	1.48	0.80
Chile	17,400	13,040	1.54	0.93	0.83	70	4.82	4	0.03%	1.52	n.c.	0.50
China	500,327	454,352	1.83	0.50	0.58	586	3.59	64	0.01%	1.82	0.98	0.16
Colombia	11,671	8,388	2.40	1.03	0.75	55	6.86	1	0.02%	4.69	n.c.	0.58
Egypt	23,482	17,597	2.35	0.86	0.74	49	2.59	3	0.02%	2.10	n.c.	0.26
India	180,315	166,603	2.05	0.85	0.64	202	4.82	20	0.01%	1.04	0.52	0.15
Indonesia	4,271	2,128	2.00	0.60	1.13	25	n.c.	2	0.09%	n.c.	n.c.	0.70
Iran	53,259	48,799	3.44	0.74	0.60	66	3.38	5	0.01%	1.19	0.64	0.16
Israel	64,395	50,051	1.00	1.17	1.23	487	3.96	33	0.07%	1.14	1.69	0.99
Japan	464,140	419,486	1.01	1.05	0.78	641	3.94	50	0.01%	1.45	0.79	0.19
Malaysia	19,274	15,491	3.15	0.54	0.68	32	n.c.	1	0.01%	0.24	n.c.	0.21
Mexico	40,710	32,621	1.30	0.87	0.74	132	9.92	7	0.02%	1.16	n.c.	0.42
New Zealand	35,779	25,436	1.33	1.03	1.29	296	4.42	24	0.09%	1.10	1.74	1.06
Nigeria	18,021	16,114	1.93	1.31	0.44	21	n.c.	2	0.01%	n.c.	n.c.	0.15
Pakistan	18,362	15,928	2.29	1.01	0.56	43	5.58	3	0.02%	4.29	n.c.	0.29
Rep. of Korea	145,567	128,344	1.91	0.82	0.92	219	4.24	14	0.01%	1.00	n.c.	0.20
Russia	54,353	44,948	1.00	0.40	0.47	418	3.88	48	0.11%	1.22	n.c.	1.00
Singapore	31,765	22,266	1.38	0.67	1.39	151	5.85	4	0.02%	3.20	0.88	0.61
South Africa	31,892	22,952	1.58	0.89	1.16	442	2.93	46	0.20%	2.54	n.c.	1.77
Switzerland	124,153	78,245	1.18	1.20	1.60	1,266	4.25	77	0.10%	1.48	1.34	1.36
Taiwan	87,195	77,908	1.47	0.74	0.93	128	4.66	6	0.01%	1.50	0.96	0.19
Thailand	27,981	20,501	1.56	1.00	0.97	67	6.99	3	0.02%	1.20	n.c.	0.30
Turkey	119,243	111,635	1.32	1.30	0.57	225	5.33	13	0.01%	0.63	0.98	0.25
United States	2,141,028	1,865,042	1.13	1.22	1.41	6,825	2.80	877	0.05%	1.30	1.08	0.46
Viet Nam	3,756	1,573	2.02	0.55	1.33	36	n.c.	4	0.24%	3.11	n.c.	1.15

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

Analyses of countries' impact scores on their co-publications with Norway present an interesting picture since most of the leaders for this indicator are not leaders in this research area in terms of output and impact. For instance, Mexico, which has an overall ARC of 0.74 in Health & Care, scores a massive 9.92 for its co-publications with Norway. Similarly, Argentina is in second place (ARC of co-publications with Norway = 9.63; number of publications FULL = 30,753; ARC = 0.95), followed by Thailand (6.99; 27,981; 0.97), Colombia (6.86; 11,671; 0.75) and the Czech Republic (0.73; 43,454; 6.03). While these impact scores are impressive, they are based on only a few co-publications and are most likely due to multilateral projects involving a huge number of researchers from different countries and resulting in high visibility and high citation scores.

At the world level, co-publications with Norway achieve an ARC score of 1.99 and most countries in the selection rank well above this level, making it difficult to identify potential partners based on this indicator. Nevertheless, the case of Singapore is worth mentioning given that its co-publications with Norway (151 FULL) are cited almost six times as often as the average Health & Care paper (ARC=5.91), while its overall score is a respectable 1.41, putting it almost on par with Norway (1.49). Since neither Norway nor Singapore present a positive affinity for each other, and their co-publications are highly cited in the literature, it might be pertinent for Norway to keep an eye on Singapore in the near future since developing a strategic partnership with this country could lead to in mutual benefits for both countries.

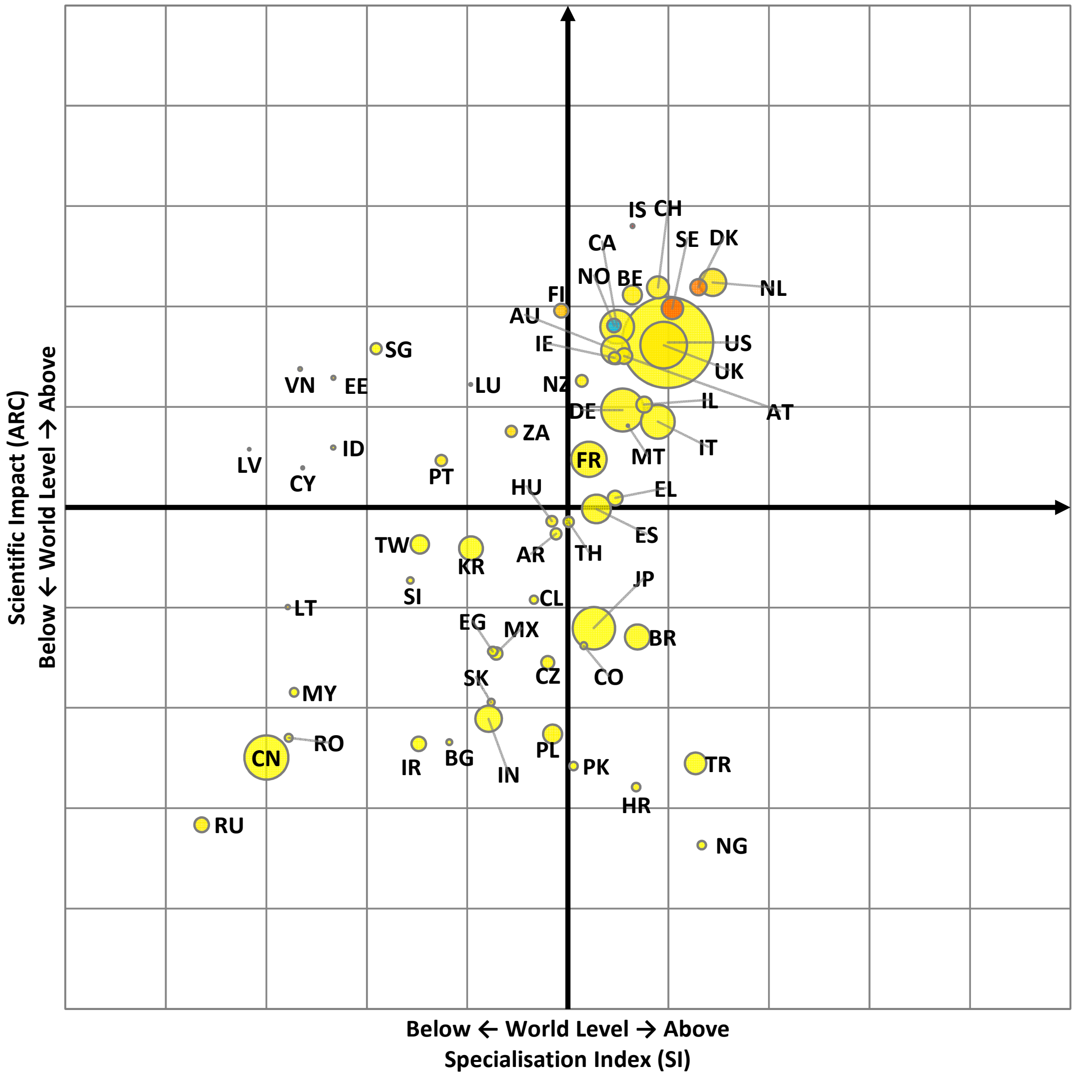


Figure 17 Positional analysis of selected countries in Health & Care with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.12 Profiles of Selected Countries in Information & Communication Technologies

Norway is not specialised in Information & Communication Technologies (ICT), publishing 16% fewer papers than expected (10,700 FULL; SI=0.84) between 2003 and 2012. Nevertheless, it does have a high scientific impact as expressed by an ARC of 1.27. This is similar to the other Nordic countries, which are also not specialised but have a high impact(with the exception of Finland), show a high level of specialisation and publish 42% more in ICT than expected (SI=1.42). While global research in this theme is growing rapidly, with an increase of 60% over the period, growth was even slightly higher for Norway (GR = 1.69).

With the exception of Japan, all the major publishing countries in ICT are included among Norway's top collaborators. The US ranks first (782 co-publications FULL), followed by the UK (635 FULL), Germany (623 FULL), France (562 FULL), Sweden (441 FULL) and China (418 FULL). Of these, only China is specialized in ICT research (SI=1.58). Although affinity scores could only be computed for a few countries, it is worth noting that all the selected countries had a positive affinity for Norway apart from Japan (Collaboration Affinity for Norway = 0.85). Consequently, the US (1.20), the UK (1.62), Germany (2.10) and China (2.64) all present strong affinities for collaborating with Norway in ICT. With the exception of the US and China, which only published 0.06% and 0.02% of their total output in collaboration with Norway, all these countries had a share above the world level (0.08%). However, given the volume of their respective outputs, it is expected that their share would be lower since their output is much larger than that of most countries.

It is reassuring for Norway to note that, except for China (ARC = 0.63), all these countries have a high scientific impact, which indicates that Norway's current collaborators are good strategic partners for improving global impact. This is particularly true for the US, which has an ARC of 1.59, one the highest among all countries, and which also produced the second largest output (436,000 FULL) in this theme after China (453,000 FULL). The UK also has an extremely high scientific impact (ARC = 1.44). Finally, the growth of China's output is worth mentioning (GR = 2.48) since it one of the strongest and is coupled with the largest output, which is quite remarkable. Although still lacking impact for now, China has already taken over the ICT strategic theme in terms of raw output and should be kept in mind for future collaborations even though its impact has not yet attained satisfactory levels.

Strategic partners for improving the scientific impact of Norway's output in ICT (see Figure 18) include the US, the UK, Israel, Singapore, Switzerland, Iceland, the Netherlands, Denmark, Canada, Turkey, Ireland, Taiwan and Luxembourg. Of these, **Israel**, the **US**, **Taiwan** and **Turkey** have lower shares of co-publications with Norway than the world average. Finland, Greece and India could also be considered; the first two due to their high impact, specialisation and proven capacity to produce high impact co-publications with Norway, and India for its high impact co-publications and the tremendous growth of its already large output.

Institutions that stand out in ICT in these strategic countries include: **Georgia Institute of Technology** and **Massachusetts Institute of Technology** (US), **University of Southampton** (UK), **Technion** (Israel), **Nanyang Technological University** (Singapore), **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **Reykjavik University** (Iceland), **TUDelft** (the Netherlands), **Aalborg University** (Denmark), **University of Waterloo** (Canada), **Middle East Technical University** (Turkey), **National Chiao Tung University** (Taiwan), **University of Luxembourg** (Luxembourg), **Aalto University** (Finland) and **University of Patras** (Greece).

Other than the above top collaborators (US, UK, Germany, Sweden, France), high impact countries with smaller outputs include Switzerland (ARC = 1.96), Iceland (1.85), Israel (1.78), Belgium (1.58), the Netherlands (1.50), Denmark (1.39) and Canada (1.38). These countries all stand out, but only for their impact. Since they all have a higher scientific impact than Norway (ARC=1.27), they would represent strong opportunities for Norway to increase its own impact through partnerships. Of these countries, Israel (Collaboration Rate = 0.06%) is the only one that allocates a smaller share of its publications to co-publications with Norway than the average at the world level (0.08%). Intensification of co-authorship with all the above countries, but especially with Israel, would probably benefit Norway in the future.

Other countries are notable for more than one indicator. For instance, Singapore (ARC = 1.60; SI = 1.96), Ireland (1.28; 1.29) and Taiwan (1.25; 1.89) stand out for their impact and specialisation. Turkey would be a good partner according to its impact and growth in output (ARC = 1.37; GR = 1.84), and Luxembourg scores well all round, with an output close to 1,500 publications (FULL), but especially in terms of specialisation and growth (ARC = 1.20; SI = 2.44; GR = 4.18). Note that, apart from Turkey and Taiwan, these countries all dedicate a share of their output to collaboration with Norway above the world average. Partnerships in the Middle East and Asia could potentially thrive if collaborations with both countries were to be intensified, serving as starting points in both regions.

In terms of co-publication impact, India, Greece and Finland should be considered in Norway's strategic plan. Both Greece (ARC = 1.15) and Finland (1.14) are cited above the world average, although they do not particularly stand out. However, both countries are highly specialised, as indicated by SIs of 1.49 and 1.42, respectively, and their collaborations with Norway are among the most cited (ARC of co-publications with Norway of 2.29 and 2.25, respectively). Finland is of particular interest since it is, as mentioned earlier, the only specialised Nordic country in this strategic theme, which would bode well for increasing collaboration between both countries. India obtained the second highest impact score for papers in co-publication with Norway (ARC = 3.20). New Zealand was not considered because of the low number of co-publications. While India on its own has a relatively low impact (ARC=0.73), its output is sizeable (62,300 FULL) and is growing tremendously, tripling in ICT from the first to the second five-year period analysed (GR = 3.21). Microanalyses would be needed to identify which collaborations with which institutions produced these high impact papers (see companion database), which would then make it possible to focus on specific collaborations to produce high quality science and take advantage of India's rapidly growing scientific output.

Table XV Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Information & Communication Technologies (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**1,962,525**	**1,962,525**	**1.60**	**1.00**	**1.00**	**5,074**	**1.72**	**1,518**	**0.08%**	**1.30**	**n.a.**	**n.a.**
Nordic	**60,800**	**46,878**	**1.40**	**0.92**	**1.25**	**767**	**1.66**	**173**	**0.44%**	**1.38**	**n.a.**	**n.a.**
Norway	10,673	7,653	1.69	0.84	1.27	0	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	800	437	2.81	0.86	1.85	21	n.c.	2	0.44%	n.c.	n.c.	n.c.
Denmark (EU-15/28)	10,811	7,586	1.51	0.69	1.39	227	1.86	50	0.66%	1.08	n.c.	n.c.
Finland (EU-15/28)	19,153	15,432	1.24	1.42	1.14	163	2.25	28	0.18%	1.92	n.c.	n.c.
Sweden (EU-15/28)	21,278	15,770	1.38	0.80	1.30	441	1.53	94	0.59%	1.35	n.c.	n.c.
EU-28	**595,204**	**532,219**	**1.50**	**0.91**	**1.15**	**3,170**	**1.76**	**844**	**0.16%**	**1.43**	**n.a.**	**n.a.**
EU-15	**537,524**	**473,724**	**1.45**	**0.92**	**1.20**	**2,966**	**1.80**	**773**	**0.16%**	**1.43**	**n.a.**	**n.a.**
Austria	18,451	14,081	1.68	1.23	1.19	159	2.07	27	0.19%	1.59	n.c.	n.c.
Belgium	18,461	13,606	1.43	0.84	1.58	109	1.35	14	0.10%	1.33	n.c.	n.c.
France	86,800	67,497	1.48	0.92	1.18	562	2.08	115	0.17%	1.19	n.c.	n.c.
Germany	109,254	88,084	1.52	0.88	1.20	623	2.53	117	0.13%	1.42	2.10	n.c.
Greece	21,924	18,083	1.42	1.49	1.15	171	2.29	34	0.19%	1.87	n.c.	n.c.
Ireland	10,881	8,328	1.44	1.29	1.28	80	1.41	10	0.12%	1.87	n.c.	n.c.
Italy	66,548	54,138	1.41	0.90	1.26	284	1.91	42	0.08%	1.27	1.84	n.c.
Luxembourg	1,463	875	4.18	2.44	1.20	29	n.c.	4	0.43%	n.c.	n.c.	n.c.
Netherlands	33,132	24,344	1.41	0.80	1.50	309	1.95	52	0.21%	1.96	n.c.	n.c.
Portugal	15,618	12,526	2.04	1.34	0.92	59	1.56	8	0.06%	0.71	n.c.	n.c.
Spain	60,584	49,693	1.67	1.00	1.20	305	1.80	56	0.11%	1.30	n.c.	n.c.
United Kingdom	109,538	83,678	1.26	0.79	1.44	635	1.71	122	0.15%	1.79	1.62	n.c.
Bulgaria	2,535	1,928	1.79	0.78	0.48	22	n.c.	5	0.25%	n.c.	n.c.	n.c.
Croatia	3,816	3,376	1.85	0.81	0.53	15	n.c.	1	0.04%	n.c.	n.c.	n.c.
Cyprus	1,830	1,189	2.32	2.06	1.00	17	n.c.	3	0.25%	n.c.	n.c.	n.c.
Czech Republic	12,001	10,066	2.00	0.91	0.86	74	1.33	16	0.16%	3.26	n.c.	n.c.
Estonia	1,144	904	2.67	0.76	1.03	27	n.c.	3	0.36%	n.c.	n.c.	n.c.
Hungary	7,302	5,630	1.43	0.87	0.97	44	1.14	8	0.14%	1.66	n.c.	n.c.
Latvia	895	802	3.99	1.33	0.70	9	n.c.	2	0.22%	n.c.	n.c.	n.c.
Lithuania	2,160	1,927	2.41	0.96	0.75	13	n.c.	1	0.05%	n.c.	n.c.	n.c.
Malta	289	231	3.73	1.45	0.78	14	n.c.	4	1.58%	n.c.	n.c.	n.c.
Poland	20,522	17,402	1.71	0.71	0.78	68	1.86	12	0.07%	5.15	n.c.	n.c.
Romania	9,866	8,360	3.64	1.16	0.59	49	1.48	10	0.12%	0.46	n.c.	n.c.
Slovakia	3,686	2,936	2.36	0.88	0.84	19	n.c.	5	0.16%	n.c.	n.c.	n.c.
Slovenia	4,589	3,743	1.36	1.15	1.04	27	n.c.	3	0.09%	n.c.	n.c.	n.c.
Argentina	3,249	2,350	1.99	0.32	0.85	8	n.c.	1	0.04%	n.c.	n.c.	n.c.
Australia	51,100	40,288	1.33	0.94	1.21	173	2.00	34	0.09%	1.88	n.c.	n.c.
Brazil	27,660	23,901	1.81	0.64	0.74	53	0.56	11	0.05%	1.14	n.c.	n.c.
Canada	84,321	65,876	1.22	1.10	1.38	363	1.75	75	0.11%	2.09	1.61	n.c.
Chile	3,501	2,347	1.74	0.56	1.14	17	n.c.	2	0.07%	n.c.	n.c.	n.c.
China	453,443	428,823	2.48	1.58	0.63	418	1.57	91	0.02%	1.75	2.64	n.c.
Colombia	2,401	1,688	3.52	0.69	0.69	4	n.c.	0	0.02%	n.c.	n.c.	n.c.
Egypt	6,710	5,462	2.19	0.89	0.64	16	n.c.	2	0.04%	n.c.	n.c.	n.c.
India	62,266	57,005	3.21	0.97	0.73	197	3.20	48	0.08%	1.51	n.c.	n.c.
Indonesia	2,119	1,563	7.31	1.48	0.50	6	n.c.	2	0.14%	n.c.	n.c.	n.c.
Iran	24,201	22,082	3.57	1.11	0.91	40	2.41	12	0.06%	1.20	n.c.	n.c.
Israel	17,737	13,352	1.22	1.04	1.78	64	1.69	8	0.06%	1.22	n.c.	n.c.
Japan	103,955	93,377	1.24	0.78	0.70	107	1.62	19	0.02%	1.59	0.85	n.c.
Malaysia	18,278	16,311	4.62	1.91	0.62	20	n.c.	5	0.03%	n.c.	n.c.	n.c.
Mexico	10,839	8,830	1.37	0.78	0.72	19	n.c.	4	0.05%	n.c.	n.c.	n.c.
New Zealand	8,010	5,995	1.50	0.81	1.13	32	4.99	5	0.08%	0.49	n.c.	n.c.
Nigeria	1,299	1,137	3.71	0.31	0.35	2	n.c.	0	0.04%	n.c.	n.c.	n.c.
Pakistan	6,340	5,179	2.75	1.10	0.54	9	n.c.	2	0.04%	n.c.	n.c.	n.c.
Rep. of Korea	73,771	65,975	1.32	1.41	0.87	79	1.95	15	0.02%	1.17	n.c.	n.c.
Russia	15,015	12,561	1.36	0.37	0.49	67	1.32	12	0.09%	0.43	n.c.	n.c.
Singapore	25,614	19,533	1.18	1.96	1.60	107	2.45	23	0.12%	0.97	n.c.	n.c.
South Africa	5,733	4,667	1.68	0.61	0.83	22	n.c.	3	0.06%	n.c.	n.c.	n.c.
Switzerland	23,751	16,172	1.40	0.83	1.96	161	2.92	21	0.13%	1.31	n.c.	n.c.
Taiwan	63,934	59,849	1.68	1.89	1.25	99	1.30	25	0.04%	0.86	n.c.	n.c.
Thailand	8,616	7,479	2.15	1.22	0.59	4	n.c.	1	0.01%	n.c.	n.c.	n.c.
Turkey	18,265	15,837	1.84	0.61	1.37	35	n.c.	7	0.05%	0.53	n.c.	n.c.
United States	435,889	373,188	1.08	0.82	1.59	970	2.56	208	0.06%	1.25	1.20	n.c.
Viet Nam	2,020	1,415	6.02	1.66	0.58	9	n.c.	2	0.11%	n.c.	n.c.	n.c.

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

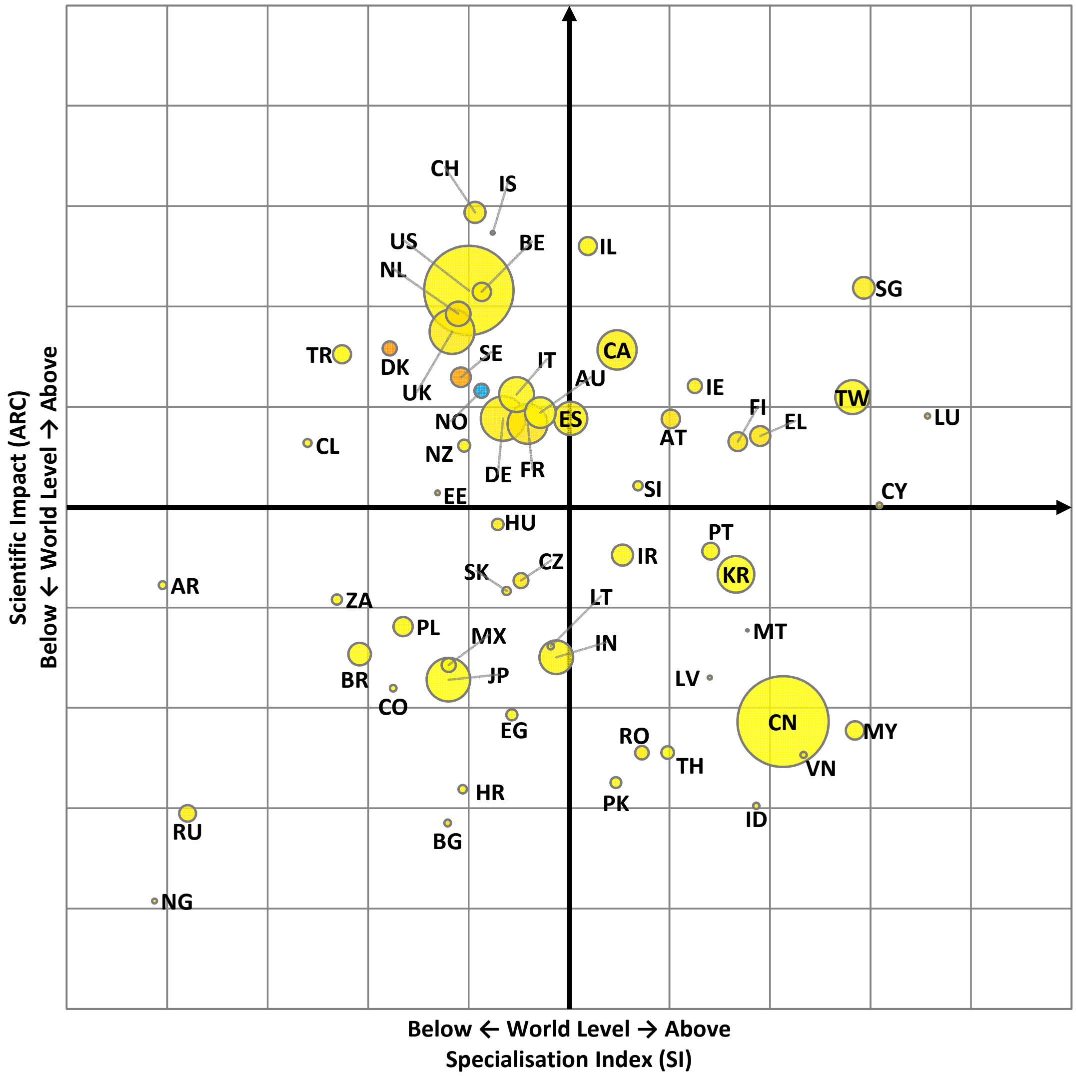


Figure 18 Positional analysis of selected countries in Information & Communication Technologies with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

3.13 Profiles of Selected Countries in Marine & Freshwater Biology

Norway's performance is notable in Marine & Freshwater Biology, showing a high impact (ARC = 1.37) and one of the highest levels of specialisation (SI = 1.99) for about 5,700 publications (FULL, 20th; see Table XVI). While Norway's output in the theme has grown by almost one-third (GR = 1.31) over the period under study, this growth was slightly weaker than the global increase in Marine & Freshwater Biology during the same period (GR = 1.40).

Unlike all the other strategic themes, the US is not the country that had the highest number of co-publications with Norway, both countries co-publishing 760 papers, putting the US in second place behind the UK (830 FULL). This is quite remarkable considering that the UK's output

(27,100 FULL) in this theme is almost four times smaller than that of the US (101,600 FULL) and that the US shows a positive affinity for Norway in Marine & Freshwater Biology (Collaboration Affinity for Norway = 1.11). This is reflected in the UK's affinity for Norway, which stands at more than twice the expected level (2.17), second only to Canada (2.51) among the four countries for which the indicator could be computed. The fourth country for which an affinity for Norway was computed is Germany (1.63), which comes in third for co-publications (549 FULL), followed by Sweden (410 FULL), Canada (398 FULL), France (398 FULL) and Denmark (390 FULL). All the countries present strong scientific performances, especially the UK (ARC = 1.54), Denmark (1.58) and Sweden (ARC 1.48), which are cited more frequently than Norway. However, while Denmark is specialised in this theme (SI = 1.34), as is Sweden although only slightly (1.08), the UK is not (0.83).

Strategic partners for improving the scientific impact of Norway's output in Marine & Freshwater Biology (see Figure 19) include Cyprus, Denmark, the UK, the Netherlands, Switzerland, Estonia, Australia, Sweden, New Zealand, Portugal, Canada and the US. Among the above, **Cyprus**, **Australia**, the **US** and **Portugal** have a share of co-publications with Norway below the world level. In the case of the US, however, this still results in a positive affinity towards Norway.

For the above nations, the most important institutions in terms of output, specialisation or impact in this strategic field include: **University of Aarhus** (Denmark), **University of Southampton** (UK), **WUR** (the Netherlands), **ETHZ** (Switzerland), **Estonian University of Life Sciences** (Estonia), **Australian Research Council** and **CSIRO** (Australia), **Stockholm University** (Sweden), **University of Otago** (New Zealand), **University of Aveiro** (Portugal), **Dalhousie University** (Canada) and the **US Department of Agriculture** (US).

In terms of shares of publications in partnership with Norway, the Nordic countries head the list. In fact, Iceland (88 FULL, Collaboration Rate = 3.27%), Denmark (390; 1.88%), Sweden (410; 1.42%) and Finland (204; 1.16%) are top ranking and all four countries have sizeable numbers of co-publications with Norway. Lithuania (1.00%) also dedicates much more of its output to collaborations with Norway compared to the world level (0.23%), as is the case for the UK (0.69%), Ireland (0.64%), the Netherlands (0.49%) and South Africa (0.44%) as well. Of these, the Netherlands is probably the most interesting potential addition to Norway's collaboration strategy, based on its high impact score (ARC = 1.58). However, as was the case above for the UK, the Netherlands is not specialised in Marine & Freshwater Biology, producing 13% fewer papers in this area of research than expected (SI=0.87).

One of the most promising partnerships for Norway might well be with Cyprus, which, despite a low output of 114 publications in this theme, showed tremendous growth, increasing its output by five times from 2003–2007 to 2008–2012 (GR = 4.98, 1st). These figures provide a promising basis for future collaborative opportunities. Cyprus also has the strongest ARC score of the selection (ARC = 2.28). Even though Cyprus is not in the least specialised (SI = 0.42), such growth and impact represent an excellent collaboration opportunity for Norway. Given the small size of the theme in Cyprus, bibliometrics could help target particular institutions and/or researchers with which partnership would be most beneficial to Norway. Australia, New Zealand, Portugal and Estonia, all countries that have direct access to seas or oceans, also represent good potential partnerships, presenting scientific performance similar to the high quality and specialisation observed for Norway. With its high impact (ARC = 1.77), Switzerland should also be considered, as should the US (102,000 FULL, 1st; ARC = 1.30) and Canada (20,900 FULL, 7th; ARC = 1.34), based on their large outputs and impact in this area. The case of Switzerland is of particular interest given its strong increase of the number of co-publications with Norway (GR = 1.97), which constitutes a basis on which Norway could build to further strengthen relations between both countries.

Belgium (ARC of publications in collaboration with Norway = 3.21), Switzerland (3.18), Japan (2.86), the Netherlands (2.83), Canada (2.54) and Austria (2.38) had the highest impact when co-publishing with Norway. While most of these countries already perform high impact research on their own, the case of Japan is notable here. Japan's partnership with Norway more than triples its scientific impact and while this could partially be the result of multilateral projects involving other countries, it nevertheless highlights the fact that Norway's co-publications with Japan are highly cited in the scientific literature, benefiting both countries.

Table XVI Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Marine & Freshwater Biology (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**376,379**	**376,379**	**1.40**	**1.00**	**1.00**	**3,553**	**1.59**	**863**	**0.23%**	**1.01**	**n.a.**	**n.a.**
Nordic	**19,302**	**13,030**	**1.12**	**1.33**	**1.40**	**899**	**1.89**	**147**	**1.54%**	**1.52**	**n.a.**	**n.a.**
Norway	5,663	3,475	1.31	1.99	1.37	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	492	261	1.19	2.67	1.34	88	2.19	9	3.27%	1.27	n.c.	n.c.
Denmark (EU-15/28)	5,002	2,828	1.05	1.34	1.58	390	1.94	53	1.88%	1.38	n.c.	n.c.
Finland (EU-15/28)	3,468	2,389	1.08	1.14	1.33	204	2.17	28	1.16%	1.51	n.c.	n.c.
Sweden (EU-15/28)	6,673	4,078	1.04	1.08	1.48	410	1.88	58	1.42%	1.70	n.c.	n.c.
EU-28	**133,721**	**111,946**	**1.25**	**1.00**	**1.19**	**2,500**	**1.72**	**513**	**0.46%**	**1.09**	**n.a.**	**n.a.**
EU-15	**120,098**	**97,643**	**1.21**	**0.98**	**1.26**	**2,393**	**1.75**	**481**	**0.49%**	**1.12**	**n.a.**	**n.a.**
Austria	3,147	1,822	1.23	0.83	1.32	68	2.38	7	0.39%	1.99	n.c.	n.c.
Belgium	5,616	3,489	1.15	1.12	1.40	94	3.21	8	0.22%	1.63	n.c.	n.c.
France	20,877	13,853	1.24	0.99	1.36	398	2.12	43	0.31%	0.97	n.c.	n.c.
Germany	25,390	16,821	1.16	0.87	1.36	549	2.17	67	0.40%	1.25	1.63	n.c.
Greece	2,851	2,115	1.36	0.91	1.14	55	1.81	6	0.29%	0.27	n.c.	n.c.
Ireland	2,050	1,263	1.50	1.02	1.36	91	1.69	8	0.64%	0.66	n.c.	n.c.
Italy	14,186	10,905	1.26	0.95	1.12	182	2.12	19	0.18%	0.99	n.c.	n.c.
Luxembourg	178	83	1.58	1.21	1.11	1	n.c.	0	0.34%	n.c.	n.c.	n.c.
Netherlands	8,488	5,105	1.10	0.87	1.58	243	2.83	25	0.49%	1.06	n.c.	n.c.
Portugal	5,349	3,753	1.71	2.09	1.25	91	1.87	10	0.25%	0.84	n.c.	n.c.
Spain	16,790	12,206	1.41	1.28	1.25	257	1.98	31	0.26%	1.14	n.c.	n.c.
United Kingdom	27,090	16,935	1.11	0.83	1.54	826	2.06	117	0.69%	1.04	2.17	n.c.
Bulgaria	663	421	1.67	0.89	0.97	7	n.c.	0	0.03%	n.c.	n.c.	n.c.
Croatia	2,340	2,012	1.28	2.51	0.43	19	n.c.	3	0.15%	n.c.	n.c.	n.c.
Cyprus	114	47	4.98	0.42	2.28	4	n.c.	0	0.10%	n.c.	n.c.	n.c.
Czech Republic	3,179	2,334	1.53	1.10	1.04	47	1.86	5	0.21%	3.28	n.c.	n.c.
Estonia	880	635	1.59	2.80	1.27	28	n.c.	2	0.30%	n.c.	n.c.	n.c.
Hungary	1,779	1,360	1.62	1.09	0.76	14	n.c.	2	0.18%	n.c.	n.c.	n.c.
Latvia	179	124	2.63	1.07	0.94	8	n.c.	1	0.93%	n.c.	n.c.	n.c.
Lithuania	473	327	1.71	0.85	0.85	24	n.c.	3	1.00%	n.c.	n.c.	n.c.
Malta	76	38	2.05	1.23	1.20	1	n.c.	0	0.03%	n.c.	n.c.	n.c.
Poland	5,987	4,957	1.40	1.05	0.68	101	1.83	15	0.29%	0.74	n.c.	n.c.
Romania	1,069	803	4.09	0.58	0.65	11	n.c.	0	0.05%	n.c.	n.c.	n.c.
Slovakia	834	599	1.34	0.94	0.59	11	n.c.	1	0.12%	n.c.	n.c.	n.c.
Slovenia	961	648	1.53	1.04	1.10	12	n.c.	0	0.05%	n.c.	n.c.	n.c.
Argentina	5,080	4,026	1.63	2.90	0.86	12	n.c.	0	0.01%	n.c.	n.c.	n.c.
Australia	21,552	15,676	1.33	1.92	1.35	185	2.31	23	0.15%	1.17	n.c.	n.c.
Brazil	13,477	11,565	2.13	1.62	0.82	49	1.77	11	0.10%	1.34	n.c.	n.c.
Canada	20,935	14,461	1.24	1.26	1.34	398	2.54	51	0.35%	1.02	2.51	n.c.
Chile	3,440	2,458	1.49	3.07	0.85	28	n.c.	4	0.14%	n.c.	n.c.	n.c.
China	38,820	35,033	2.40	0.67	0.74	83	1.78	15	0.04%	1.09	n.c.	n.c.
Colombia	1,237	832	2.74	1.78	0.77	6	n.c.	1	0.13%	n.c.	n.c.	n.c.
Egypt	2,024	1,531	2.63	1.30	0.61	4	n.c.	0	0.02%	n.c.	n.c.	n.c.
India	14,201	12,975	1.91	1.16	0.69	32	n.c.	4	0.03%	0.70	n.c.	n.c.
Indonesia	949	394	2.20	1.95	0.97	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Iran	3,370	2,921	4.06	0.77	0.57	9	n.c.	2	0.06%	n.c.	n.c.	n.c.
Israel	3,029	2,133	1.13	0.86	1.22	30	n.c.	2	0.09%	1.08	n.c.	n.c.
Japan	21,111	17,490	1.06	0.76	0.85	90	2.86	10	0.06%	2.76	n.c.	n.c.
Malaysia	2,335	1,811	4.65	1.11	0.69	4	n.c.	0	0.01%	n.c.	n.c.	n.c.
Mexico	6,394	4,857	1.41	2.25	0.72	12	n.c.	2	0.04%	n.c.	n.c.	n.c.
New Zealand	5,687	3,732	1.20	2.63	1.37	86	1.69	9	0.24%	0.69	n.c.	n.c.
Nigeria	1,482	1,306	1.92	1.85	0.36	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	1,519	1,319	2.39	1.46	0.70	2	n.c.	0	0.02%	n.c.	n.c.	n.c.
Rep. of Korea	7,612	6,248	1.94	0.70	0.88	15	n.c.	2	0.04%	n.c.	n.c.	n.c.
Russia	10,150	8,366	1.15	1.28	0.45	191	1.39	31	0.37%	1.29	n.c.	n.c.
Singapore	1,326	858	1.51	0.45	1.29	2	n.c.	0	0.01%	n.c.	n.c.	n.c.
South Africa	4,754	3,409	1.32	2.31	1.11	113	1.59	15	0.44%	1.45	n.c.	n.c.
Switzerland	5,179	2,827	1.30	0.75	1.77	91	3.18	6	0.22%	2.11	n.c.	n.c.
Taiwan	4,182	3,445	1.53	0.57	0.97	8	n.c.	1	0.04%	n.c.	n.c.	n.c.
Thailand	2,653	1,943	2.12	1.65	0.72	7	n.c.	0	0.02%	n.c.	n.c.	n.c.
Turkey	4,710	4,163	1.65	0.84	0.79	13	n.c.	2	0.04%	n.c.	n.c.	n.c.
United States	101,592	82,206	1.15	0.94	1.30	762	1.98	111	0.14%	1.08	1.11	n.c.
Viet Nam	617	237	1.88	1.45	0.95	9	n.c.	2	0.80%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

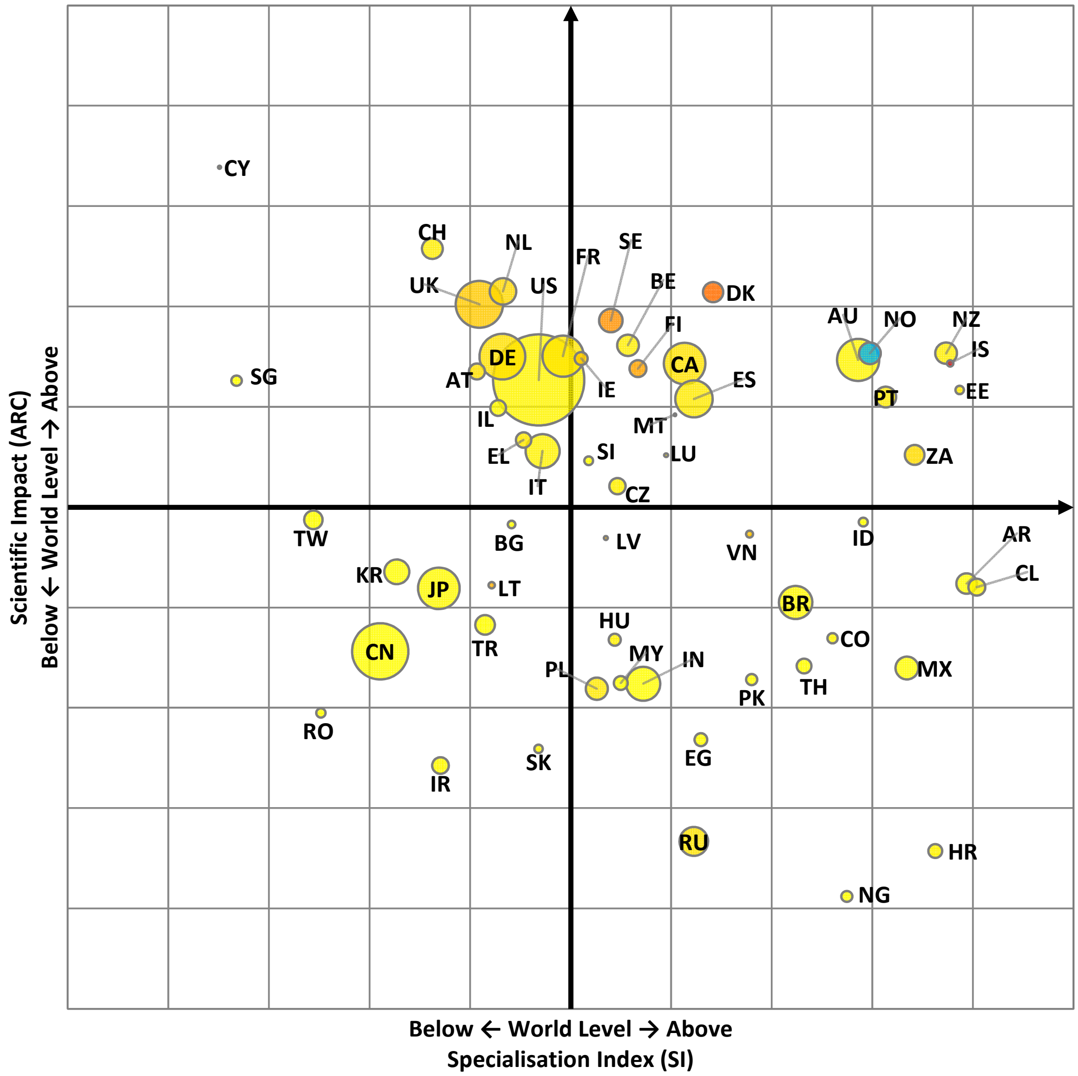


Figure 19 Positional analysis of selected countries in Marine & Fresh Water Biology with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.14 Profiles of Selected Countries in Maritime Research

Norway is highly specialised in Maritime Research, ranking 10th in output (2,700 FULL), 1st in terms of specialisation (SI = 5.54), and with an increase of 78% (GR = 1.78), it has grown more rapidly than the world level (GR = 1.48, see Table XVII). Norway's papers are cited on average 36% more than the world average (ARC = 1.36). However, this ARC score places Norway in last place among the Nordic Countries (ARC between 1.36 and 1.81).

Unfortunately, given the relatively small size of this theme, no affinities between countries could be computed for any country and analysis thus relies on counts and shares of co-publications with Norway. The US is once again the country that was co-involved in the highest number of publications with Norway (267 FULL). However, this represents only 0.29% of the US total in this theme, which is below the world level (Collaboration Rate = 0.36%). In comparison, the UK ranks second with 229 (FULL) co-publications with Norway, but based on an output more than three times smaller, which results in a much higher share (0.74%). Germany (127 FULL, 0.65%), France (88 FULL, 0.42%), Denmark (81 FULL, 3.39%) and the Netherlands (81 FULL, 0.89%) follow, all presenting shares of publications with Norway higher than the world level.

Among these countries, Denmark stands out in terms of scientific performance since it is slightly specialised in this theme (SI = 1.11) and presents one of the highest ARCs (1.70). As is the case with the other Nordic countries, Norway is an important collaborator for Denmark, as expressed by its share of output in collaboration with Norway at 10 times above the world level. These analyses show that Norway should continue in this direction and encourage the development of this partnership since it could clearly benefit from Denmark's higher scientific impact, even though this impact is not yet reflected on the impact of their mutual co-publications (ARC for co-publications with Norway = 1.28).

Strategic partners for improving the scientific impact of Norway's output in the sciences in Maritime Research (see Figure 20) include Denmark, Portugal, Sweden, Singapore, Belgium, Greece and New Zealand. Even though their impact on their own is slightly below the world average, special attention should also be paid to Canada, Germany and France as potential avenues to increase Norway's impact as they all present sizable outputs in the theme and have an extremely high impact when collaborating with Norway. Among the above, only **New Zealand** has a share of co-publications with Norway below the world level.

In terms of institutions that stand out in Maritime research for these countries, the following are worth mentioning: **DTU** (Denmark), **University of Lisbon** (Portugal), **National University of Singapore** (Singapore) and **National Technical University of Athens** (Greece).

As mentioned above, the other Nordic countries have strong collaboration ties with Norway, with 2.42% of all publications in the region involving Norway, and the Nordic countries primarily dominating the field for this indicator. In fact, Iceland ranks first with 4.84% of all its publications resulting from international efforts with Norway, although this is based on only 16 publications (FULL). Iceland is followed by Denmark (3.39%), Sweden (2.13%) and Finland (1.37%). Estonia and Cyprus were excluded here because of their low numbers of co-publications with Norway. As mentioned for Denmark, Norway should seek to continue developing collaborations with its Nordic partners since they all present a high scientific impact (ARCs ranging from 1.55 to 1.81). Also, the fact that Iceland (SI = 1.82) and Denmark (1.11) are both specialised in Maritime Research makes them important partners to consider.

Table XVII Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Maritime Research (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**81,518**	**81,518**	**1.48**	**1.00**	**1.00**	**1,005**	**1.74**	**287**	**0.36%**	**1.16**	**n.a.**	**n.a.**
Nordic	**4,654**	**3,706**	**1.59**	**1.74**	**1.46**	**176**	**1.74**	**39**	**2.42%**	**1.15**	**n.a.**	**n.a.**
Norway	2,684	2,101	1.71	5.54	1.36	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	72	39	1.53	1.82	1.81	16	n.c.	2	4.84%	n.c.	n.c.	n.c.
Denmark (EU-15/28)	721	510	1.39	1.11	1.70	81	1.28	17	3.39%	0.96	n.c.	n.c.
Finland (EU-15/28)	532	379	1.81	0.84	1.55	35	n.c.	5	1.37%	2.13	n.c.	n.c.
Sweden (EU-15/28)	925	677	1.29	0.83	1.68	69	2.31	14	2.13%	1.51	n.c.	n.c.
EU-28	**25,154**	**22,324**	**1.45**	**0.92**	**1.25**	**625**	**1.83**	**152**	**0.68%**	**1.09**	**n.a.**	**n.a.**
EU-15	**22,624**	**19,733**	**1.41**	**0.92**	**1.33**	**615**	**1.84**	**148**	**0.75%**	**1.09**	**n.a.**	**n.a.**
Austria	229	146	1.11	0.31	2.04	6	n.c.	1	0.43%	n.c.	n.c.	n.c.
Belgium	609	398	1.84	0.59	1.81	20	n.c.	2	0.59%	n.c.	n.c.	n.c.
France	3,253	2,425	1.33	0.80	1.41	88	2.60	10	0.42%	0.87	n.c.	n.c.
Germany	3,480	2,678	1.39	0.64	1.46	127	2.75	17	0.65%	1.03	n.c.	n.c.
Greece	915	743	1.58	1.48	1.53	21	n.c.	3	0.42%	n.c.	n.c.	n.c.
Ireland	259	177	2.06	0.66	1.71	14	n.c.	2	0.87%	n.c.	n.c.	n.c.
Italy	2,643	2,123	1.60	0.85	1.42	70	2.29	11	0.54%	0.73	n.c.	n.c.
Luxembourg	20	13	3.49	0.89	n.c.	3	n.c.	0	3.19%	n.c.	n.c.	n.c.
Netherlands	1,932	1,448	1.50	1.14	1.26	81	2.96	13	0.89%	1.25	n.c.	n.c.
Portugal	1,072	835	1.82	2.14	1.74	25	n.c.	6	0.76%	n.c.	n.c.	n.c.
Spain	1,982	1,593	1.67	0.77	1.52	30	n.c.	3	0.22%	0.90	n.c.	n.c.
United Kingdom	7,162	5,588	1.20	1.27	1.33	229	1.76	41	0.74%	1.31	n.c.	n.c.
Bulgaria	94	67	3.43	0.65	1.45	3	n.c.	0	0.04%	n.c.	n.c.	n.c.
Croatia	907	841	1.64	4.84	0.45	3	n.c.	0	0.03%	n.c.	n.c.	n.c.
Cyprus	56	35	2.91	1.46	2.23	1	n.c.	1	1.42%	n.c.	n.c.	n.c.
Czech Republic	118	78	2.91	0.17	1.57	2	n.c.	0	0.09%	n.c.	n.c.	n.c.
Estonia	110	81	2.45	1.65	1.59	5	n.c.	1	1.44%	n.c.	n.c.	n.c.
Hungary	81	54	1.29	0.20	1.02	2	n.c.	0	0.05%	n.c.	n.c.	n.c.
Latvia	29	25	9.66	1.00	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Lithuania	105	88	1.78	1.06	0.87	2	n.c.	0	0.08%	n.c.	n.c.	n.c.
Malta	28	20	2.08	3.03	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Poland	1,073	979	1.81	0.96	0.74	14	n.c.	2	0.16%	n.c.	n.c.	n.c.
Romania	249	201	2.72	0.67	0.47	6	n.c.	0	0.04%	n.c.	n.c.	n.c.
Slovakia	77	36	0.88	0.26	2.03	1	n.c.	0	0.41%	n.c.	n.c.	n.c.
Slovenia	122	87	0.96	0.64	0.87	2	n.c.	0	0.08%	n.c.	n.c.	n.c.
Argentina	207	158	1.18	0.53	1.49	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Australia	3,004	2,357	1.50	1.33	1.43	65	2.28	13	0.55%	2.06	n.c.	n.c.
Brazil	1,531	1,347	1.79	0.87	0.59	23	n.c.	5	0.39%	n.c.	n.c.	n.c.
Canada	3,391	2,545	1.26	1.02	1.33	63	3.45	13	0.51%	2.12	n.c.	n.c.
Chile	223	152	1.07	0.87	1.57	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
China	15,369	14,664	2.72	1.30	0.67	42	0.89	10	0.07%	0.94	n.c.	n.c.
Colombia	70	41	4.43	0.41	0.55	2	n.c.	1	1.41%	n.c.	n.c.	n.c.
Egypt	290	242	1.42	0.95	0.79	3	n.c.	1	0.36%	n.c.	n.c.	n.c.
India	1,610	1,434	1.54	0.59	0.94	6	n.c.	1	0.07%	n.c.	n.c.	n.c.
Indonesia	124	72	2.38	1.64	0.65	2	n.c.	0	0.15%	n.c.	n.c.	n.c.
Iran	734	664	2.50	0.81	1.20	4	n.c.	1	0.17%	n.c.	n.c.	n.c.
Israel	303	243	1.11	0.45	1.37	2	n.c.	0	0.04%	n.c.	n.c.	n.c.
Japan	3,946	3,409	1.10	0.69	0.89	39	1.36	9	0.25%	1.40	n.c.	n.c.
Malaysia	488	365	7.62	1.03	0.77	5	n.c.	1	0.25%	n.c.	n.c.	n.c.
Mexico	418	290	1.12	0.62	0.96	4	n.c.	0	0.13%	n.c.	n.c.	n.c.
New Zealand	594	427	1.11	1.39	1.72	7	n.c.	1	0.17%	n.c.	n.c.	n.c.
Nigeria	133	112	1.74	0.74	0.32	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	71	55	1.90	0.28	0.92	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Rep. of Korea	2,943	2,575	1.87	1.33	1.08	27	n.c.	6	0.25%	n.c.	n.c.	n.c.
Russia	996	769	1.19	0.55	0.70	26	n.c.	3	0.35%	n.c.	n.c.	n.c.
Singapore	781	611	1.83	1.48	1.73	14	n.c.	5	0.75%	n.c.	n.c.	n.c.
South Africa	335	250	1.82	0.78	1.14	4	n.c.	1	0.23%	n.c.	n.c.	n.c.
Switzerland	401	222	1.20	0.27	1.83	13	n.c.	2	0.94%	n.c.	n.c.	n.c.
Taiwan	1,347	1,208	1.75	0.92	1.53	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Thailand	164	109	2.02	0.43	1.07	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Turkey	826	705	1.93	0.66	1.47	6	n.c.	1	0.09%	n.c.	n.c.	n.c.
United States	23,113	20,196	1.03	1.06	1.16	267	1.80	59	0.29%	1.52	n.c.	n.c.
Viet Nam	93	56	1.09	1.57	0.93	1	n.c.	0	0.60%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

There are many other potential partners for Norway to target in this theme based on overall performance, including output, growth, specialisation and impact. Portugal ranks first on this list with a relatively large output (1,070 FULL), strong growth (GR = 1.82), high specialisation

(SI=2.14) and high impact (ARC = 1.18). As expressed by its share of publications in collaboration with Norway (Collaboration Rate = 0.76%), Portugal already frequently partners with Norway, which should seek to build on this strong base to further develop this collaboration. This is also true for Singapore, which scores well all round (780 FULL, GR = 1.83, SI = 1.48, ARC = 1.18) and also collaborates relatively often with Norway (Collaboration Rate = 0.75%). Belgium, with its high impact (ARC = 1.23) and growth (GR = 1.84); Greece, with its level of specialisation (SI = 1.48); and New Zealand, also with its high impact (ARC = 1.17), represent good potential collaborators for Norway as well.

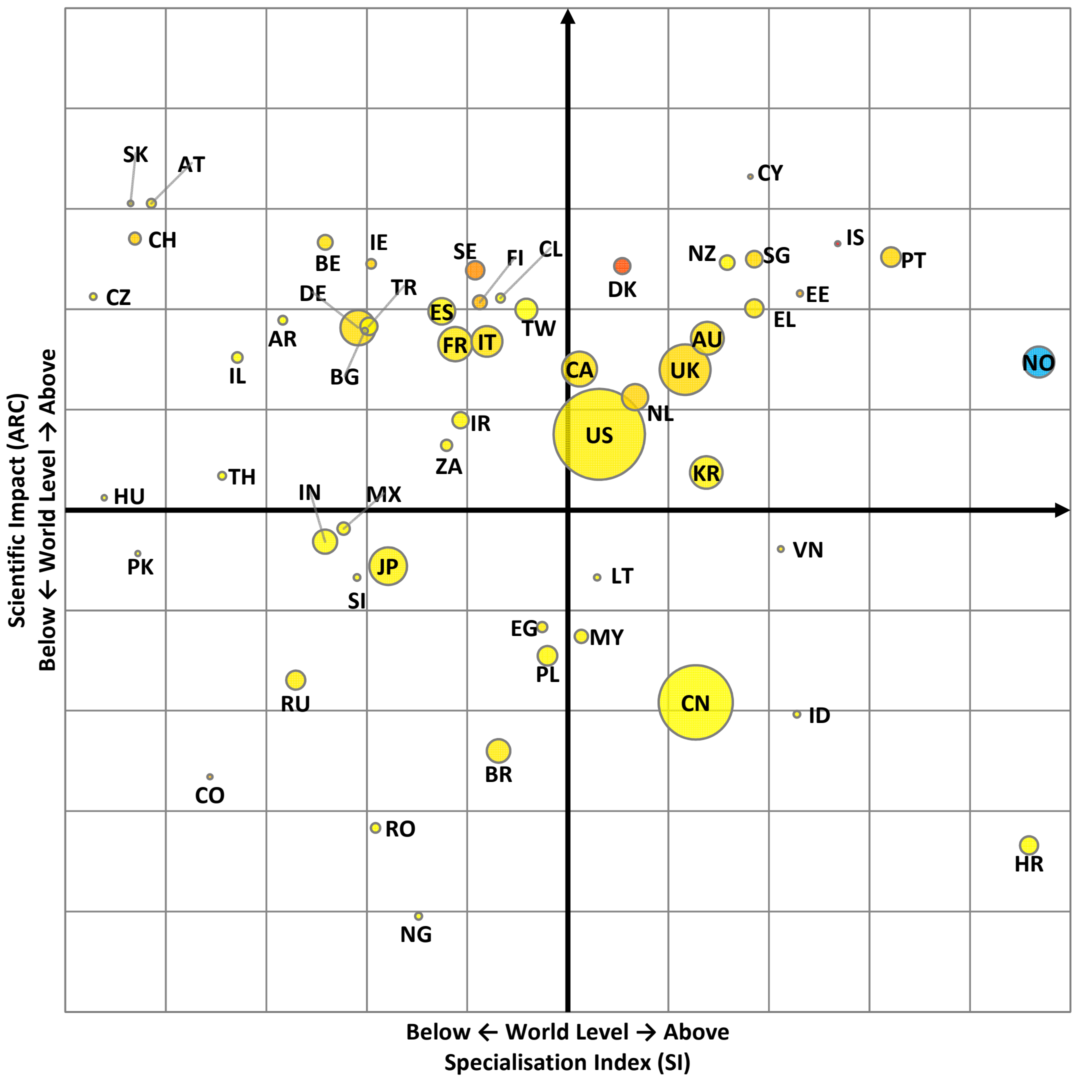


Figure 20 Positional analysis of selected countries in Maritime Research with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

An analysis of the citation impact of co-publications with Norway indicates that collaboration with Canada results in the highest impact (63 co-publications, ARC = 3.45). This score is much higher than Canada's as a whole (3,400 publications FULL, ARC = 1.33) and seems to indicate that both Norway and Canada significantly benefit from their collaborations and that both experience a tremendous increase in impact. The same can be said for the Netherlands (81 co-publications FULL; ARC of co-publications = 2.96; ARC = 1.26), Germany (127; 2.75; 1.46) and France (88; 2.60; 1.41), which otherwise all have impact scores below the world level. Collaborations with these countries benefit both Norway and its partner, increasing the impact for both parties.

3.15 Profiles of Selected Countries in Nanotechnology & New Materials

With about 2,800 publications (FULL) (39th), research in Nanotechnology & New Materials is not a high specialisation area for Norway, which has one of the lowest SIs of the selected countries (0.35, compare Table XVIII). Nevertheless, Norway has a scientific impact above the world level in this area, achieving an ARC of 1.11 (18th).

Norway and at least one other country were involved in slightly more than 1,700 publications in this field at the world level from 2003 to 2012. The US was the most active, which is reflected in its collaborations with Norway that show it has the highest number of co-publications with this country (364 FULL). Interestingly, the aggregate of the Nordic countries (excluding Norway) has about the same output in collaboration with Norway (372 FULL), but is based on a scientific production almost 10 times smaller, which is indicative of the high level of collaboration between Norway and the other Nordic countries. Norway's other very frequent collaborators include Germany (272 FULL), Sweden (232 FULL), France (22 FULL), the UK (189 FULL) and China (179 FULL). While many Asian countries rank very high in terms of output, they very infrequently collaborate with Norway, allocating less than 0.2% of their publications to collaborations with this country in comparison with 0.04% at the world level. Asian countries, i.e., Japan (82 FULL; Collaboration Rate = 0.01%), India (31; 0.01%), the Republic of Korea (16; 0.005%), Singapore (8; 0.01%) and Taiwan (3; 0.001%), are also among the most specialised in this field, and, apart from Japan, all present strong growth and scientific impact, which would present new avenues of collaborations for Norway in this strategic theme.

Strategic partners for improving the scientific impact of Norway's output in Nanotechnology & New Materials (see Figure 21) include Singapore, Iran, the US, Switzerland, the Netherlands, Denmark, Australia, Germany, China, the Republic of Korea and the UK.

Singapore, **Iran**, the **US**, the **Republic of Korea** and **China** are among the countries for which the share of co-publications with Norway is below expectations.

At the micro-level, the following organisations stand out in this thematic field for in above countries: **Nanyang Technological University** (Singapore), **Isfahan University of Technology** (Iran), **US Department of Energy** and **Northwestern University** (US), **ETHZ** and **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **University of Groningen** (the Netherlands), **DTU** (Denmark), **Australian Research Council** (Australia), **Max Planck Society** (Germany), **Chinese Academy of Sciences** and **Peking University** (China), **KAIST** (Republic of Korea) and **University of Cambridge** (UK).

As observed for most strategic themes, Norway's strongest ties are with the other Nordic countries, especially Iceland (Collaboration Rate = 0.67%), Sweden (0.52%) and Denmark (0.38%), which are the three countries that allocate the highest share of their output to co-publications with Norway. Based on this indicator, other frequent collaborators for Norway include Lithuania (17 FULL, Collaboration Rate = 0.26%), South Africa (24; 0.25%) and Slovakia (19; 0.23%). Of these, Denmark is notable in terms of scientific impact (ARC = 1.42) and growth of output (GR = 1.87). Other noteworthy countries with high scientific performances and shares of collaboration with Norway above the world level include Switzerland (ARC = 1.47; Collaboration Rate = 0.07%), the Netherlands (1.53; 0.12%), Australia (1.35; 0.07%), Germany (1.22; 0.07%) and the UK (1.28; 0.08%). Conversely, some countries with high scientific performance do not frequently cooperate with Norway. These include Singapore (ARC = 1.43; Collaboration Rate = 0.01%), which as mentioned earlier stands out for all indicators; Iran (1.01; 0.01%), which has an overall performance slightly above the world average, but is especially worth noting for its high output growth (GR = 8.46); the US (1.37; 0.03%) in terms of output and impact; the Republic of Korea (0.97; 0.005%) for its output and specialisation; and China (0.89; 0.02%) mainly for its output and growth (GR = 2.22).

Table XVIII Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Nanotechnology & New Materials (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	FULL	FRAC	GR	SI	ARC	FULL	ARC	FRAC	Coll. Rate	GR	for NO	of NO
World	**1,054,154**	**1,054,154**	**1.68**	**1.00**	**1.00**	**1,711**	**1.26**	**396**	**0.04%**	**1.32**	**n.a.**	**n.a.**
Nordic	**25,429**	**17,095**	**1.61**	**0.62**	**1.21**	**372**	**1.48**	**60**	**0.39%**	**1.13**	**n.a.**	**n.a.**
Norway	2,791	1,738	2.23	0.35	1.11	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	176	89	3.41	0.33	1.24	7	n.c.	1	0.67%	n.c.	n.c.	n.c.
Denmark (EU-15/28)	5,713	3,630	1.87	0.61	1.42	105	1.54	14	0.38%	0.96	n.c.	n.c.
Finland (EU-15/28)	6,445	4,400	1.58	0.75	1.09	63	1.30	8	0.17%	1.62	n.c.	n.c.
Sweden (EU-15/28)	11,575	7,237	1.40	0.69	1.21	237	1.54	38	0.52%	1.17	n.c.	n.c.
EU-28	**296,761**	**250,150**	**1.53**	**0.80**	**1.09**	**1,132**	**1.39**	**225**	**0.09%**	**1.23**	**n.a.**	**n.a.**
EU-15	**265,156**	**216,516**	**1.51**	**0.78**	**1.15**	**1,038**	**1.45**	**201**	**0.09%**	**1.17**	**n.a.**	**n.a.**
Austria	7,398	4,489	1.50	0.73	1.20	18	n.c.	2	0.04%	n.c.	n.c.	n.c.
Belgium	10,617	6,712	1.58	0.77	1.21	27	n.c.	3	0.05%	n.c.	n.c.	n.c.
France	54,319	36,623	1.43	0.93	1.08	222	1.39	29	0.08%	1.16	1.58	n.c.
Germany	76,945	54,092	1.43	1.00	1.22	272	1.11	38	0.07%	1.40	1.52	n.c.
Greece	6,140	4,271	1.72	0.66	1.10	21	n.c.	2	0.05%	n.c.	n.c.	n.c.
Ireland	4,808	3,213	1.76	0.93	1.17	19	n.c.	2	0.06%	n.c.	n.c.	n.c.
Italy	33,006	24,790	1.60	0.77	1.01	86	2.41	12	0.05%	1.34	1.39	n.c.
Luxembourg	272	121	7.49	0.63	1.07	3	n.c.	0	0.17%	n.c.	n.c.	n.c.
Netherlands	14,354	9,593	1.54	0.59	1.53	94	2.81	11	0.12%	0.95	3.40	n.c.
Portugal	6,634	4,525	1.92	0.90	1.09	26	n.c.	3	0.06%	n.c.	n.c.	n.c.
Spain	29,260	20,398	1.71	0.77	1.20	90	1.41	12	0.06%	0.75	n.c.	n.c.
United Kingdom	47,165	32,420	1.44	0.57	1.28	189	1.31	27	0.08%	1.07	1.70	n.c.
Bulgaria	2,705	1,712	1.59	1.29	0.68	5	n.c.	0	0.03%	n.c.	n.c.	n.c.
Croatia	1,159	772	1.51	0.34	0.78	4	n.c.	0	0.01%	n.c.	n.c.	n.c.
Cyprus	381	210	5.51	0.68	0.96	4	n.c.	0	0.05%	n.c.	n.c.	n.c.
Czech Republic	7,191	4,759	1.82	0.80	0.80	13	n.c.	1	0.03%	n.c.	n.c.	n.c.
Estonia	814	518	1.69	0.82	1.08	5	n.c.	0	0.04%	n.c.	n.c.	n.c.
Hungary	4,036	2,520	1.30	0.72	0.72	23	n.c.	2	0.08%	n.c.	n.c.	n.c.
Latvia	916	562	2.59	1.74	0.49	5	n.c.	0	0.06%	n.c.	n.c.	n.c.
Lithuania	1,623	1,145	2.03	1.07	0.58	17	n.c.	3	0.26%	n.c.	n.c.	n.c.
Malta	32	18	2.21	0.21	n.c.	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Poland	16,984	12,292	1.43	0.93	0.63	43	1.13	6	0.05%	4.95	n.c.	n.c.
Romania	7,845	5,829	2.37	1.50	0.58	25	n.c.	6	0.10%	n.c.	n.c.	n.c.
Slovakia	2,381	1,496	1.54	0.84	0.53	19	n.c.	3	0.23%	n.c.	n.c.	n.c.
Slovenia	2,694	1,801	1.81	1.03	0.92	5	n.c.	0	0.02%	n.c.	n.c.	n.c.
Argentina	3,571	2,423	1.90	0.62	0.86	2	n.c.	0	0.02%	n.c.	n.c.	n.c.
Australia	18,547	12,840	1.93	0.56	1.35	51	2.01	10	0.07%	4.77	1.58	n.c.
Brazil	14,211	11,439	1.61	0.57	0.79	15	n.c.	2	0.02%	n.c.	n.c.	n.c.
Canada	26,806	20,013	1.67	0.62	1.16	38	n.c.	6	0.03%	0.69	1.00	n.c.
Chile	1,613	959	1.79	0.43	0.78	10	n.c.	1	0.13%	n.c.	n.c.	n.c.
China	237,356	218,615	2.22	1.50	0.89	179	0.79	35	0.02%	2.79	3.20	n.c.
Colombia	1,131	709	2.78	0.54	0.56	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Egypt	3,889	2,645	2.64	0.80	0.83	4	n.c.	0	0.02%	n.c.	n.c.	n.c.
India	45,939	40,186	2.84	1.28	0.91	31	n.c.	5	0.01%	18.77	n.c.	n.c.
Indonesia	638	342	6.96	0.60	0.53	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Iran	15,977	14,636	8.46	1.37	1.01	7	n.c.	1	0.01%	n.c.	n.c.	n.c.
Israel	7,579	5,529	1.38	0.80	1.21	15	n.c.	1	0.01%	n.c.	n.c.	n.c.
Japan	104,374	90,730	1.04	1.42	0.82	82	1.14	13	0.01%	7.08	1.09	n.c.
Malaysia	6,018	4,917	8.10	1.07	0.72	8	n.c.	1	0.02%	n.c.	n.c.	n.c.
Mexico	7,215	5,426	1.70	0.90	0.65	15	n.c.	1	0.02%	n.c.	n.c.	n.c.
New Zealand	2,242	1,472	1.85	0.37	1.08	6	n.c.	1	0.04%	n.c.	n.c.	n.c.
Nigeria	270	177	3.17	0.09	0.53	0	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	1,624	1,019	4.48	0.40	0.91	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Rep. of Korea	64,114	54,953	1.73	2.19	0.97	16	n.c.	3	0.005%	n.c.	n.c.	n.c.
Russia	35,635	27,696	1.46	1.52	0.47	75	1.07	10	0.04%	1.06	n.c.	n.c.
Singapore	17,120	13,347	1.71	2.49	1.43	8	n.c.	1	0.01%	n.c.	n.c.	n.c.
South Africa	2,492	1,792	2.72	0.43	0.89	24	n.c.	4	0.25%	n.c.	n.c.	n.c.
Switzerland	15,931	10,093	1.43	0.96	1.47	69	1.79	8	0.07%	1.79	n.c.	n.c.
Taiwan	35,508	32,363	1.86	1.91	0.86	3	n.c.	0	0.001%	n.c.	n.c.	n.c.
Thailand	4,533	3,617	3.71	1.10	0.86	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Turkey	7,525	6,025	2.44	0.44	1.06	20	n.c.	4	0.07%	n.c.	n.c.	n.c.
United States	239,073	198,848	1.37	0.81	1.37	364	1.41	57	0.03%	1.40	1.38	n.c.
Viet Nam	1,084	654	3.83	1.43	0.61	2	n.c.	0	0.02%	n.c.	n.c.	n.c.

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

Of the 10 countries for which a collaboration affinity for Norway could be computed, only the performances of Canada (Collaboration Affinity for Norway = 1.00) and Japan (1.09) are not distinctively above expectations. The Netherlands (3.40), China (3.20), the UK (1.70), France

(1.58), Australia (1.58) and Germany (1.52) present the strongest affinities for collaborating with Norway. Of these, only France did not stand out in the previous analysis, indicating the potential for Norway to further relations with these countries. Norway should indeed continue to strengthen its relations with these countries, especially with those where collaboration has already produced strong results in terms of impact, as is the case for the Netherlands (ARC of co-publications with Norway = 2.81), Australia (2.01), Switzerland (1.79), Denmark (1.54) and Sweden (1.54).

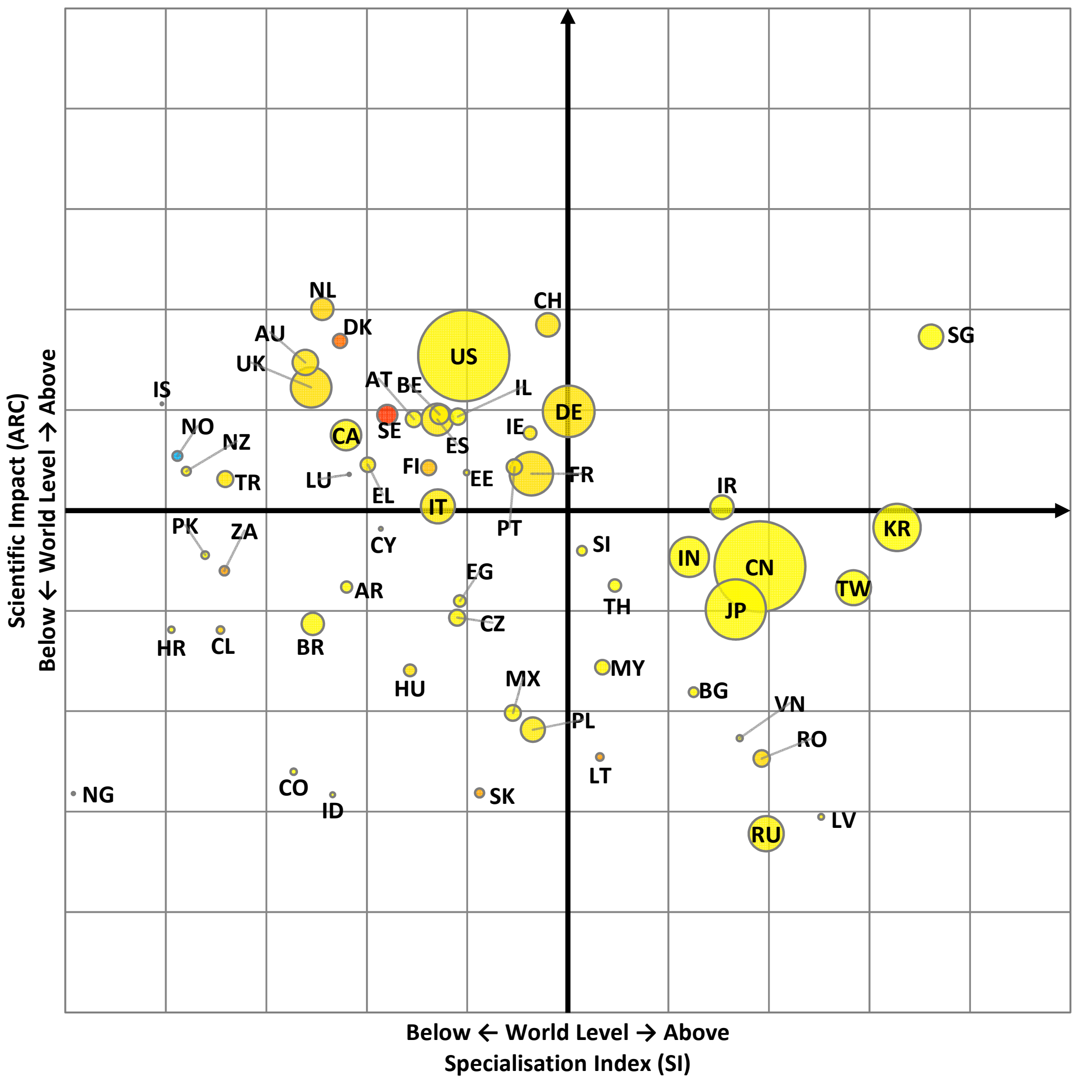


Figure 21 Positional analysis of selected countries in Nanotechnology & New Materials with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*
Source: Computed by Science-Metrix using Scopus (Elsevier)

3.16 Profiles of Selected Countries in Welfare & Working Life

As Table XIX shows, Norway's scientific performance in Welfare & Working Life is one of the strongest for the countries selected in this study, reflecting both high specialisation (SI 1.29, 6th) and high scientific impact (ARC = 1.25, 8th). With more than 4,900 publications (FULL) between 2003 and 2012, Norway has a sizeable output (17th in the selection), which has been growing slightly more rapidly (GR=1.75) than the world output (1.64).

The highest numbers of collaborations with Norway in Welfare & Working Life are observed for the UK (431 FULL); the US (404 FULL), which has about three times the output of UK in this theme,; and Sweden, which is in third position (388 FULL). Based on output alone, these countries are by far Norway's most significant collaborators. Other major collaborators include the Netherlands (192 FULL), Denmark (193 FULL), Germany (182 FULL), Finland (140 FULL), Australia (139 FULL), and Canada (111 FULL). Based on fractional counts of publications, these same countries are top ranking, which indicates that no particular collaboration patterns occur in this theme.

Strategic partners for improving the scientific impact of Norway's output in Welfare & Working Life (see Figure 22) include the Netherlands, the UK, Denmark, the US, Sweden, Australia, Switzerland, Canada, New Zealand and Belgium. Of these, countries for which the share of co-publications with Norway stands below the world level include the **US**, **Switzerland**, **Canada** and **New Zealand.** The **US**, **Switzerland** and **New Zealand** also collaborate less than expected with Norway based on their affinity scores.

The highest performing institutions for these strategic countries in Welfare & Working Life include: **VU University Amsterdam** and **TUDelft** (the Netherlands), **University of Oxford** (UK), **Copenhagen Business School** (Denmark), **Harvard University** and **New York University** (US), **Stockholm University** (Sweden), **Griffith University** and **Deakin University** (Australia), **University of Zurich** (Switzerland), **University of Toronto** (Canada), **Massey University** (New Zealand) and **University of Antwerp** (Belgium).

Unsurprisingly, as the shares of countries' publications in collaboration with Norway demonstrate, the Nordic countries have strong collaboration ties with Norway, with 0.89% of all publications in the region involving Norway, and the Nordic countries essentially topping the list for this indicator. In fact, Iceland ranks first with 1.37% of all its publications stemming from international efforts with Norway, although this ranking is based on only 37 publications (FULL, 3 FRAC). Iceland is followed by Sweden (Collaboration Rate = 1.06%) and Denmark (0.83%). At 0.57%, Finland ranks fifth (slightly behind Latvia) at 0.61%, although its score is based on only five co-publications (FULL, 1 FRAC). Other partners dedicating a high share of their output to collaborations with Norway include Austria (0.40%, 83 FULL) and Russia (0.48%, 24 FULL).

Interestingly, Iceland is the only one of these major collaborators to have substantially increased its focus on collaboration with Norway. It presented a growth ratio of 13.98 over the period under study, while the remaining countries increased collaborations with Norway at about the global level or less (GR = 1.32). Among the countries for which GRs of co-publications (FRAC) with Norway could be computed, Switzerland (GR=6.88), Belgium (3.68), Israel (2.98) and Australia (2.02) also stand out. Given the relatively small size of this theme, affinities between countries could only be computed for a few countries. Of these, three show positive affinities for Norway – the Netherlands (Collaboration Affinity for Norway = 1.78), the UK (1.26) and Canada (1.07). In contrast, the US, which ranks first in output in this theme, collaborates less than expected with Norway (0.73). The reciprocal indicator for Norway (i.e. Collaboration Affinity of Norway) could not be computed because of the low level of correlation in the data for the country.

International co-publications in Welfare & Working Life involving Norway have a high impact, as expressed by the ARC of 1.66 associated with these publications at the world level. However, some collaborations are more fruitful than others. For instance, co-publications with France have the highest impact in Welfare & Working Life (ARC of co-publications with Norway = 3.46), which is more than twice the impact level of Norway's international co-publications. Also, both countries greatly benefit from this partnership as shown by their overall ARC in the theme, which is much lower (1.25 for Norway, 0.80 for France). While it is common to note substantial increases in impact for international co-publications, a slight language bias might be at play here given the theme. Because Welfare & Working Life is a social science, researchers might publish more in regional journals, which could potentially result in a negative bias for non-English speaking countries. Two facts point to this possibility. The first is that many non-English speaking countries, which usually perform well in science, score relatively low in terms of the impact of their publications in this field, as shown by Germany (ARC = 1.03), Portugal (0.98), Spain (0.87), Italy (0.97) and France (0.80). The second is that these countries have a strong scientific impact when they co-publish with Norway, which tends to demonstrate that they can indeed produce high quality output in this theme. Of course, this could be the result of high impact multilateral projects affecting all countries equally. However, given the nature of this research area, this appears less plausible than would be the case if it were a highly international research area (e.g. Astrophysics). However, further micro-analyses would be needed to confirm this hypothesis. The strongest beneficial collaborations include those with Canada (ARC of co-publications with Norway = 3.21), Italy (3.15), Switzerland (3.08), the Netherlands (2.93), South Africa (2.68), Austria (2.58), Germany (2.51), Belgium (2.46) and the UK (2.43).

Overall, many potential partnerships in the theme of Welfare & Working Life could be considered as possible avenues to improve Norway's capacity for producing quality output in this theme. One of these would be to strengthen Norway's ties with collaborators that show strong performance. For instance, tightening Norway's relations with Canada could prove highly beneficial as Canada is, as is Norway, one of the leaders in this theme, ranking 3rd in output (FULL and FRAC), 11th in SI and 12th in ARC. Norway could build on Canada's slight affinity for it (1.07) and develop a stronger relationship with this North American country. This applies to the US as well, which also dedicates only a few of its publications to collaborations with Norway (Collaboration Rate = 0.06%), but presents a high impact when both countries collaborate (ARC of co-publications with Norway = 2.16). However, in this case, Norway might have to find ways to encourage these collaborations as the US presents a negative affinity for Norway (0.73), collaborating 27% less than expected. Nonetheless, there are opportunities for improvement in relations between both countries in this theme. Norwegian policy makers should also keep in mind that the other Nordic countries, with which Norway already has strong ties, are also leaders in this field and should try to preserve and build on these relationships since they appear to benefit both parties.

Table XIX Scientific Performance & Collaboration Profiles of Selected Countries with Norway in Welfare & Working Life (2003–2012)

	Papers					Co-Publications with Norway					Coll. Affinity	
Country	**FULL**	**FRAC**	**GR**	**SI**	**ARC**	**FULL**	**ARC**	**FRAC**	**Coll. Rate**	**GR**	**for NO**	**of NO**
World	**417,325**	**417,325**	**1.64**	**1.00**	**1.00**	**1,841**	**1.66**	**522**	**0.13%**	**1.32**	**n.a.**	**n.a.**
Nordic	**21,264**	**17,851**	**1.67**	**1.64**	**1.28**	**602**	**1.64**	**126**	**0.89%**	**1.17**	**n.a.**	**n.a.**
Norway	4,913	3,824	1.75	1.97	1.25	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
Iceland	292	191	1.63	1.76	1.00	37	n.c.	3	1.37%	13.98	n.c.	n.c.
Denmark (EU-15/28)	4,259	3,241	1.90	1.38	1.46	193	1.94	27	0.83%	1.11	n.c.	n.c.
Finland (EU-15/28)	4,195	3,367	1.68	1.45	1.20	140	1.66	19	0.57%	0.98	n.c.	n.c.
Sweden (EU-15/28)	8,976	7,229	1.53	1.73	1.34	388	1.62	77	1.06%	1.22	n.c.	n.c.
EU-28	**156,987**	**143,774**	**1.64**	**1.16**	**1.04**	**1,270**	**1.77**	**314**	**0.22%**	**1.31**	**n.a.**	**n.a.**
EU-15	**146,740**	**133,292**	**1.60**	**1.21**	**1.08**	**1,242**	**1.79**	**303**	**0.23%**	**1.34**	**n.a.**	**n.a.**
Austria	3,042	2,169	1.62	0.89	1.14	83	2.58	9	0.40%	1.29	n.c.	n.c.
Belgium	4,910	3,535	1.82	1.02	1.33	74	2.46	8	0.22%	3.68	n.c.	n.c.
France	14,430	11,636	1.44	0.75	0.80	106	3.46	7	0.06%	0.66	n.c.	n.c.
Germany	20,294	16,286	1.57	0.76	1.03	182	2.51	26	0.16%	1.30	n.c.	n.c.
Greece	2,614	2,128	1.94	0.83	0.87	30	n.c.	0	0.01%	1.51	n.c.	n.c.
Ireland	3,083	2,425	2.31	1.77	1.04	36	n.c.	3	0.10%	0.71	n.c.	n.c.
Italy	11,455	9,273	1.80	0.73	0.97	110	3.15	10	0.11%	1.73	n.c.	n.c.
Luxembourg	223	116	2.32	1.53	1.29	7	n.c.	0	0.25%	n.c.	n.c.	n.c.
Netherlands	12,646	9,740	1.66	1.50	1.50	194	2.93	23	0.24%	1.53	1.78	n.c.
Portugal	2,333	1,823	3.05	0.91	0.98	37	n.c.	3	0.14%	1.08	n.c.	n.c.
Spain	12,343	10,453	2.24	0.99	0.87	121	2.29	14	0.13%	1.16	n.c.	n.c.
United Kingdom	58,733	49,871	1.40	2.21	1.27	431	2.43	79	0.16%	1.68	1.26	n.c.
Bulgaria	255	174	1.92	0.33	0.80	8	n.c.	1	0.43%	n.c.	n.c.	n.c.
Croatia	1,414	1,293	2.12	1.45	0.31	6	n.c.	1	0.08%	n.c.	n.c.	n.c.
Cyprus	329	232	2.99	1.89	1.02	6	n.c.	0	0.00%	n.c.	n.c.	n.c.
Czech Republic	1,908	1,633	1.86	0.69	0.67	24	n.c.	2	0.12%	n.c.	n.c.	n.c.
Estonia	477	351	2.50	1.40	1.12	16	n.c.	1	0.34%	n.c.	n.c.	n.c.
Hungary	1,217	966	1.83	0.70	0.68	12	n.c.	1	0.12%	n.c.	n.c.	n.c.
Latvia	145	103	4.18	0.81	0.85	5	n.c.	1	0.61%	n.c.	n.c.	n.c.
Lithuania	673	584	2.93	1.37	0.88	13	n.c.	1	0.18%	n.c.	n.c.	n.c.
Malta	113	91	2.79	2.69	0.66	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Poland	2,605	2,220	2.03	0.43	0.57	28	n.c.	2	0.07%	n.c.	n.c.	n.c.
Romania	1,499	1,357	10.83	0.88	0.61	10	n.c.	0	0.01%	n.c.	n.c.	n.c.
Slovakia	765	649	1.34	0.92	0.41	5	n.c.	0	0.02%	n.c.	n.c.	n.c.
Slovenia	962	827	3.00	1.19	0.62	9	n.c.	1	0.07%	n.c.	n.c.	n.c.
Argentina	1,395	1,117	2.29	0.73	0.62	3	n.c.	1	0.05%	n.c.	n.c.	n.c.
Australia	22,903	19,408	1.81	2.14	1.13	139	1.76	25	0.13%	2.02	n.c.	n.c.
Brazil	8,581	7,771	2.92	0.98	0.58	8	n.c.	1	0.01%	n.c.	n.c.	n.c.
Canada	25,278	20,947	1.55	1.65	1.17	111	3.21	20	0.10%	0.99	1.07	n.c.
Chile	1,435	1,110	2.40	1.25	0.68	8	n.c.	1	0.12%	n.c.	n.c.	n.c.
China	18,274	15,970	3.09	0.28	0.73	37	n.c.	7	0.04%	0.97	0.68	n.c.
Colombia	1,060	801	3.40	1.55	0.55	1	n.c.	0	0.00%	n.c.	n.c.	n.c.
Egypt	622	453	2.83	0.35	0.75	4	n.c.	1	0.22%	n.c.	n.c.	n.c.
India	7,096	6,277	2.13	0.50	0.60	22	n.c.	4	0.07%	n.c.	n.c.	n.c.
Indonesia	515	312	2.06	1.39	0.96	4	n.c.	1	0.25%	n.c.	n.c.	n.c.
Iran	1,846	1,623	5.27	0.38	0.55	8	n.c.	1	0.04%	n.c.	n.c.	n.c.
Israel	4,847	4,082	1.33	1.49	0.98	30	n.c.	5	0.13%	2.98	n.c.	n.c.
Japan	9,633	8,504	1.45	0.34	0.62	24	n.c.	3	0.04%	n.c.	n.c.	n.c.
Malaysia	2,269	1,974	6.11	1.09	0.59	5	n.c.	1	0.04%	n.c.	n.c.	n.c.
Mexico	2,838	2,252	1.88	0.94	0.71	6	n.c.	1	0.04%	n.c.	n.c.	n.c.
New Zealand	4,260	3,275	1.80	2.08	1.18	21	n.c.	2	0.07%	n.c.	0.83	n.c.
Nigeria	1,350	1,189	2.83	1.52	0.43	2	n.c.	0	0.00%	n.c.	n.c.	n.c.
Pakistan	1,159	973	2.72	0.97	0.63	9	n.c.	2	0.26%	n.c.	n.c.	n.c.
Rep. of Korea	4,144	3,340	2.41	0.34	0.86	11	n.c.	2	0.05%	n.c.	n.c.	n.c.
Russia	1,333	1,002	1.51	0.14	0.48	24	n.c.	5	0.48%	n.c.	n.c.	n.c.
Singapore	2,136	1,601	1.50	0.76	1.05	8	n.c.	2	0.10%	n.c.	n.c.	n.c.
South Africa	5,223	4,299	1.84	2.63	0.89	46	2.68	9	0.21%	1.12	n.c.	n.c.
Switzerland	5,640	3,855	1.54	0.93	1.49	45	3.08	3	0.07%	6.88	0.71	n.c.
Taiwan	4,162	3,647	2.55	0.54	0.96	6	n.c.	1	0.02%	n.c.	n.c.	n.c.
Thailand	1,266	909	2.36	0.70	0.85	4	n.c.	0	0.04%	n.c.	n.c.	n.c.
Turkey	3,567	3,201	2.42	0.58	0.80	11	n.c.	1	0.04%	n.c.	n.c.	n.c.
United States	152,645	138,929	1.38	1.43	1.24	404	2.16	81	0.06%	1.23	0.73	n.c.
Viet Nam	355	170	2.35	0.94	0.94	4	n.c.	1	0.43%	n.c.	n.c.	n.c.

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

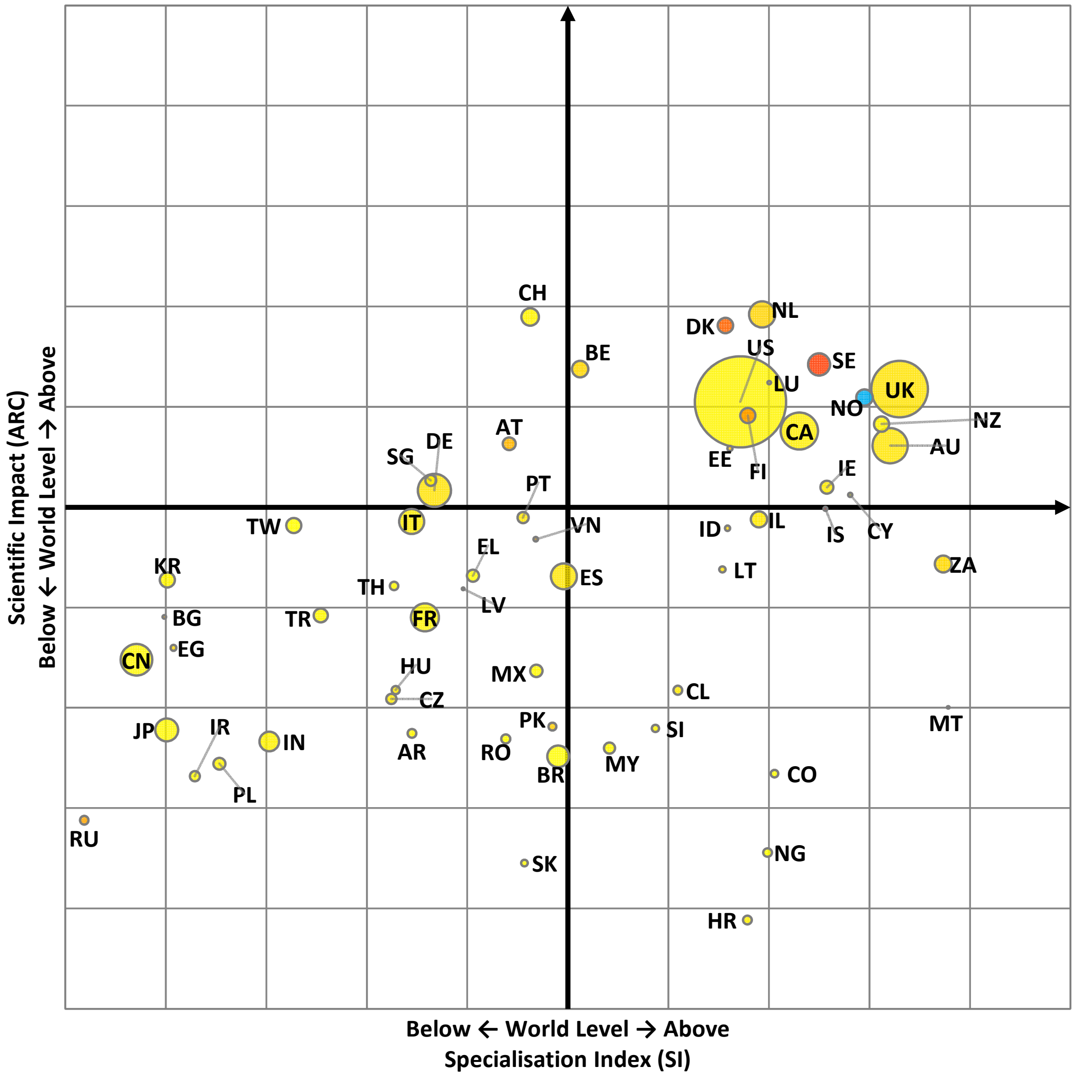


Figure 22 Positional analysis of selected countries in Welfare & Working Life with the mapping of their collaboration rate with Norway, 2003–2012

Note: *Ibid.*

Source: Computed by Science-Metrix using Scopus (Elsevier)

3.17 Mapping of the Scientific Strengths and Collaboration Intensity with Norway for the Country's Privileged Partners across the 15 Themes

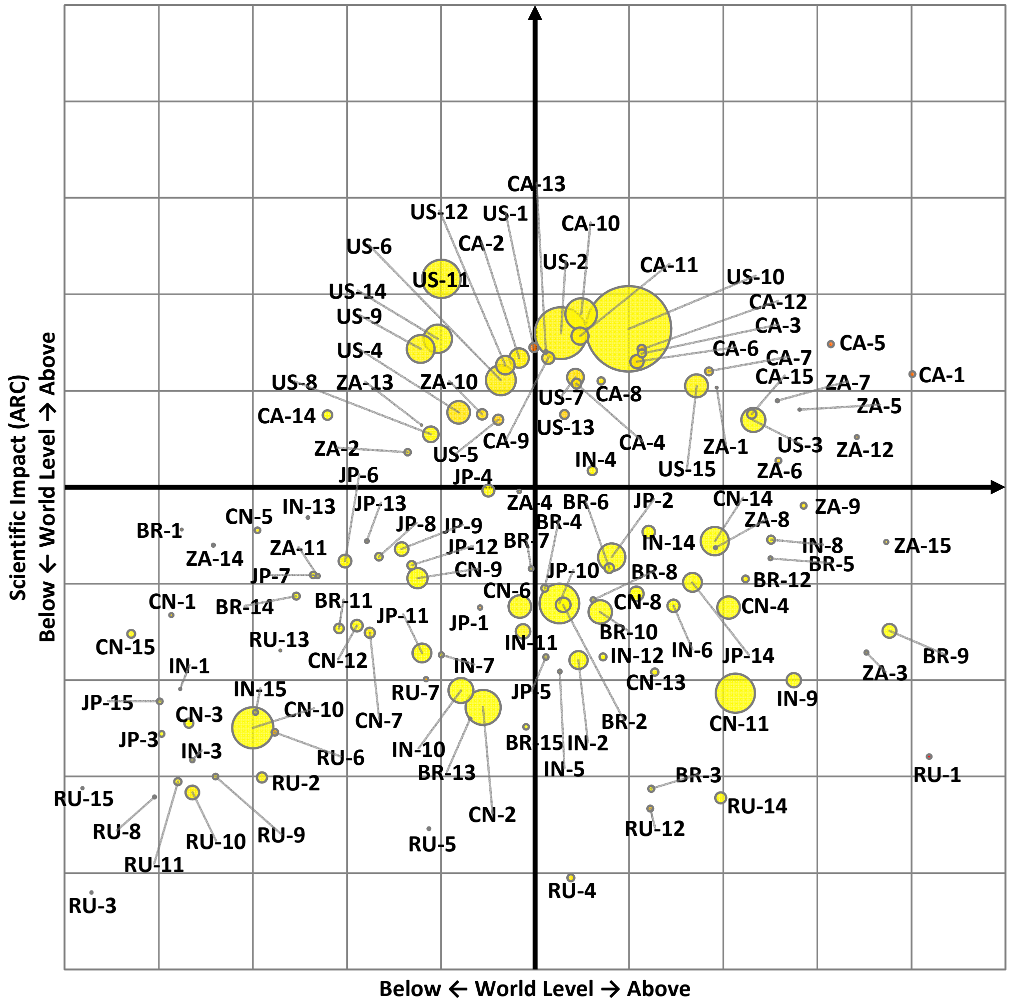
This section aims to determine those themes that represent strengths for the countries identified by Norway as key scientific partners with which to expand and/or reinforce collaboration in the future (i.e., Brazil, Canada, China, India, Japan, Russia, South Africa and the United States). It also highlights whether the collaboration intensity of the corresponding country with Norway is highest in those areas of strengths or in the remaining themes.

- **Brazil:** Brazil's most remarkable performances are noted in Environment, Marine & Freshwater Biology and Food Sciences research. Environmental research in Brazil resulted in about 26,800 publications (full counting), coupled with one of the highest impact scores for Brazil (0.84) and a specialisation index of 1.17. One of Brazil's most significant themes in terms of output is Food Sciences. Brazil is highly specialised in this theme with an SI of 2.67 based on slightly more than 57,000 publications. Since collaboration with Norway is quite rare within this theme (0.01%), Norway could benefit from increasing collaboration in this domain. Brazil's performance is also noteworthy in Fisheries & Aquaculture; although the number of publications is low (4,412), it produces one of the country's highest specialisation and impact scores (SI 1.73 and ARC 0.86).

- **Canada:** The two most notable themes for Canada are Arctic & Antarctic Research and Fisheries & Aquaculture. Although small in terms of output (close to 9,800 and 10,300 publications, respectively), they both present excellent ARC and SI scores. However, Norway already benefits from this high impact research since Canada's shares of output with Norway in those themes are considerably high – 0.87% for Arctic & Antarctic Research and 0.90% for Fisheries & Aquaculture. Other strong themes for Canada include Environment, Education and Marine & Freshwater Biology. Canadian research in these themes results in high impact publications, as indicated by an ARC above 1.31. In addition, Norway could benefit from a collaborative partnership with Canada in Environment given that Canada's collaboration rate with Norway is low (0.04%). In comparison, at 0.25%, collaboration in Climate Change is much higher. Another theme worth mentioning for Canada is Health & Care, which includes a substantial output of more than 290,000 papers, allied with a strong ARC of 1.46 and an SI slightly above the world level (1.10).
- **China:** China's main strength clearly lies in Nanotechnology & New Materials science. With close to 238,000 publications, China almost tied with the US for the largest output in this theme. It also scored among the highest ARC and SI of all selected countries (ARC 0.89 and SI 1.50, respectively). However, only 0.02% of these publications were collaborations with Norway. Consequently, China should definitely be a key partner for Norway in this theme. Another important theme of note for China is Information & Communication Technologies (ICT). China is the world leader in terms of output with slightly more than 450,000 papers in this domain and is highly specialised (SI 1.58). However, China's impact is rather low (ARC 0.63). Energy (SI 1.55) is another highly specialised theme for China, but here again the theme has a low ARC score of 0.77. With 148,480 publications it could still be considered a potential candidate for fruitful collaborations. Collaborations with Norway stand at only 0.02% for China in both ICT and Energy.
- **India:** India's dominant theme in terms of scientific performance is definitely Energy, which is India's only theme that shows an ARC above world level (ARC= 1.04). India is slightly specialised in Energy research with an SI of 1.13. Nanotechnology & New Materials is also interesting; in terms of impact it is comparable to China (0.91 for India, 0.89 for China), but it is less specialised with an SI of 1.28 (1.50 for China). India's output is also smaller, though still relatively large, with 46,000 publications. Of the countries selected as key strategic partners in this section, India is the most specialised country in Environmental Technology, scoring 1.74 for this indicator. India produced close to 18,800 scientific papers in this theme and has an ARC slightly below the world average. The theme with the greatest SI for India is Food Sciences research, for which India scores a high SI of 1.86, coupled with a considerable output (61,200 publications). However, India's ARC in Food Sciences research is low (0.65). Collaboration with Norway is very low all round, at only 0.06% in Energy and equal to or below 0.02% for the others.
- **Japan:** As noted for the other Asian countries, Nanotechnology & New Materials is a very strong research theme in Japan. It totals more than 104,000 publications and presents an SI of 1.42, which places Japan between India and China in terms of specialisation. However, Japan has slightly less impact than these two countries with an ARC of 0.82. Japan is on par with the world average impact in Energy (ARC 0.99) and has a sizable output in this area (40,000 publications) even though it is not specialised (SI 0.91). Another theme that could be very attractive in terms of partnership for Norway is Biotechnology. Japan is the most specialised in Biotechnology (1.18) of all the countries discussed in this section, and it has the third largest output after the US and China with some 220,000 publications. Although

Japan's ARC stands a little below the world level (ARC 0.86) in this theme, it remains one of the most specialised and impactful themes for this country. In general, Japan's collaboration rate with Norway is very low, with the highest noted in Climate Change research (0.09%).

- **South Africa:** This country excels in a number of themes as it is specialised with an impact above the world level in Climate Change, Marine & Freshwater Biology, Environment, Fisheries & Aquaculture, and Arctic & Antarctic Research. Interestingly, it is in these themes that South Africa's collaboration rate with Norway is highest. This collaboration rate is particularly high in Arctic & Antarctic Research and Fisheries & Aquaculture. Efforts to intensify collaboration could perhaps be concentrated in Environment, which, although it is the most significant theme among South Africa's main strengths and ranks among the top five themes, is the area in which collaboration with Norway is the lowest. South Africa is also highly specialised and has a solid output size in Welfare & Working Life and Food Sciences.
- **Russia:** Within the current selection, Russia is the country most specialised in Arctic & Antarctic Research, with a score of 3.37. This theme is the area in which Russia shows the highest collaboration rate with Norway (1.36%). However, Russia scores below the world level for the ARC in every theme, the highest ARC being noted in Maritime Research (0.70). A theme worth mentioning is again Nanotechnology & New Materials, which accounts for a large share of Russia's research output with 35,600 publications (2nd largest theme after Health & Care), representing about 50% more output than expected in this theme (SI = 1.52). However, Russia's impact is low (ARC 0.47). Research in Marine & Freshwater Biology is also important for Russia, even though it again shows a low impact in this theme (ARC 0.45), it scores the second highest SI (1.28), after Brazil within this selection of key partners. Collaborations with Norway are already high in Arctic & Antarctic Research, Marine research and Freshwater Biology and Climate change (1.46%, 0.37%, 0.49%, respectively), although they could be higher in Nanotechnology & New Materials where they stand only at 0.04%.
- **United States:** Health & Care in the US is larger than any other theme across all countries. In fact, Health & Care represents an impressive total of 2,140,000 publications in the US, resulting in an SI above the world level (1.22). American publications are highly cited at the world level (ARC 1.41). Co-publications with Norway stand at 0.05% of the US total, which, in absolute number, comprises more than 6,800 co-publications. Biotechnology comes in second place in terms of relevance here due to the large number of publications (close to 800,000) and the high ARC (1.39). The US collaboration rate with Norway stands at 0.06% in Biotechnology. Another interesting theme is Welfare & Working Life, which has the highest ARC of all countries in this section, and is one of the two countries (with Canada) where the ARC is above the world level. As well, the US output of 153,000 publications in this theme makes Welfare & Working Life a promising area for collaboration between Norway and the US. Finally, the US achieves the highest impact in Nanotechnology & New Materials with an ARC of 1.37 and is, with Canada, one of the only countries presented in this section with an ARC above the world level. Specialisation is somewhat low but since collaborations with Norway are low in this theme (0.03%), it could be considered an interesting choice for collaboration.



Theme Legend

1 - Arctic & Antarctic	6 - Environment	11 - Inform. & Comm. Tech.
2 - Biotechnology	7 - Climate Change	12 - Marine & Freshwater Biology
3 - Education	8 - Environmental Technology	13 - Maritime Research
4 - Energy	9 - Food Research	14 - Nanotech & New Materials
5 - Fisheries & Aquaculture	10 - Health & Care	15 - Welfare & Working Life

Figure 23 Positional analysis of selected countries in each theme with the mapping of their collaboration rate with Norway (2003–2012)

Note: The bubbles are coloured from yellow to red in ascending order based on the collaboration rate with Norway (based on FRAC). The SI and ARC were transformed in the graph so that the values are symmetrically distributed around the world level. The size of bubbles is proportional to the number of publications (full counting).

Source: Computed by Science-Metrix using Scopus (Elsevier)

4 Network Analysis

This section of the report presents international collaboration networks for each of the themes selected for this study on the organisational level. After a brief description of the networks focusing on the main clusters at the world level (e.g., regional and national aggregations of organisations), the position of Norwegian organisations within the international community is examined. Note that due to the study's focus on Norway, Norwegian organisations are over-represented in the networks. This could cause a bias towards distinct clusters of Norwegian institutions that have strong connections among each other and thus appear to be less connected internationally.

The scientific performance of Norway's collaborators is addressed to determine whether Norway's existing ties at the international level involve high performing organisations. Based on their specialisation and scientific impact (i.e., ARIF), organisations were separated according to the following five colours for the nodes (Figure 24) green (specialised and high impact), blue (not specialised, but impact above the world level), orange (specialised, but low impact), red (not specialised and low impact) and grey (close to the world level for both specialisation and impact).

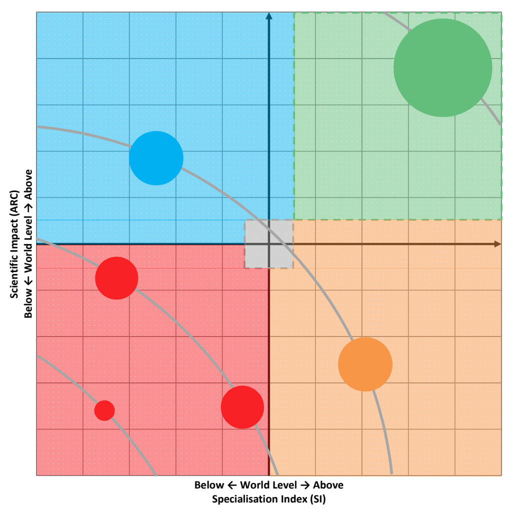


Figure 24 Colouring and size of bubbles in the collaboration network according to the scientific performance of organisations

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations.

Source: Computed by Science-Metrix using Scopus (Elsevier)

This colour scheme helps identify clusters of excellence in the network. A composite indicator based on the SI and ARIF was also calculated to define the size of the bubbles within the network, with the top performing organisations represented by the largest bubbles. Given that the composite indicator combines the SI and ARIF, organisations presenting different patterns of specialisation and impact can obtain the same composite score (i.e., the same size of bubble). For instance, identical scores can result in a blue or an orange bubble of the same size (Figure 24), with the former being the result of a strong impact combined with a low specialisation, and the latter being the result of a scientific performance combining high specialisation and low impact. The colour scheme was used in all thematic areas, with the exception of Scopus overall since the composite indicator cannot be computed when all scientific publications are accounted for (SI = 1.00 for all entities).

Finally, the countries and organisations identified as key strategic partners in Section 1 are analysed in more detail to complement the report and provide avenues for Norway to improve its performance and positioning at the international level. When considered relevant, social network indicators such as the PageRank are used to provide more insights on the structure of the networks and positioning of organisations.

4.1 Scopus

The international scientific community appears to be heavily clustered according to regional proximity (e.g., national and continental), although it also follows linguistic affinities, with most English-speaking countries (e.g., the US, Canada, Australia and the UK) located in a large cluster on the right side of the network, and European countries (e.g., Germany, Spain, Italy and Portugal) and other non-English-speaking countries in a large cluster on the left. These two clusters dominate the network, while other smaller substructures gravitate around them. It is interesting to note the proximity of the Chinese and Japanese clusters to the English-speaking clusters as opposed to the European cluster, which might indicate a preferred relationship with these organisations. As for Norway, its organisations are mainly located between both the American and the European clusters, although they are slightly closer to the European side of the network. Another cluster of Norwegian organisations is also located in the lower left section of the report. These organisations are largely isolated from the network due to their relatively weak collaboration link with the rest of the network.

Based on the PageRank indicator, the most central institution at the world level is by far the French National Center for Scientific Research (CNRS - *Centre National de la Recherche Scientifique*) (FR-5) (0.0211), followed by the US Department of Energy (DOE) (US-7) (0.0102), the Helmholtz Association (DE-7) (0.0092), the Chinese Academy of Sciences (CN-8) (0.0089), Harvard University (US-11) (0.0088) (0.97), CSIC (ES-4) (0.0078), Max Planck Society (DE-10) (0.0072) and the French Alternative Energies and Atomic Energy Commission (CEA - Commissariat à l'énergie atomique et aux énergies alternatives) (FR-3) (0.0068). Unsurprisingly, most of these organisations are large national institutions or distinguished universities, and six of the top 10 are located in Europe, which tends to demonstrate the high connectivity within the European community. The University of Oslo is highly central to this network, achieving the 11th highest PageRank score (0.0063), which is by far the highest score among the Norwegian organisations (University of Bergen is second for Norwegian organisations, ranking 41th overall). However, it should be kept in mind that given the over-representation of Norwegian organisations in this network, their centrality scores might be slightly boosted. Nevertheless, these scores should correctly approximate the importance of Norwegian institutions in the networks.

In terms of scientific impact, Norwegian organisations perform strongly at the international level, presenting ARIF scores generally above the world level. For instance, the Norwegian Knowledge Centre for the Health Services (NO-50) ranks 8th (1.70), while the National Institute of Occupational Health (NO-31) ranks 12th (1.65). American organisations dominate with 11 of the top 20 organisations for this indicator. However, the leading institution at the world level is the Icelandic company DeCODE Genetics (IS-1) (ARIF 2.44).

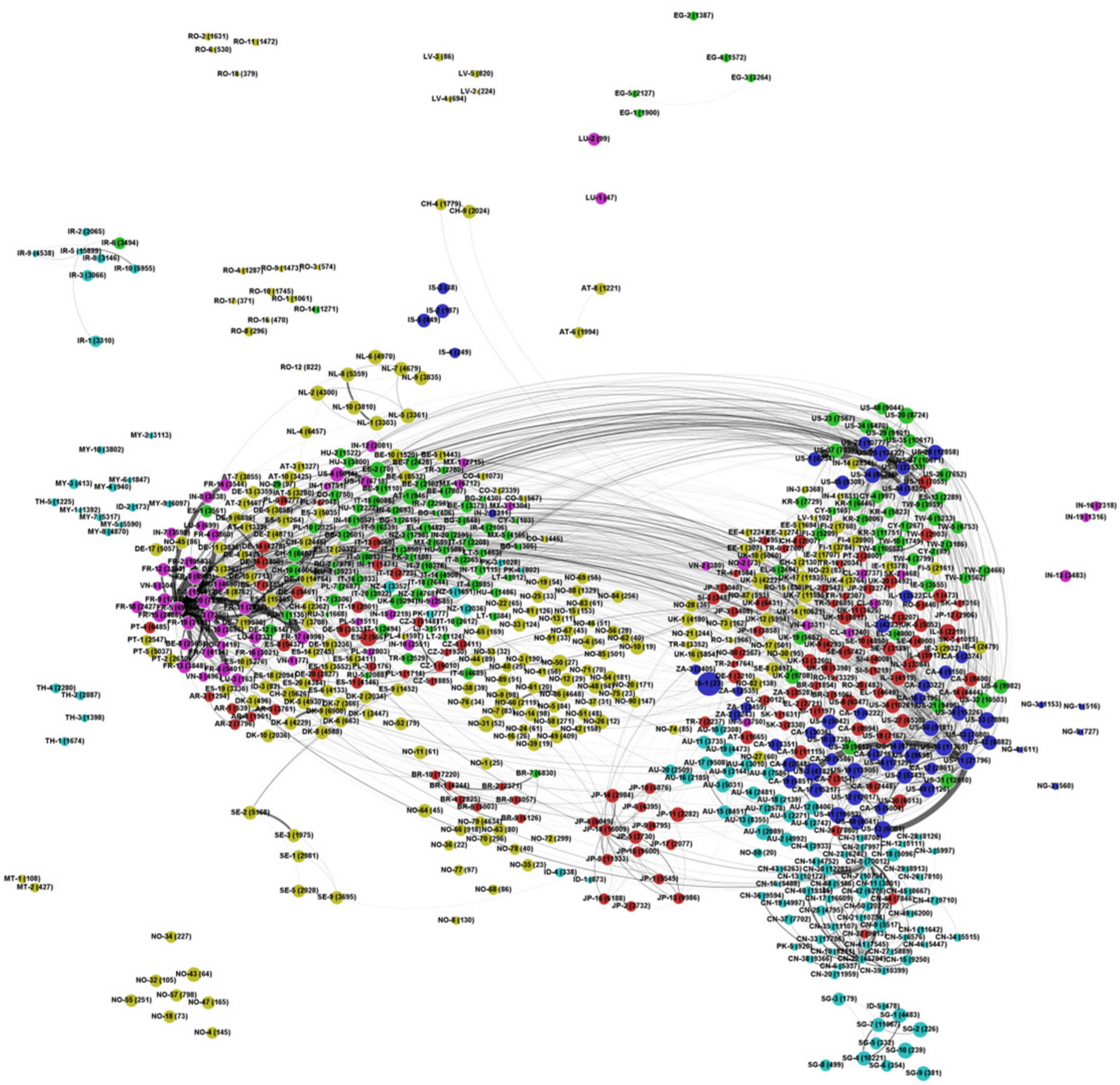


Figure 25 International collaboration network of selected organisations in Scopus, 2010–2012

Note: The bubbles are coloured based on a modularity score identifying communities in the network. The size of the bubbles is proportional to the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.2 Arctic & Antarctic Research

As Figure 26 shows, the international network in Arctic & Antarctic Research presents three distinct clusters: a European component (top), an American component (lower right) and a Scandinavian component (lower left). Norwegian organisations are all located in the Scandinavian cluster of the network, mostly collaborating nationally or with Finnish, Danish, Swedish and Icelandic organisations. Exceptions to these include the Queen Mary University of London (UK-13) in the UK, the Tallinn University of Technology (EE-4) and the University of Tartu (EE-5) in Estonia, and the Dalian University of Technology (CN-13) in China, which all present ties with the Norwegian cluster. Within this cluster, the University of Copenhagen (DK-9) and the University of Tromso (NO-88) act as central hubs, achieving the highest PageRank scores (respectively 0.0120 (8th overall) and 0.0110 (10th overall)). The Norwegian Polar Institute (NO-52) (0.0108, 11th) and the University of Bergen (NO-80) (0.0100, 14th) are also highly central, both in this cluster and in the network overall.

Norwegian organisations are among the best performers worldwide in Arctic & Antarctic Research, combining strong specialisation and impact scores well above the world level (as reflected by the nodes' colour [green = SI and ARIF above 1.1], as well as their size, which is proportional to a composite score accounting for both the SI and ARIF). Nevertheless, while most organisations in the Scandinavian cluster are specialised and have an impact above the world level in this research theme, a few Norwegian organisations have relatively low impact scores (orange nodes) although they are specialised. These include the Norwegian University of Science and Technology (NO-79), SINTEF (NO-66), the Norwegian University of Life Sciences (NO-57) and STATOIL (NO-72).

In section 3.2, Iceland, Denmark, Canada, the US, New Zealand and Switzerland were among those countries identified as potential key strategic partners for Norway to increase its scientific performance (in particular citation impact) in Arctic & Antarctic Research. Of these, Norway collaborates less than expected with Canada, the US and New Zealand. This network mainly confirms these findings as it appears that a close proximity already exists between Norway and both Iceland and Denmark, while relations with Canada, the US, New Zealand and Switzerland are more distant. More specifically, the University of Iceland (IS-5), the University of Aarhus (DK-8) and the University of Copenhagen (DK-9) were highlighted as possible key partners because of their overall strong performances in the field, and these three universities are all present in the Scandinavian cluster alongside Norwegian organisations. Regarding Canada, the US, New Zealand and Switzerland, organisations from these countries are primarily located in the American component of the network. Norway should seek to increase its ties with organisations in this cluster, especially considering that most of these organisations present strong scientific performances (mostly green and blue nodes).

Unsurprisingly, large organisations lead the way in terms of centrality scores: CNRS (FR-5, 0.0407), the Helmholtz Association (DE-7, 0.0274) and NASA (US-17, 0.0255). These organisations act as the main hubs in the European cluster (CNRS, the Helmholtz Association) and the American cluster (NASA). The University of Copenhagen (DK-9) is strategically positioned in the network, serving as a hub between the Scandinavian cluster and both the European and American clusters. Norway could try to capitalize on its strong relationship with the University of Copenhagen to increase its opportunities for collaboration overseas.

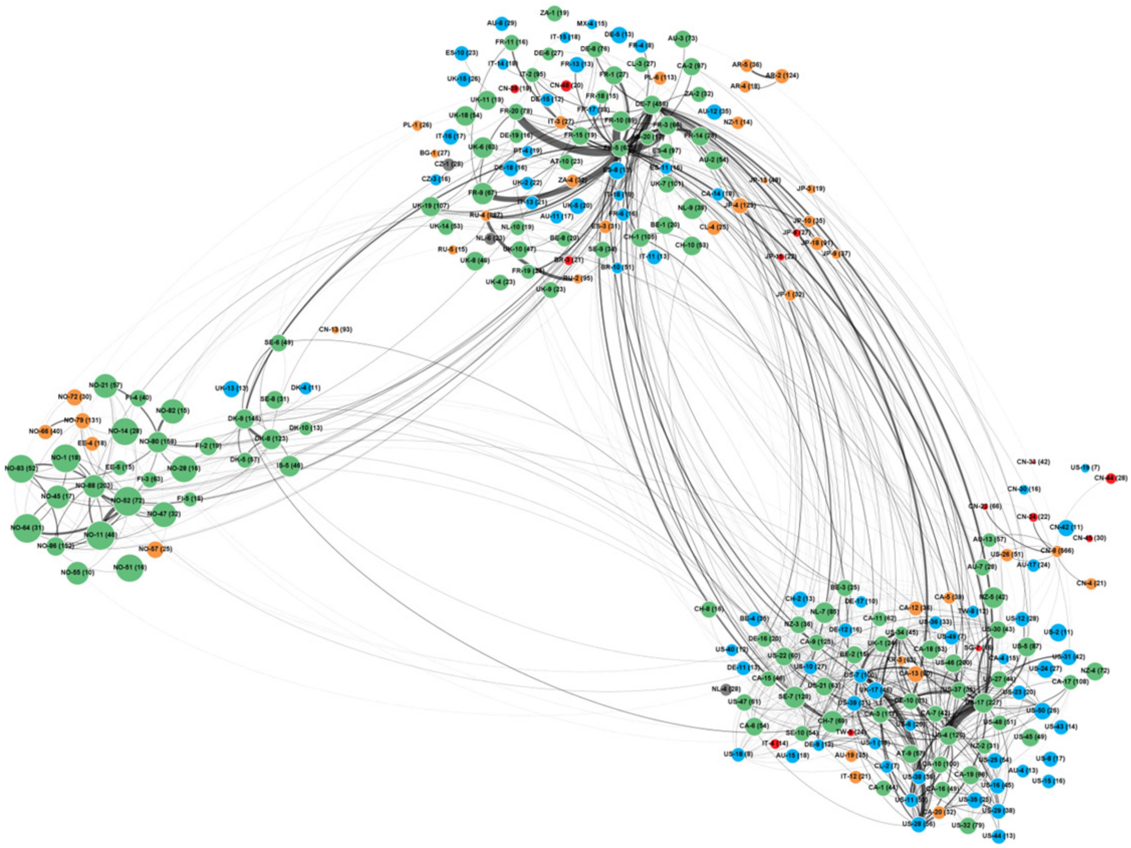


Figure 26 International collaboration network of selected organisations in Arctic & Antarctic Research, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.3 Biotechnology

While many structures emerge in the international network in Biotechnology research at the world level, the network is dominated by a large international cluster (Figure 27, upper right section). However, within this sub-structure, regional aggregations can still be observed, with American organisations occupying the centre of the cluster, Canadian organisations on their left, Chinese organisations above and European organisations below. It appears that while research in Biotechnology is highly integrated at the world level, regional and national preferences still play a significant role in this network, as is generally the case in scientific research.

A smaller European cluster, which is slightly disconnected from the European part of the main cluster and with the CNRS acting as the main hub (PageRank 0.0043), can also be observed. As well, many other national clusters are present in the network, indicating strong national preferences for such clusters (e.g., Italy, Brazil, Hungary, Romania, Argentina, Mexico and Portugal). This is also the case for Norway, whose organisations are all clustered in the lower right part of the network, mainly separated from any other structure. Indeed, only Norwegian organisations are part of this cluster, and even though other Scandinavian organisations appear in its vicinity, Swedish and Danish organisations are still closer to the international cluster than to the Norwegian one. Note that this might be caused to a certain extent by the over-representation of Norwegian organisations in the network.

While most Norwegian organisations in this cluster present strong scientific performance (mainly green and blue nodes), collaboration at the international level could help Norway strengthen its position in Biotechnology research. This state of isolation could be reversed by seeking collaboration partnerships with countries and organisations identified in section 3.3, which include Iceland, Luxembourg, the US, Denmark, Switzerland, the Netherlands, Ireland, Belgium and Germany. While Ireland and Switzerland were also identified as countries with which Norway should particularly intensify collaborations based on their less frequent cooperative efforts, all countries listed above are from the Norwegian cluster in the network, indicating that they could all be targeted in the Norwegian strategy.

Given the large number of countries mentioned above, developing stronger ties with organisations from the main international cluster would be beneficial to Norway. Collaborations with Harvard University, which was highlighted as a potential strategic partner in the US and comes 4th according to the PageRank indicator (0.0035), would be an efficient way for Norway both to increase its scientific impact based on Harvard's excellence in this theme, and to develop ties with other strong players in the international community based on Harvard's central role in the network. With most of the organisations at the core of the main cluster presenting strong scientific performances (green and blue nodes), many benefits could emerge from increasing partnerships between Norwegian organisations and these institutions.

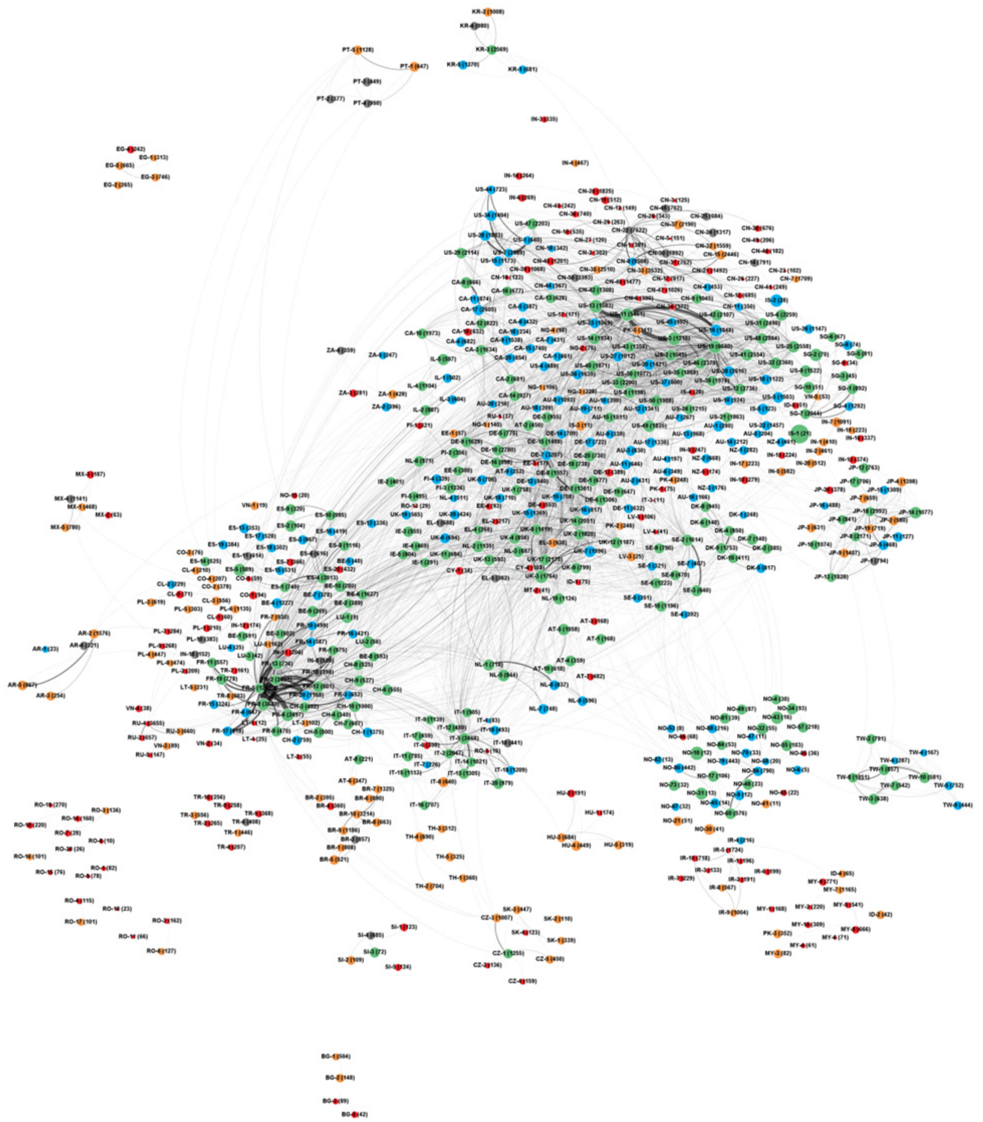


Figure 27 International collaboration network of selected organisations in Biotechnology, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.4 Education

The international network in Education research consists of many clusters mainly organised according to country affiliations (Figure 28), with the exception of two international clusters, one primarily dominated by American organisations (lower left section) and another comprised of European institutions (centre). Contrary to Norway's isolation observed in Biotechnology, some Norwegian organisations are integrated into a cluster involving actors from many countries

(Sweden, Denmark, Finland, the UK and Estonia). These organisations are the University of Agder (NO-85), the University of Stavanger (NO-87) and the University of Tromso (NO-88). With most organisations in the cluster presenting high scientific performance (green and blue nodes), these Norwegian organisations are already well positioned in the network, particularly considering that the University of Nottingham (UK-16) and the University of Oxford (UK-17), which section 3.4 identified among Norway's potential candidates for collaboration, belong to this cluster.

Interestingly, another cluster of Norwegian organisations can be found in the vicinity of the network's main cluster, primarily encompassing American universities. This disconnect from the three previous Norwegian organisations results from the links between the University of Oslo (NO-86) and three Californian universities: the University of Southern California (US-43), the University of California, Irvine and Stanford University. Norway should exploit these existing partnerships to develop its relationship with American universities as the US was also listed as one of the key potential strategic partners for collaboration in the theme of Education. Also, given that Canadian organisations are mostly encompassed in the American cluster and that Canada was among the list of recommended potential key partners, collaborations with these American organisations could help develop ties with Canada. Since it was suggested that Norway should seek to intensify collaboration with Canada based on the low levels of collaboration between both countries and Canada's overall strong performance, partnerships with solid Canadian actors such as the University of Toronto (CA-17) would fit well into Norway's global strategy.

Contrary to other themes where large national centres serve as the main hubs in the international network, universities, chiefly from English-speaking countries (i.e., the US, Canada, Australia and the UK), dominate in terms of PageRank scores. Harvard University (US-11) ranks 1st (0.0145), followed by the University of Toronto (CA-17) (0.0118) and the CNRS (FR-5) (0.0108). Norwegian universities rank low according to this indicator, the University of Oslo (NO-86) ranking the highest in 53rd position with a score of 0.0041. While Norwegian universities are integrated into some clusters, their ties in the network appear to be relatively weak compared to other leaders, which emphasises how important it is for Norway to strengthen its ties with its current partners and to seek new partners in the future.

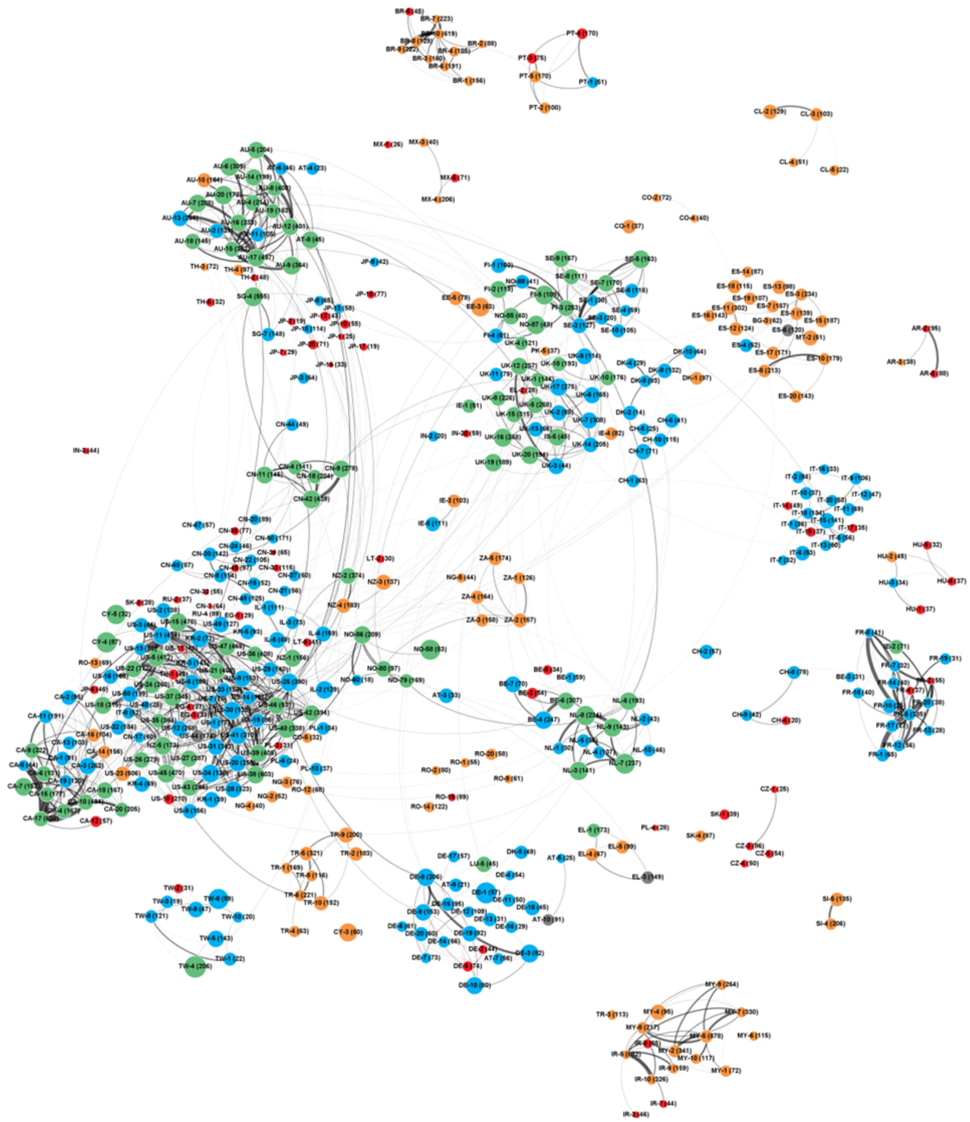


Figure 28 International collaboration network of selected organisations in Education, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.5 Energy

The international network in Energy is relatively dense (Figure 29), involving slightly more than 500 organisations clustered in four main structures: two international clusters, one of which is dominated by American organisations (upper left section) and the other by European organisations (lower left section), one Chinese cluster and another European cluster. In the American-dominated cluster, strong ties can be observed between a group of five organisations that constitute its core: DOE (US-7), Battelle Memorial Institute (US-1), the University of Tennessee at Knoxville (US-44), the University of Chicago (US-34) and the University of California, Berkeley (US-28). The international European cluster is essentially divided into two sections, with the CNRS acting as the main hub for the lower section and UK organisations representing most of the upper section.

Even though the majority of organisations belong to these four clusters, Norwegian organisations are almost isolated and mainly collaborate among themselves. The University of Bergen (NO-80) stands out here as it was clustered with other European organisations, although its ties with other organisations are relatively weak (less than 20 co-publications). While most Norwegian organisations in the network are specialised in Energy research, many have a low impact (orange nodes). In fact, Norwegian organisations closer to other international structures in the network have a high impact (NO-7, NO-88, NO-86, NO-80), while those isolated in the Norwegian cluster have a low impact, which tends to demonstrate the benefit of collaboration for Norway's organisations.

Collaboration with Singapore and the Republic of Korea, which were identified earlier as potential partners based on their scientific performance, and with which Norway rarely collaborates, could prove beneficial for all parties given that Singapore and Korea are also isolated in the network. Norway could seek partnerships with the Nanyang Technological University (SG-4), the National University of Singapore (SG-7) and the Korea Advanced Institute of Science and Technology (KAIST, KR-1) since they show strong scientific performance (green nodes) and have large outputs (over 500 publications each). If Norway was aiming at integrating the international network more directly, Canada would probably be its best opportunity based on its high level of scientific performance and its position in the network, i.e., close to the US and many top ranking European countries. Collaborations with the University of Alberta (CA-9) could present excellent opportunities for Norwegian organisations based on the university's strong scientific performance and its importance in the network (eigenvector centrality of 0.0040, 17th).

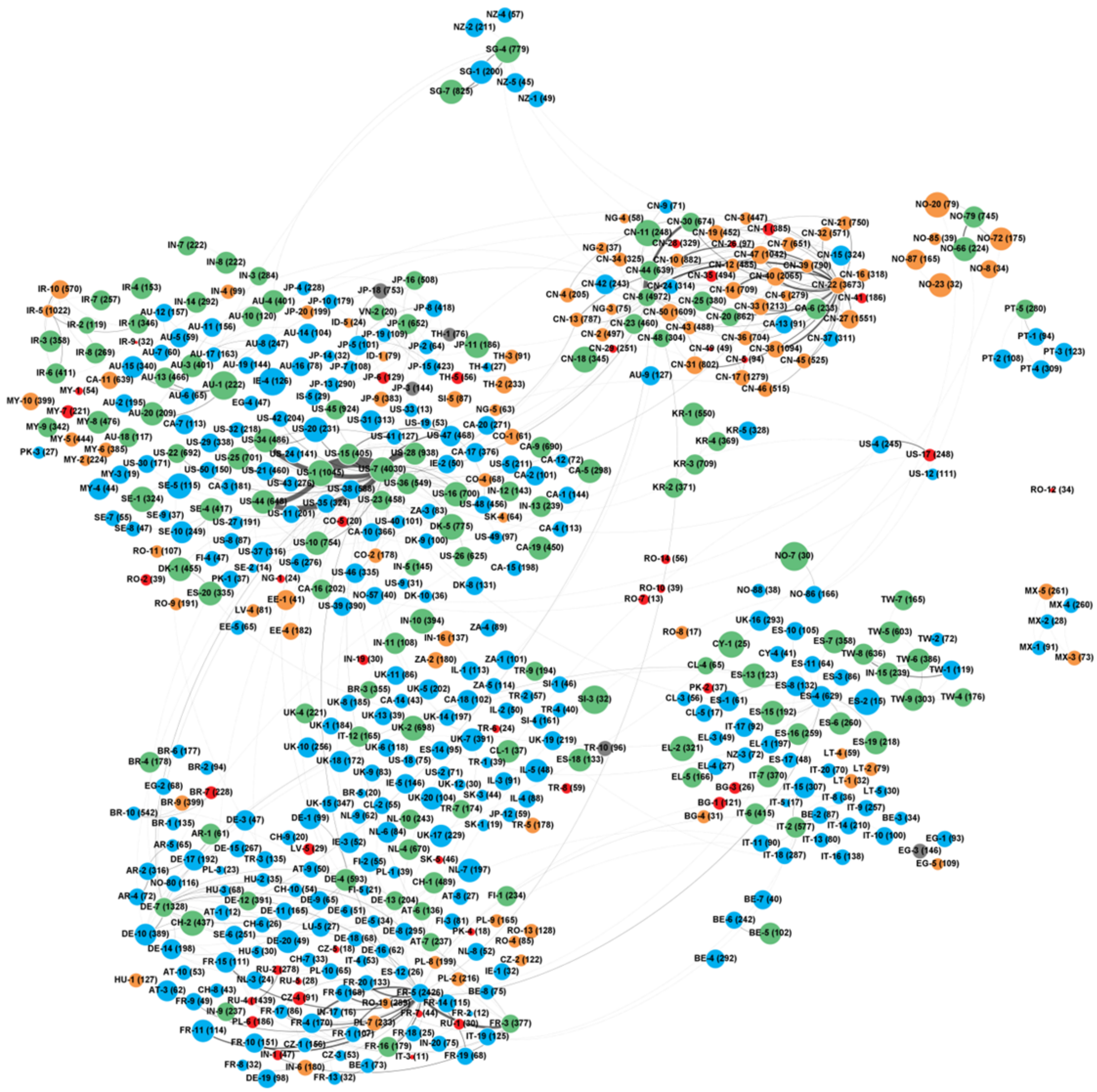


Figure 29 International collaboration network of selected organisations in Energy, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.6 Environment

The international network in Environment is highly clustered following country affiliations (Figure 30), with many organisations grouped in mainly isolated national clusters (e.g., Japan, China, Australia, Canada and Romania). As usual, American and European organisations each fall in two respective clusters dominating the network. Norwegian organisations are clustered together at the bottom of the network and show few links with other structures. The University of

Oslo (NO-86) is one of the only Norwegian organisations with notable links outside the Norwegian cluster, collaborating with Danish and Swedish organisations in the European cluster. This reflects on its PageRank score, which is the highest by far among Norwegian organisations (21st, at 0.0037, compared to 84th at 0.0030 for the second Norwegian organisation, the Norwegian University of Science and Technology [NO-80]).

While Norwegian organisations primarily do research on their own compared to practices at the international level, they nevertheless present strong scientific performances, with most being specialised and having a high scientific impact (green nodes). If Norway sought collaboration with other strong players at the international level, both countries could benefit from these partnerships. Section 3.6 lists many countries and organisations as potential key partners for Norway and, although Norway should try to develop its relationship with all of these (e.g., Switzerland, Denmark, Netherlands and the UK), it might be easier to develop relations with organisations that are not already highly connected in the international network since opportunities to collaborate with highly collaborative organisations might not be possible. Following this line of reasoning, Canada, Australia and Portugal, which are all mostly clustered on their own in the network and have high performing organisations (green and blue nodes), would be attractive choices for Norway. This is particularly true for Australia and Canada as they have large national structures in this theme. Also, Canada is close to both the European and the American clusters, which could open more doors for Norwegian organisations. As for Australia, co-publications with Norway remain below expectations, which might leave more room for improvement. The University of British Columbia (CA-10) in Canada and CSIRO - Commonwealth Science and Industrial Research Organisation (AU-3) in Australia are both important actors in their respective countries, present strong performances overall, are highly central in the network based on PageRank scores of 0.0037 (21th) and 0.0038 (19th), respectively, and could thus be targeted by Norway in its strategic plan. The University of Leeds (UK-10) would also represent a valid choice if Norway sought to integrate the international network through the European cluster since it performs strongly in this theme (green node) and is central to the network (PageRank: 0.0036, 31st).

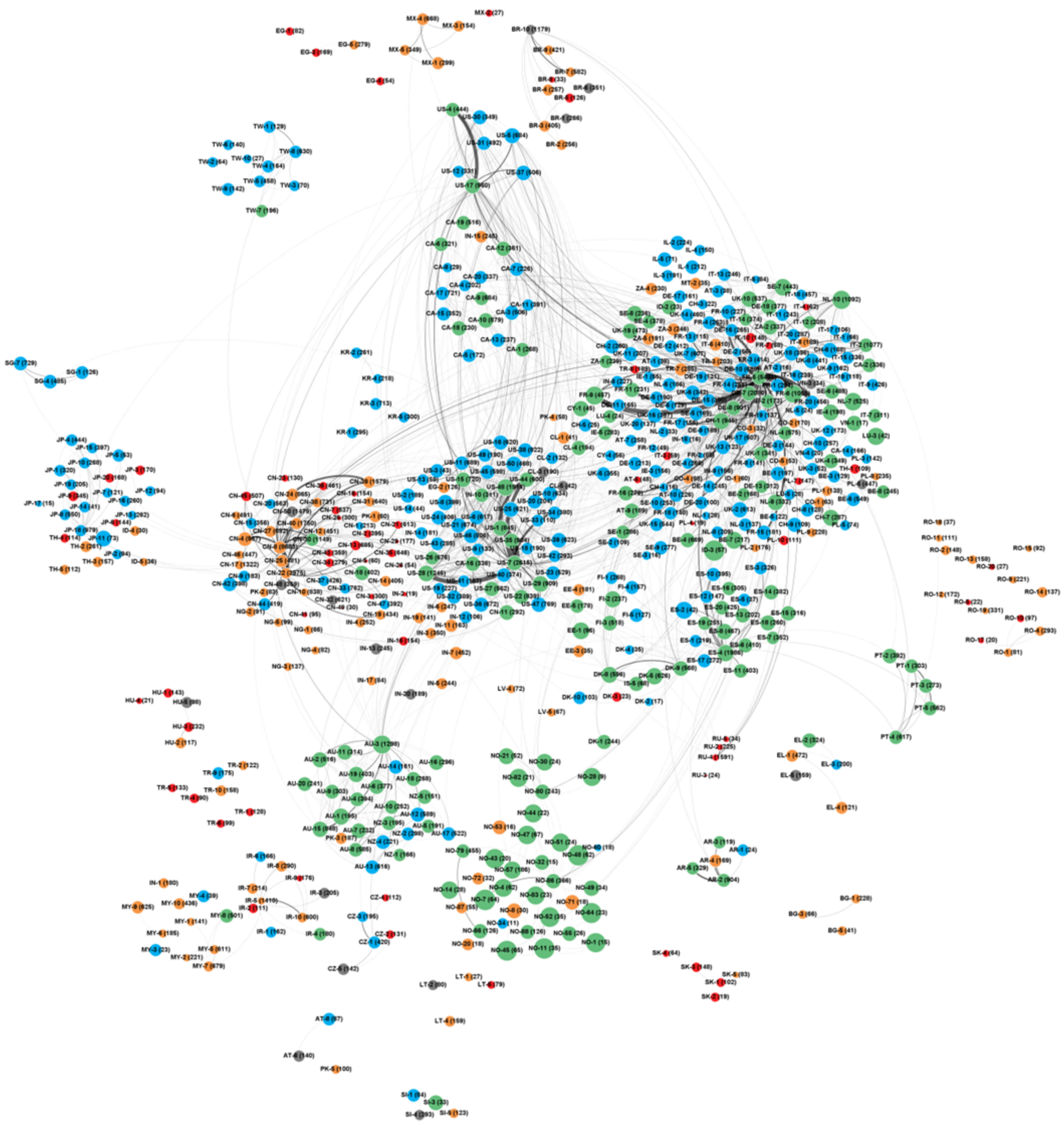


Figure 30 International collaboration network of selected organisations in Environment, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.7 Climate Change

The climate change community is highly interconnected at the international level, with most organisations involved in a large international cluster (lower left section of the network, Figure 31). In fact, the US, Taiwan, China, Canada, Japan, Australia and New Zealand are the only countries not highly connected with organisations in this cluster. However, some institutions of these countries also figure in the main cluster, for example institutions from the US and Canada.

A cluster encompassing Asian and Oceania countries (e.g., Japan, Singapore, Australia, New Zealand and Malaysia) is also visible in the network, which might be the result of regional affinities given the global nature of Climate Change research.

Norwegian organisations are positioned in the vicinity of the main international cluster. Overall, they present strong scientific performances in Climate Change research, aligning both specialisation and high impact (green nodes). While Norway's organisations are usually located close to other Scandinavian organisations, this is not the case in this theme. Given that Finland, Sweden and Denmark were all identified as potential strategic partners for Norway in this area (Section 3.7), increasing collaborations with organisations from these countries could be beneficial, particularly considering that some leading organisations from these countries are slightly or equally integrated in the network compared to Norwegian organisations. In fact, the University of Oslo, the most central Norwegian organisation based on the PageRank indicator, ranks 28th (0.0058), slightly below the University of Copenhagen (DK-9) in 24th position (0.0065) and just above Stockholm University (SE-7) (0.0055, 32nd). Note that centrality indicators for Norwegian institutions might be slightly overestimated due to the focus on Norway in the network.

Australia, Canada, New Zealand and the US were also highlighted as potential key partners for Norway's strategic plan, and in these cases Norway collaborated less than expected with these countries, which appears to be reflected in their position in the network. Collaborations with the DOE (US-7), which is highly central to both the network and the American cluster (PageRank of 0.0174, 3rd) and was highlighted as a valid candidate for collaboration in the US, would benefit Norway, as would cooperative agreements with the University of British Columbia (CA-10) (eigenvector centrality of 0.0058, 28th) and the Commonwealth Science and Industrial Research Organisation (CSIRO) (AU-3) (eigenvector centrality of 0.0083, 17th).

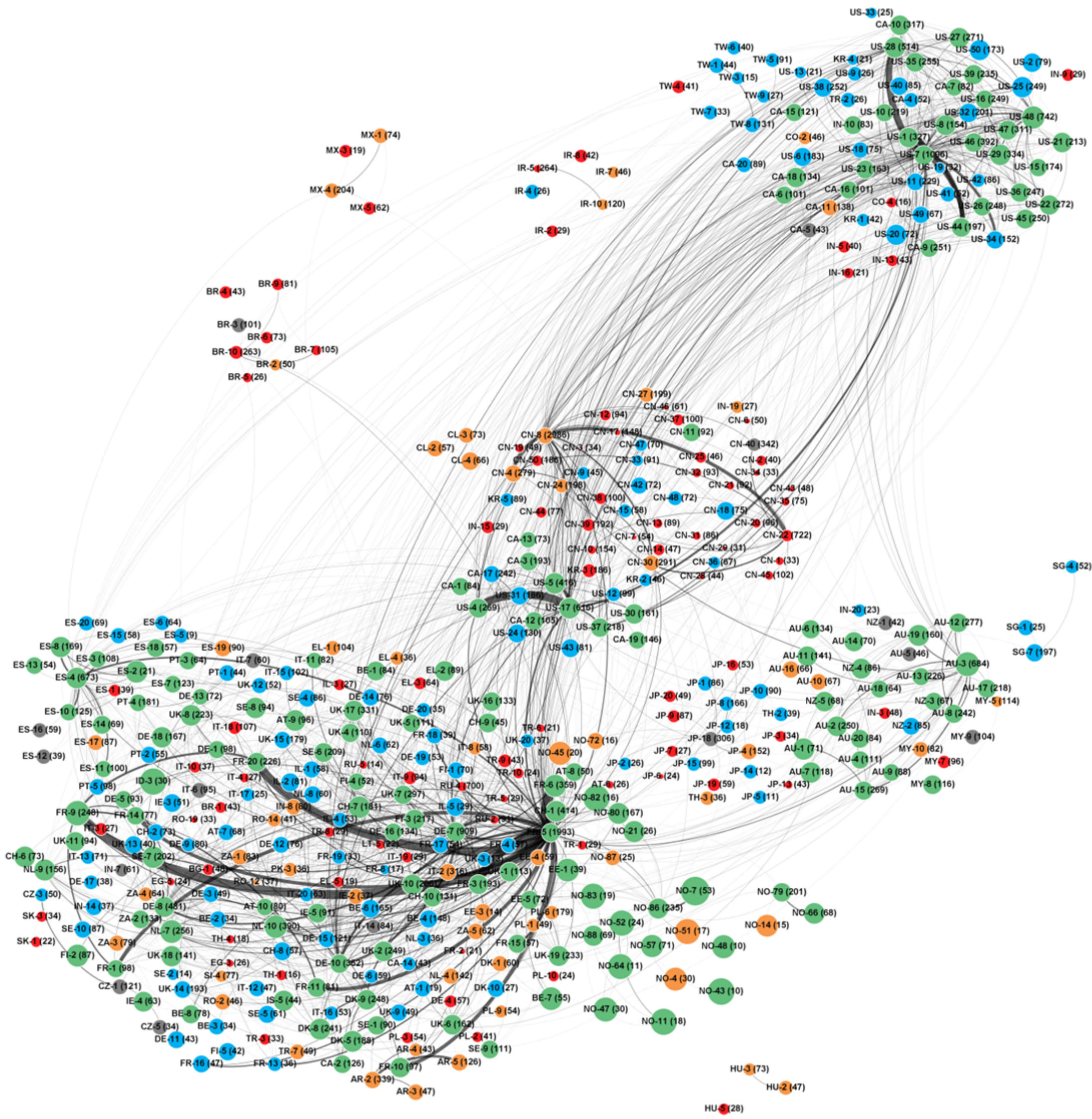


Figure 31 International collaboration network of selected organisations in Climate Change, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.8 Environmental Technology

Collaboration patterns in Environmental Technology are particularly interesting as they are somewhat unusual compared to the network structures in other themes. While American organisations are clustered together as usual and European organisations have a tendency to collaborate frequently, China exercises much more influence on the structure of the network than in the other themes, pulling towards it organisations from around the world (e.g., from Canada, UK, Belgium and Poland) (Figure 32). This is reflected in its PageRank scores, where the Ministry of Education of the People's Republic of China (CN-22) and the Chinese Academy of Sciences (CN-8) rank 2nd (0.0240) and 4th (0.0204) respectively. China appears to be an important player in the international network, and even though its main organisations are not all yet among the strongest (high specialisation, low impact: orange nodes), it was identified as one of the potential key strategic partners for Norway in Section 3.8, which should be kept in mind as concerns Norway's perspective in the region. For instance, collaboration with the Chinese Academy of Science (CN-8) could be sought given its strong performance (green node) and its high importance in the network, as was previously discussed. This partnership would be extremely attractive for Norway because it would provide new untapped opportunities, since Norway does not yet frequently collaborate with China.

Norwegian organisations are closer to other Scandinavian and European organisations as well as to those in the US and Canada. Although most of Norway's organisations (those obtaining some of the highest composite indicators) and close collaborators are top performing organisations, diversification could be important in the future, especially considering China's attraction in the international community and its increasing impact at the world level. Other partnerships that could be developed based on current low levels of collaboration include Spain, with the Spanish National Research Council (ES-4), and Australia, with the University of Queensland (AU-15), which both perform strongly at the international level and are highly central to the network, as reflected in their high PageRank scores of 0.0127 (5th) and 0.0063 (14th) respectively.

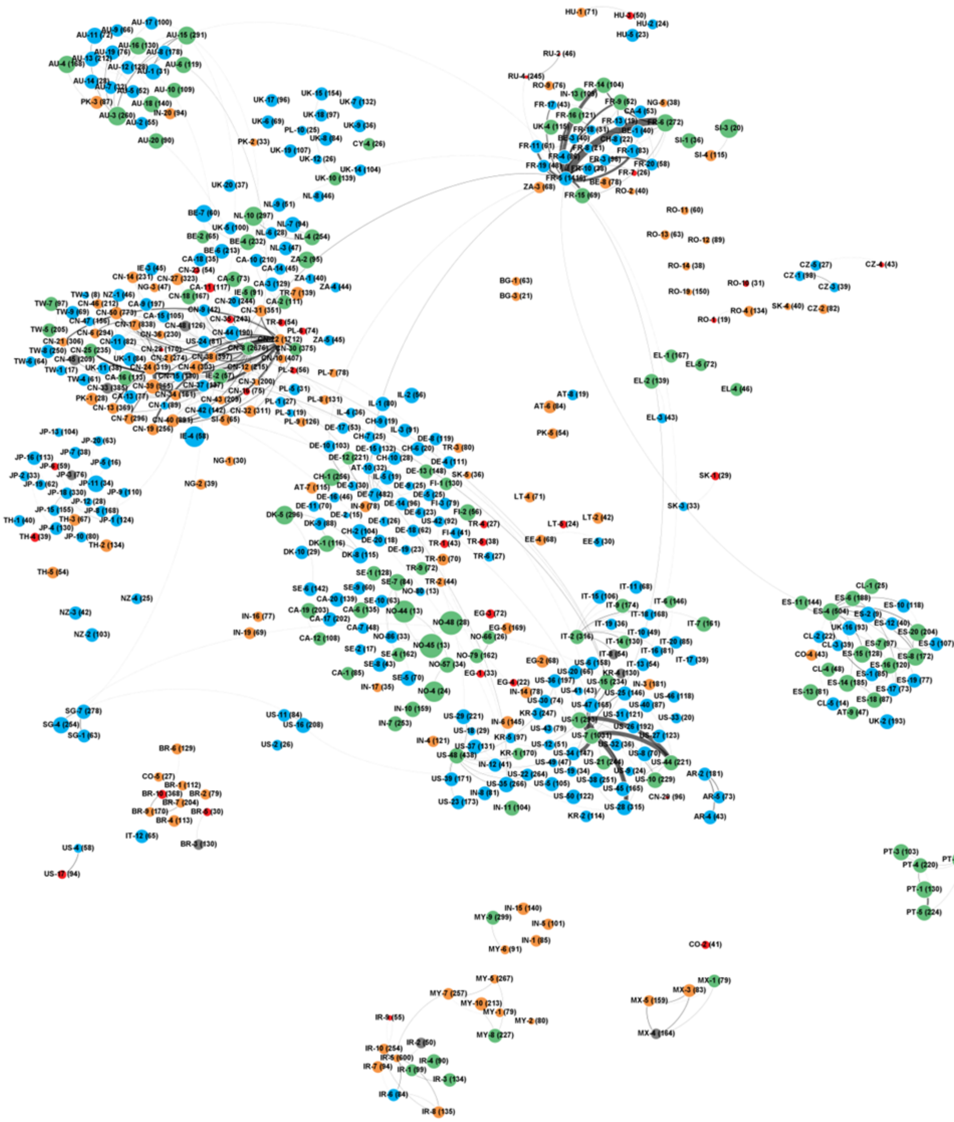


Figure 32 International collaboration network of selected organisations in Environmental Technology, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.9 Fisheries & Aquaculture

Three important structures at the international level can be identified in Fisheries & Aquaculture (Figure 33). The first encompasses mainly Canadian, Australian and American organisations, representing a highly promising pool of collaborators for Norway given that both Canada and Australia were identified as potential strategic partners in Section 3.9. The second cluster primarily involves European organisations, centred on the CNRS in France (FR-5). Lastly, the third cluster encompasses Norwegian as well as Scandinavian organisations and a mix of international institutions close to them, for example organisations from the Netherlands, Switzerland, the US and the UK. Most organisations in this cluster have a high scientific impact (blue and green nodes) and many are also specialised (green nodes). As mentioned in Section 3.9, Norway is one of the strongest countries in this theme, which is reflected at the institutional level where Norwegian organisations achieve some of the highest composite scores in the network. Norwegian organisations are also highly central to this network. According to the PageRank indicator, the Institute of Marine Research (NO-21) ranks 3rd (0.0189), the University of Bergen (NO-80) 5th (0.0141) and the University of Oslo (NO-86) is in 15th position (0.100).

Since Norway is already one of the top actors in this theme and already collaborates with top performing organisations at the world level, it could seek to strengthen its current ties with its collaborators, particularly with Denmark, which stood out as a potential strategic partner. The Technical University of Denmark (DK-5) would be well suited for this approach since it is highly specialised in this theme (SI 4.63) and has a strong scientific impact (ARIF 1.22), while it also acts as one of the most central entities in the community (eigenvector centrality of 0.0114, 11th). Increasing collaborations with Canadian and Australian organisations is also recommended based on their overall performances (listed as potential partners) and the strong cluster of research both countries developed together alongside the US. In this respect, Dalhousie University (CA-1) in Canada and the Commonwealth Science and Industrial Research Organisation (CSIRO) (AU-3) in Australia would be highly desirable partners. Spain and the Spanish National Research Council (CSIC) (ES-4) were also listed as potentially strong partners for Norway and would represent a strong entry point into the European cluster, the CSIC ranking second in terms of PageRank centrality (0.0206).

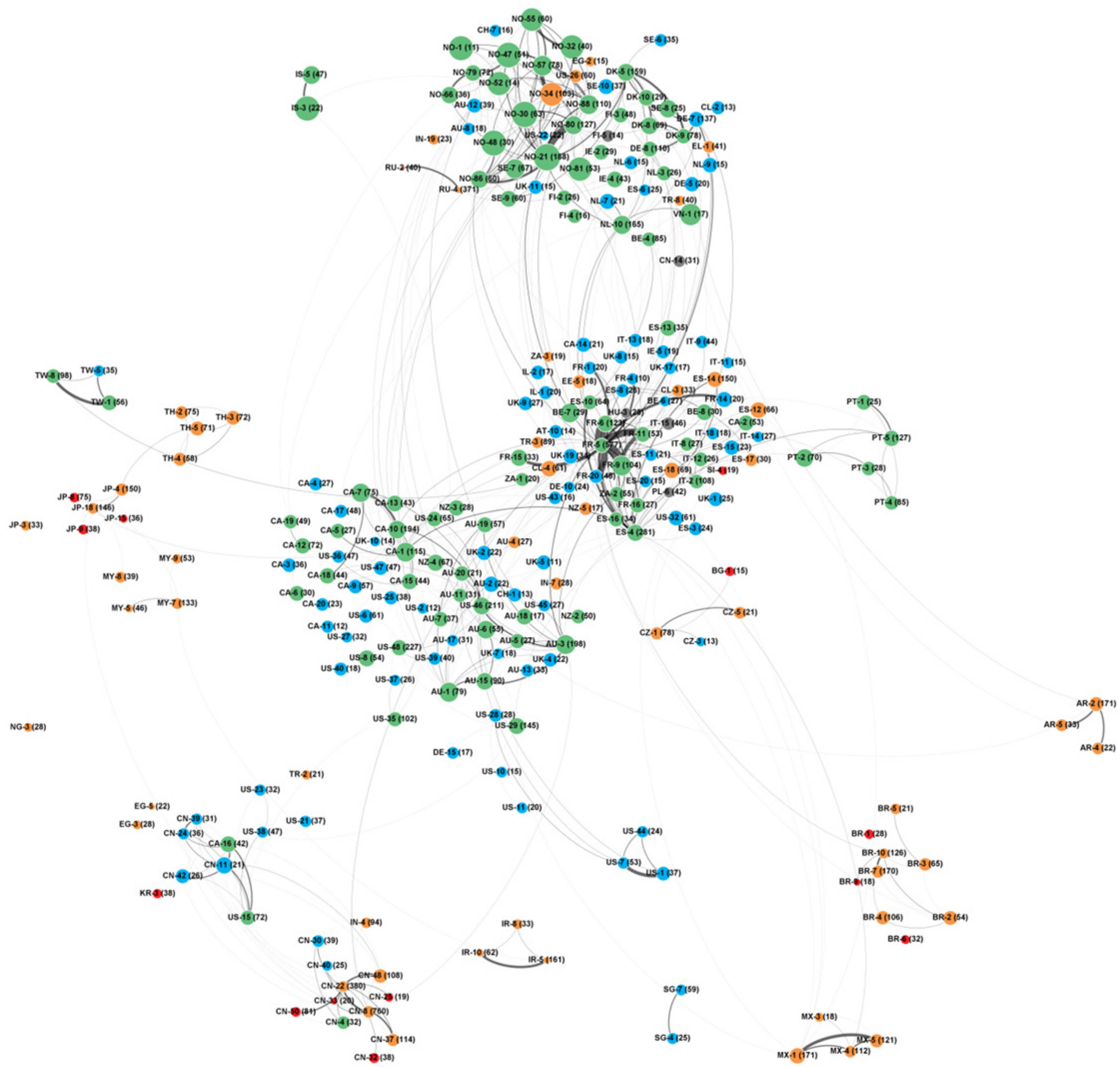


Figure 33 International collaboration network of selected organisations in Fisheries & Aquaculture, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.10 Food Sciences

Similarly to the other themes, the international collaboration network in Food Sciences research is mainly composed of an American and two European clusters, one centred on France and the UK and the other on Germany. Other smaller national clusters gravitate around these larger clusters. Norwegian organisations are again closely connected to other Scandinavian organisations, as well as to UK institutions. As it is encompassed in the large European network, the University of

Tromso (NO 88) stands out, in contrast to other Norwegian institutions that are in the vicinity of this cluster. Overall, most Norwegian organisations present strong scientific performances, achieving high levels of specialisation and scientific impact (green nodes). Such results are quite rare in this cluster as most of Norway's close neighbours are not specialised in this theme, despite their obtaining high ARIF scores (blue nodes). This cluster is structured around the Helmholtz Association (DE-7), which ranks 11th in terms of eigenvector centrality (0.0081). The second European cluster located below is centred on the CNRS (FR-5), which has the highest PageRank centrality in the network (0.0379), as well as on the INRA (2nd, 0.0210) and the Max Planck Society (DE-10) (7th, 0.0091). As usual, American organisations are close to one another, with the USDA - US Department of Agriculture (US-48) serving as an important hub in both the American cluster and at the international level with a PageRank score of 0.0166 (3rd).

In Section 3.10, some dozen countries were listed as candidates for key strategic partnerships with Norway, most of which are European (e.g., Denmark, the Netherlands and the UK). The US and Singapore were also listed and were specifically highlighted because of their low shares of co-publications with Norway, which is reflected in the network as both countries are located far from the Norwegian cluster. However, given their position in the network, some Norwegian organisations are already close to organisations from Denmark and the UK. Nevertheless, because national collaborations are dominant in Norway, the country could benefit from the expertise of other international leaders. For instance, the Wageningen University and Research Centre (NL-10), which was highlighted as a candidate for key partnership, acts as a bridge between both European clusters and presents one of the strongest scores for the composite indicator, which would make it an ideal partner for Norwegian organisations. Collaborations with the USDA (US-48) and the University of Aarhus (DK-8) could also be highly beneficial.

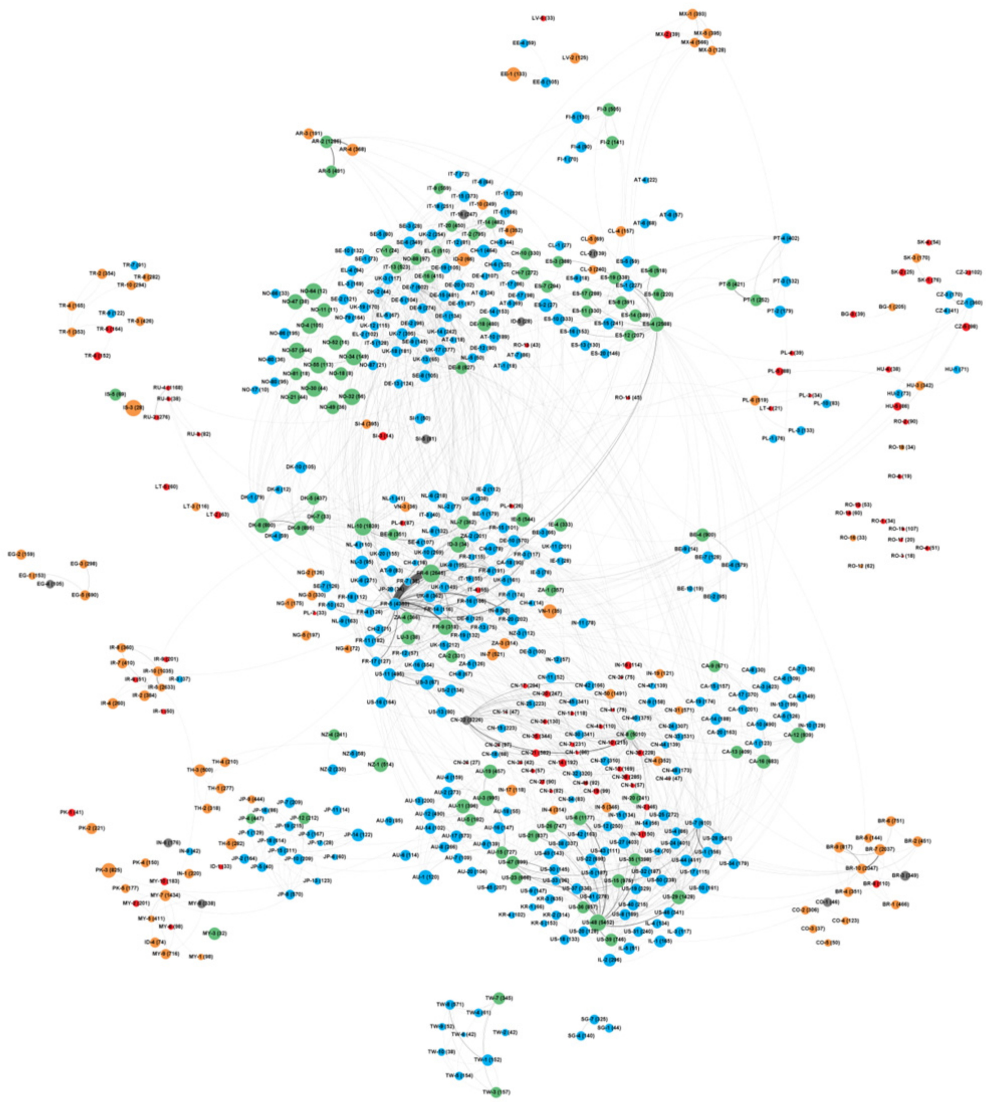


Figure 34 International collaboration network of selected organisations in Food Sciences 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.11 Health & Care

Health & Care represents by far the largest dataset in this study. Consequently, it is not surprising to observe the high quantity of co-publication links between organisations in the network (Figure 35), where most entities are aggregated in one big cluster, within which country aggregations can then be detected. While European organisations tend to be clustered on the left section of the cluster and American organisations on the right, organisations from many other countries can be detected close to the cores of theses sub-sections, which tends to highlight the fact that international collaborations are of significant importance in Health & Care.

While forming a part of the main international cluster, Norwegian organisations are grouped at the border of the cluster, almost on their own. National collaborations dictate the structure of the Norwegian sub-cluster, and most organisations, while being involved with collaborators abroad, are less central to the network than most other institutions at the international level. Nevertheless, in terms of PageRank centrality, the University of Oslo (NO-86), the highest ranked Norwegian organisation, ranks 18th (0.0062), ahead of the Oslo University Hospital (NO-60) in 23rd place (0.0058). As a result, Norwegian organisations are close to only a few organisations from Sweden, Denmark and the US.

Fortunately, these collaborators have a high scientific impact, and most are also specialised, which is also the case for Norwegian organisations. Since these three countries were listed as potential candidates for Norway's strategic plan, Norway's actual positioning in the network seems to be ideal. If Norway wanted to solidify its position in the network, collaboration with the NIH in the US (US-19), which was listed as potential partner, could be extremely beneficial as the organisation is highly central to the network (PageRank centrality of 0.0123, 4th), offers a wide set of opportunities to collaborate given its large output (about 12,700 papers in three years), and presents strong performance (high specialisation and impact, green node). Collaborations with US organisations should especially be encouraged given that Norway collaborates less than expected with American institutions. The Karolinska Institute (SE-2) would be a valid choice for strengthening collaboration with Sweden since it is also highly central to the network (0.0079, 11th) and combines strong specialisation and impact. Another potentially fruitful partnership could involve the Medical Research Council (UK-3), which ranks 10th in terms of centrality (0.0080) and was short-listed as one of the UK's organisation with which Norway should seek collaboration to increase its scientific performance.

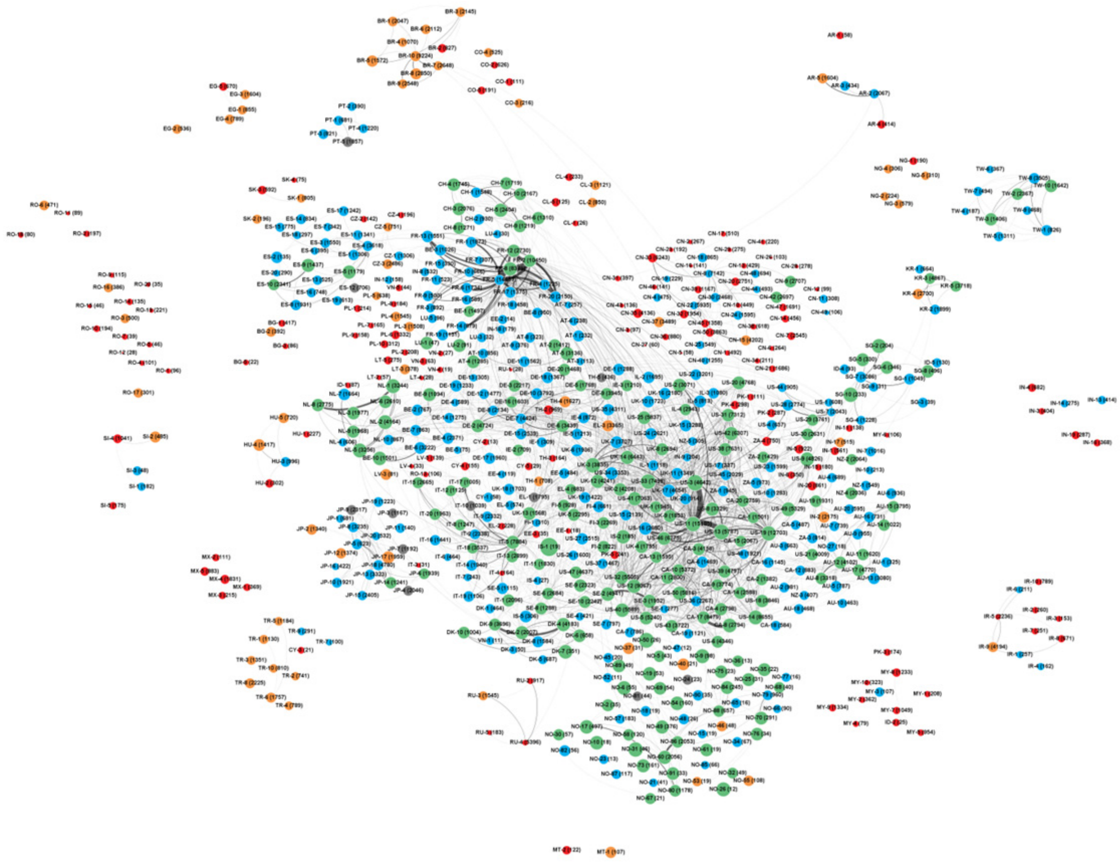


Figure 35 International collaboration network of selected organisations in Health & Care, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.12 Information & Communication Technologies

As Figure 36 shows, the international network in Information & Communication Technologies follows what could be described as a traditional pattern in terms of structures, with many national clusters, as well as the usual European cluster encompassing national sub-structures. Interestingly, European countries are split into two clusters, one centred on the CNRS (FR-5), and the other less centralised, with many organisation from Germany, Austria and one Norwegian organisation (the University of Bergen [NO-80]), which presents stronger ties to this cluster than to other Norwegian organisations that are clustered on the opposite side of the network (lower central section).

The Chinese and Japanese clusters are of particular interest for Norway. In fact, the Norwegian cluster is closer to both these than to any other group in the network. While not many links are visible between Norwegian organisations and these clusters in Figure 36 because weaker links were filtered out, many ties exist between Norway and both China and Japan in this theme. However, in both cases, the overall performance of Japanese and Chinese institutions is fairly weak, most of them performing below the world level in terms of impact. Although many Chinese organisations are highly specialised in this theme (orange nodes), most Japanese organisations are not (red nodes). However, this does not mean that Norway should discontinue its cooperation with these countries. It could instead focus on strong performers such as Japan's National Institute for Materials Science (JP-11), which is not specialised at all (SI 0.07) but presents a strong scientific impact (ARIF 2.63); or the City University of Hong Kong (CN-11), which combines high specialisation (SI 2.44) and impact (ARIF 1.77).

As mentioned in Section 3.12, Singapore and Taiwan were identified as two of Norway's potential candidates for strategic partnerships. Figure 36 shows that organisations in both these countries are clustered relatively close to Norwegian institutions. Given their actual proximity, particularly based on links to the University of Oslo (NO-86), it would be profitable to further support these partnerships in the future. Opportunities should be particularly significant in the case of Taiwan given that its share of co-publications with Norway is lower than the world average. The National Chiao Tung University (TW-6) and the Nanyang Technological University (SG-4) would be excellent candidates for the development of stronger partnerships as both were identified as top actors at the world level. Nanyang Technological University (SG-4) is also highly central to this network (0.0063, 13th). Given the overall strong performance of Taiwanese and Singaporean organisations in this theme, most partnerships with these countries could be highly beneficial to Norway. Even though most Norwegian organisations perform above the world level in terms of impact (green and blue nodes), their performance is less strong than that of these two countries. Lastly, if Norway is considering collaborating with highly central institutions in the network, the Massachusetts Institute of Technology (US-16) would probably be its more natural choice, the institution ranking 6th in terms of PageRank centrality (0.0078), and achieving strong levels of specialisation (SI 1.40) and impact (ARIF 1.70).

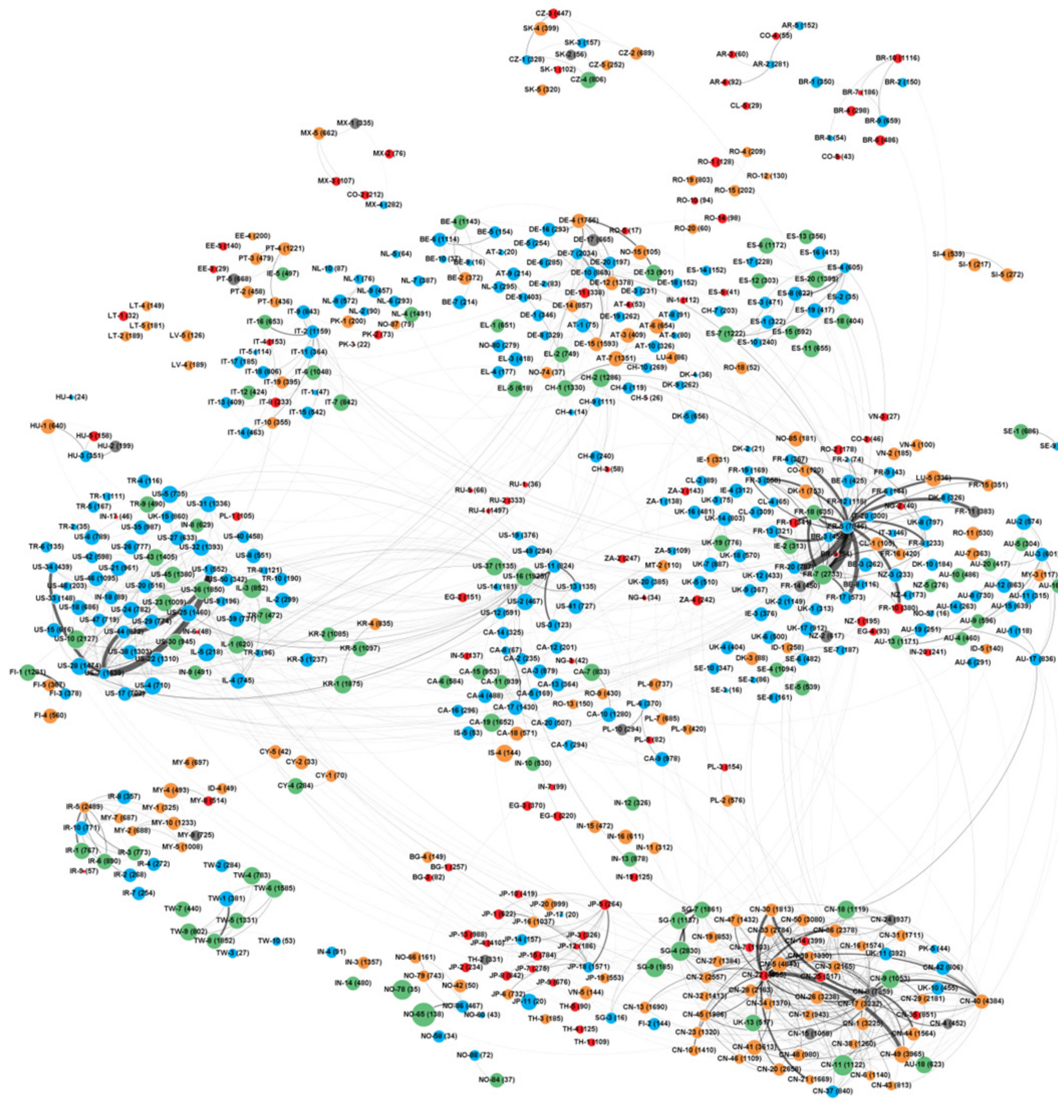


Figure 36 International collaboration network of selected organisations in Information & Communication Technologies, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.13 Marine & Freshwater Biology

Some interesting structures emerge from the international collaboration network in Marine & Freshwater Biology (Figure 37). As usual, national aggregations are the dominant factor determining the structure of the network, but organisations appear to be highly connected to one another the world over in this theme, resulting in a dense network with large clusters close to one another. With two mainly European clusters, a Chinese cluster on the left, completed by a

Japanese and Taiwanese substructure below, and an American cluster at the bottom accompanied by a mix of Canadian, Australian and New Zealand organisations, this network presents a number of notable findings. As is often the case, one of the European clusters is structured around the CNRS (FR-5), while the second at its right contains mainly German and Spanish organisations. Scandinavian countries are all clustered together in the upper section of the network, which should come as no surprise given not only the usual proximity of Nordic countries in scientific partnerships, but also the nature of the subject in question. The fact that these countries share common seas most likely strongly influences the decision to collaborate, even more so than in other themes. This Scandinavian cluster is close to the European cluster encompassing the CNRS, which highlights the importance of its other collaborators on the European side as opposed to other clusters to which Norway is less connected (the US for instance). In terms of scientific performance, Norwegian organisations are among the strongest in the network, allying strong specialisation and high scientific impact (green nodes). They score some of the highest composite scores, chiefly because of their high levels of specialisation. In fact, nine of the ten leading organisations for the composite indicator are from Norway, with SIs ranging from 9.26 to 32.8, and ARIFs from 1.14 to 1.37.

If Norway wishes to improve its already strong performance in this theme, it should seek to collaborate with other leaders at the world level. In fact, Norway is already doing so, as is demonstrated by its surroundings in the network. Norwegian organisations are close to other Scandinavian and some European organisations that exhibit strong scientific performances and have a high impact at the world level (blue and green nodes),a number of which are also specialised (green nodes). However, more effort could be made in this regard; for instance by collaborating more frequently with the University of Aarhus, which was short-listed in Section 3.13 as a valid key partner within Norway's strategic plan. Although the university is close to other Norwegian organisations in the network, none of these collaborated more than 10 times with the University of Aarhus between 2010 and 2012. Also, given the central role of the University of Aarhus in the network (eigenvector centrality of 0.0063, 18th), a partnership with this university could prove highly successful in helping Norway play a more central role at the international level.

The University of Southampton (UK-19) would also be an interesting partner for Norway as it was also short-listed as a candidate for the development of a strategic partnership. This collaboration would strengthen Norway's relation both with the English community in the theme and with the European community as a whole. The Wageningen University and Research Centre (NL-10) would also represent a strong candidate for new partnership based not only on its strong scientific performance, as highlighted in Section 3.13, but also on its centrality (eigenvector centrality of 0.0048, 35th). The university is located between both European clusters, connecting the two European communities. This is reflected in its betweenness centrality score (957, 14th), i.e. how often a node appears on the shortest paths between nodes in the network. Finally, partnerships with high performing countries that have shares of co-publications with Norway below the world average, such as Cyprus, Australia, the US and Portugal, would be beneficial in extending Norway's collaboration patterns beyond its traditional boundaries. CSIRO (AU-3), Dalhousie University (CA-1), the USDA (US-48) and the University of Aveiro (PT-2) could act as anchor points for the development of ties with these countries based on their strong scientific performances in Marine & Freshwater Biology research.

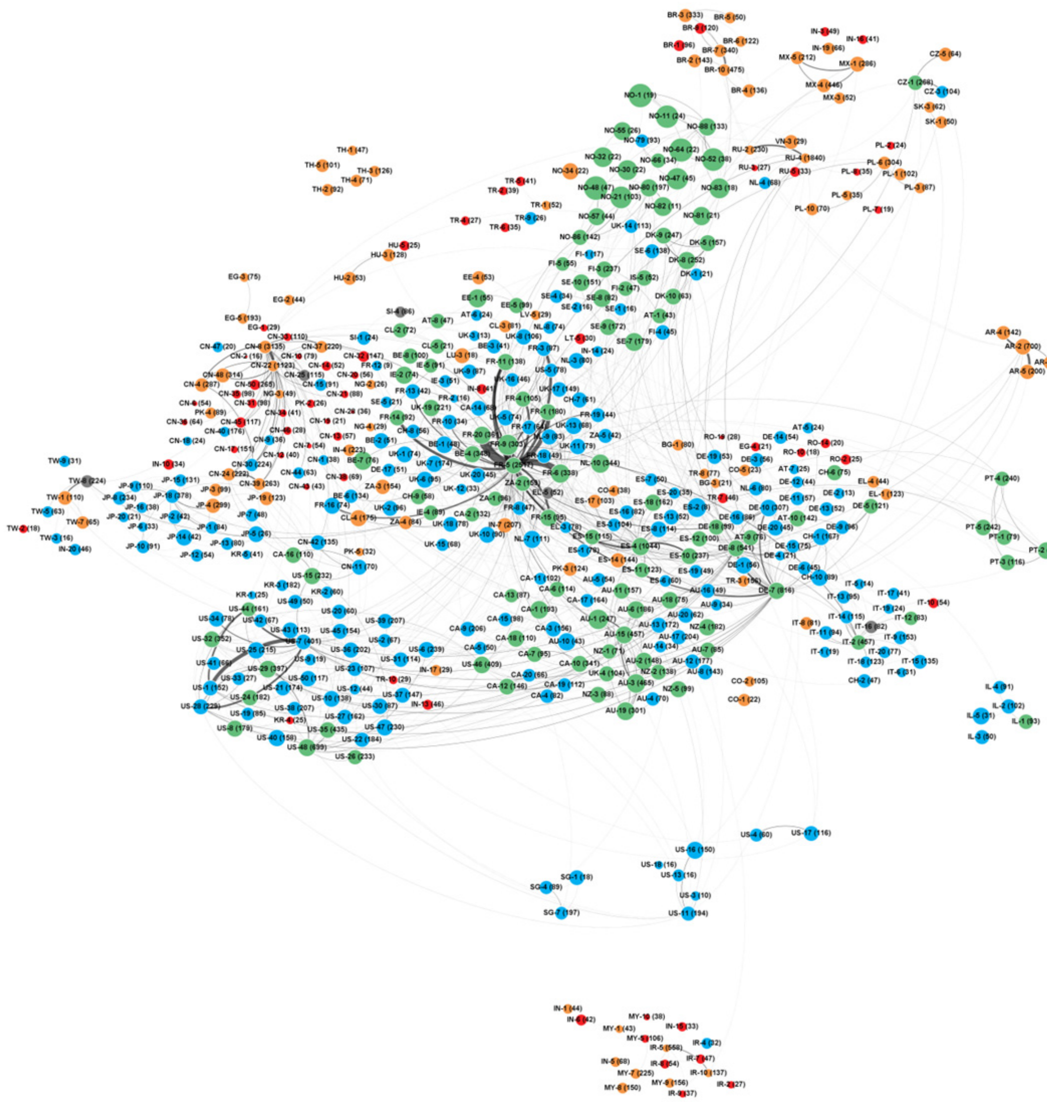


Figure 37 International collaboration network of selected organisations in Marine & Freshwater Biology, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.14 Maritime Research

The international network in Maritime Research is one of the smallest in this study, with 141 organisations included in the analysis (Figure 38). Given the small number of organisations involved in the network, national structures appear to be less visible. Possibly because of a lack of opportunities to collaborate nationally, organisations have had to turn to the international scene. While some clusters are clearly present (e.g., the US), most other structures are in fact multinational, especially the cluster in the lower right section of the network, which encompasses organisations from China, Australia, the UK, Portugal and Finland. Norwegian organisations fall into two clusters at the centre of network, surrounded by organisations specialised in this theme presenting strong scientific impact (mostly green and blue nodes).

With Norwegian organisations performing strongly at both these levels, resulting in the highest composite scores in the network, ties with high performing organisations abroad could be developed or strengthened to further improve Norway's current performance. For instance, the University of Oslo (NO-86) and the University of Bergen (NO-80), positioned close to the European cluster at the top of the network, could become more central by collaborating with the Helmholtz Association (DE-7), one of the most central hubs in this network (0.0236 for eigenvector centrality, 6th) and a strong performer overall for both ARIF and specialisation. Even though the Helmholtz Association was not short-listed in Section 3.14 because Germany did not stand out in this theme, the Association would represent a strong partner for Norway. The National University of Singapore (SG-7) would also be an excellent partner for Norway based on its scientific performance and Singapore's overall performance in this theme, especially considering that the university already has ties with Norway. Norway should develop this relationship as it could clearly benefit both factions.

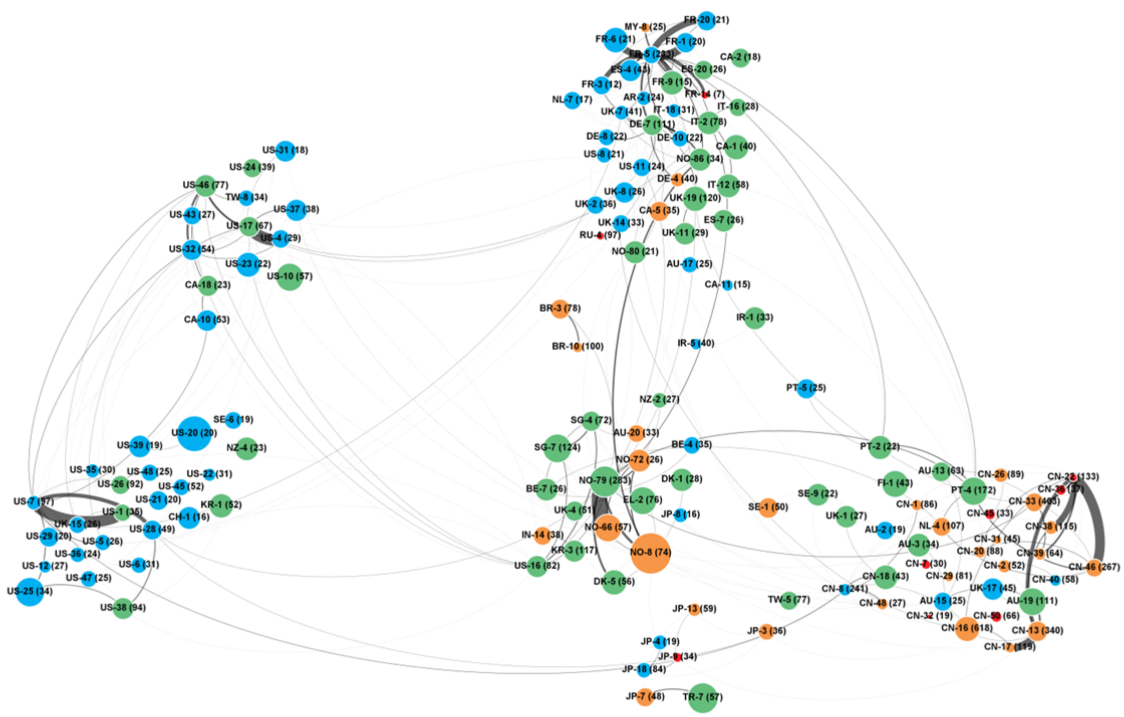


Figure 38 International collaboration network of selected organisations in Maritime Research, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.15 Nanotechnology & New Materials

As Figure 39 shows, research in Nanotechnology & New Materials is strongly clustered at the national level. While an international cluster that mainly encompasses European organisations can be observed, most countries are aggregated on their own. Even the US follows this pattern, which is quite rare as it usually pulls many countries into its vicinity.

Norway follows this same pattern, with Norwegian organisations being clustered in the left section of the network and presenting only a few notable links (more than 30 co-publications) between themselves and none with organisations from other countries. In terms of scientific performance, this theme is probably one of the weakest for Norwegian organisations, although most have a high impact and only lack specialisation. Nevertheless, this represents a strong opportunity for Norway to improve its performance by increasing collaboration with foreign partners. As discussed in Section 3.15, close to a dozen countries, including the US, Germany and China, would be suitable partners for increasing Norway's scientific performance. Interestingly, the three organisations selected as key partners for these countries are all highly central to the network: the DOE (US-7) (0.0267, 2nd), Max Planck Society (DE-10) (0.0111, 8th) and Chinese Academy of Sciences (CN-8) (0.0204, 4th). Since all three organisations present high levels of specialisation and impact, combined with large outputs, they offer many opportunities for collaboration.

Given that Singaporean institutions are close to the US cluster, collaboration with US organisations could also open connections to Singapore, one of the top performing countries in this theme. Collaboration with Nanyang Technological University (SG-4) could be sought to develop ties with Singapore based on its strong performance in Nanotechnology & New Materials. Overall, the US, Singapore and China have shares of co-publications with Norway below the world average, although all present strong scientific performances. This is also the case for the Republic of Korea, where KAIST (KR-1) stands out in terms of performance. As a general conclusion, it appears that Norway should extend its network to connect closer with Asian countries in Nanotechnology & New Materials research as the region includes numerous leaders in this theme, many of which do not collaborate frequently with Norwegian researchers.

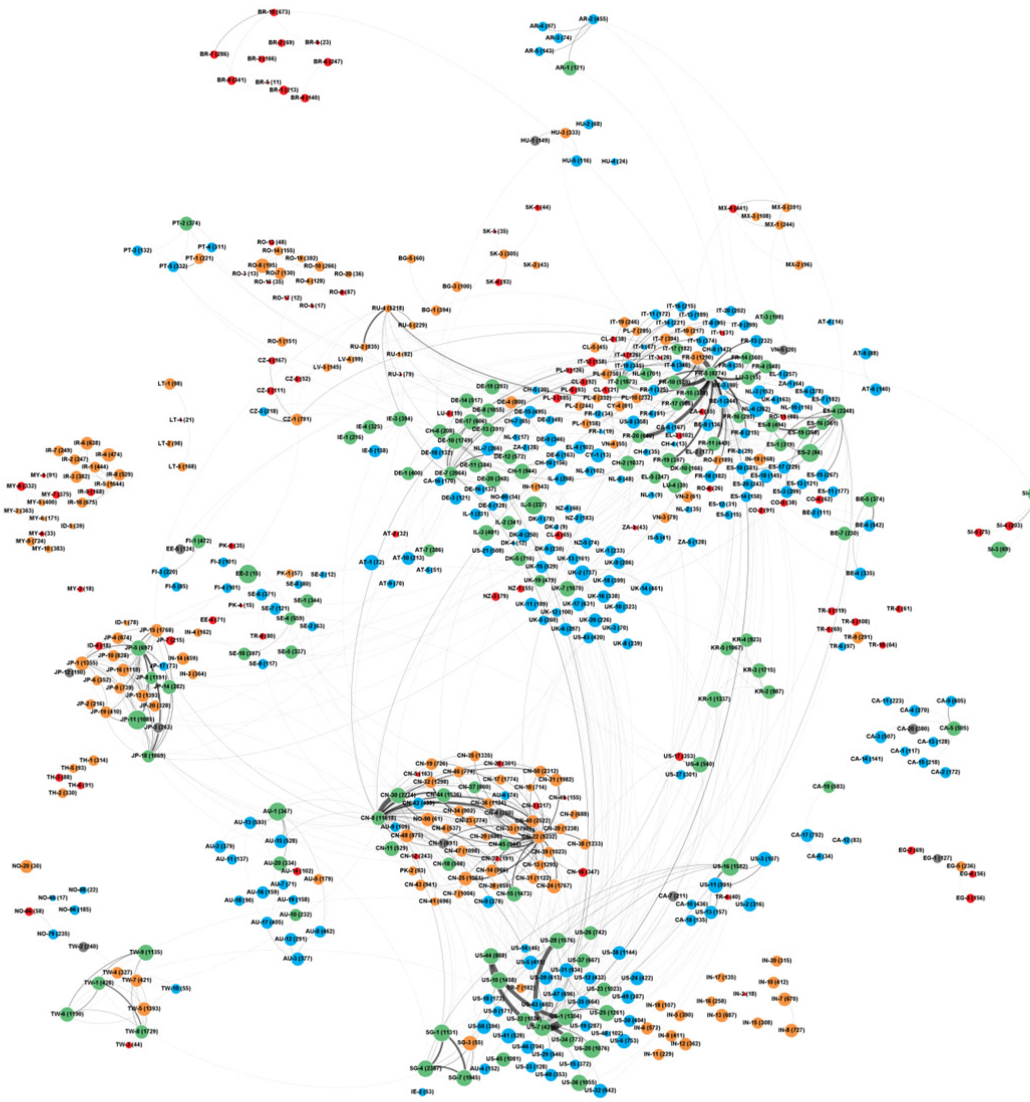


Figure 39 International collaboration network of selected organisations in Nanotechnology & New Materials, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

4.16 Welfare & Working Life

As Figure 40 indicates, the international collaboration network in Welfare & Working Life research appears less integrated than in a highly collaborative theme such as Health & Care. National clusters are well defined for many countries (e.g. Canada, Japan, Brazil, Taiwan, Australia and Norway), and even organisations that present international ties are nevertheless mainly clustered following national aggregations. Norway's collaborative pattern appears to be standard at the world level, with most Norwegian organisations collaborating with each other rather than showing strong connections at the international level. One exception is the University of Stavenger (NO-87), which is clustered with other European organisations on the right section of the network because of its ties with Dutch and English organisations. However, the university is not highly central to the network, as expressed by its eigenvector centrality of 0.0010 (316th), and is most probably limited by its low output in this theme (42 FRAC).

In terms of scientific performance, Norwegian organisations produce top quality research, achieving some of the highest scores based on the composite indicator. Overall, most of the Norwegian organisations are represented by large green bubbles, indicating that they have some of the highest levels of specialisation and impact at the world level. In order to retain their assets and even improve upon them, Norway could try to incorporate itself into the international community more frequently, seeking partnerships with countries and organisations listed in Section 3.16 as candidates for strategic partnerships (e.g., Denmark, Sweden, US, Canada and Switzerland). While Norway's relationship with Denmark and Sweden is strong in this theme, as it is in most research areas, this is not the case for Switzerland, the US or Canada, which have shares of co-publications with Norway below the world average. Accordingly, Norway should develop partnerships with organisations from these countries. For instance, partnerships with Harvard University (US-11) and the University of Toronto (CA-17) would be highly beneficial given their strong performances and their importance in the network, as expressed by their 2nd and 3rd highest PageRank centrality scores. Collaborations with the University of Toronto would open up opportunities with other high performing organisations, especially in the Canadian cluster, while a partnership with Harvard University could potentially open up even more borders given the huge pool of organisations to which it is linked in the network, both in the US and internationally. As for Switzerland, the University of Zurich would represent a strong actor in the community to expand Norway's collaboration and to increase its general scientific performance in the strategic theme of Welfare & Working Life.

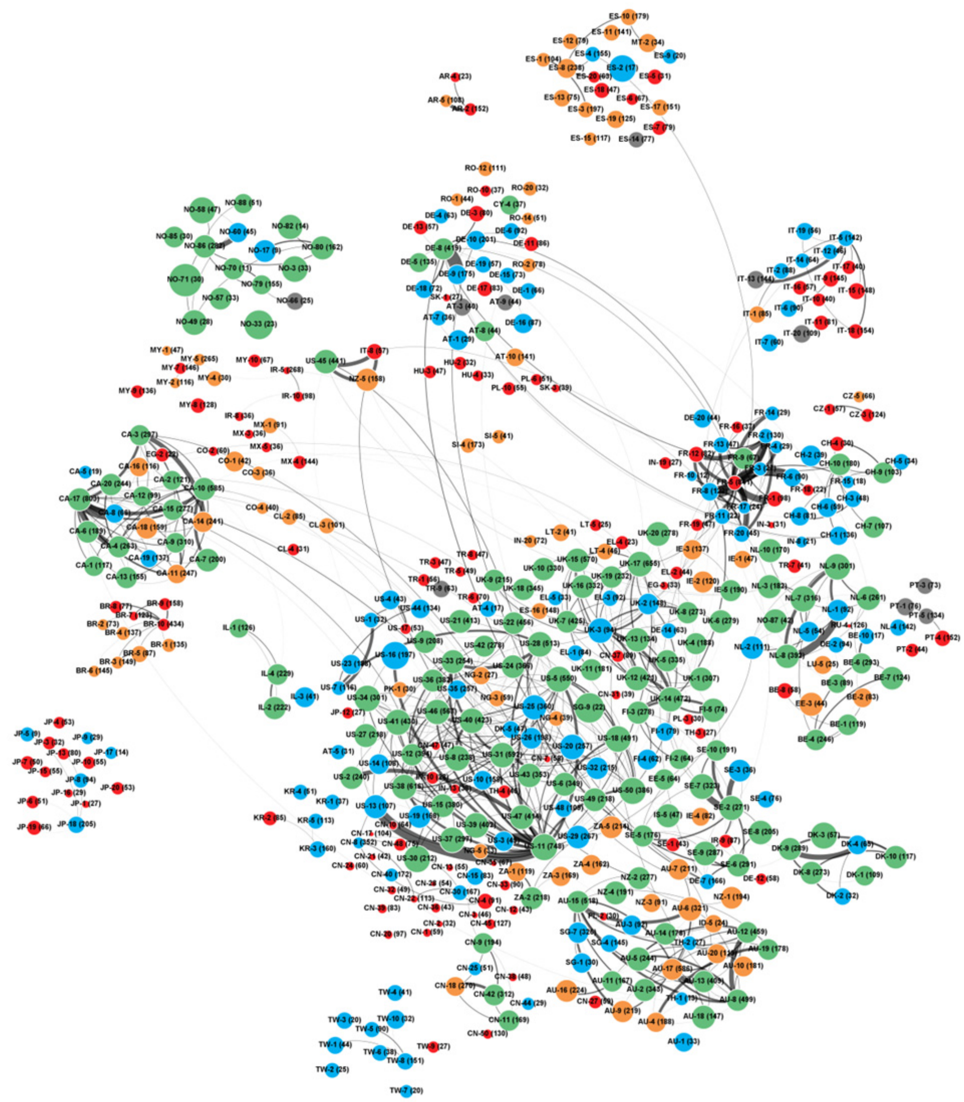


Figure 40 International collaboration network of selected organisations in Welfare & Working Life, 2010–2012

Note: The bubbles can be coloured the following five colours: green (specialised and high impact), blue (not specialised and high impact), orange (specialised and low impact, red (not specialised and low impact) and grey (at the world level both for specialisation and impact). The size of the bubbles is proportional to a composite indicator based on both the SI and the ARIF. The width of the links is proportional to the number of co-publications (FULL) between organisations. The number of publications (FRAC) of each entity is listed in parentheses next to its organisation's label. Organisations are labelled based on their country code plus a serial number; see the Appendix for the legend.

Source: Computed by Science-Metrix using Scopus (Elsevier)

5 Effect of Multilateral Co-Authorship on the Scientific Impact of Research Output

Which type of scientific partnership is most beneficial to a country's scientific impact (and to Norway in particular) and what are the mechanisms underlying such gains in impact? This question has attracted much attention from the scientific community in bibliometrics, as well as from decision makers within the context of collaboration policy development. For instance, it is well known that international co-publications have, on average, more impact than domestic co-publications, and that the latter have more impact than single author publications in most scientific areas and disciplines.[21,22,23] Various explanations have been proposed to account for the increased scientific impact of papers resulting from partnerships in the scientific literature, the most common being author self-citations.[24] There is no doubt that as the number of co-authors increases on scientific publications, so does the likelihood of self-citations; thus, the more authors on a paper, the higher its chances of being cited. If this were the sole mechanism underlying the increased impact of co-publications, serious questions could be raised about the benefit of scientific partnerships since the increased influence or impact of a given paper within the scientific community would not extend beyond its actual co-authors, unless nearly all researchers in a given field contributed to the paper, which is generally not the case, apart from rare instances involving research consortia.

5.1 Effect of Author Self-Citations on the Citation Impact of Co-publications

Although self-citations probably explain some of the differences observed in the impact of international co-publications, domestic only co-publications and single author publications, other factors may also very well be at play. As a first line of investigation for a better understanding of the mechanisms involved in increasing co-publications' citation impact, the ARC of the above three categories of papers was measured with and without self-citations, thereby providing a mean to assess the size effect of self-citations on the citation impact of various publication types.[25] In excluding the self-citations of a paper, all citations by any of the paper's

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[21] Costas, R., van Leeuwen, T.N. and Bordons, M. (2010) Self-Citations at the Meso and Individual Levels: Effects of Different Calculation Methods. *Scientometrics*, 82: 517-537.

[22] Campbell, D., Roberge, G., Haustein, S. and Archambault, E. (2013). Intra-European Cooperation Compared to International Collaboration of ERA Countries. Produced by Science Metrix-Canada under the coordination and guidance of the European Commission, Directorate-General for Research and Innovation, Economic analysis and indicators Unit, ISSN: 1831-9424, http://ec.europa.eu/research/innovation-union/pdf/intra-european_intern_collab.pdf#view=fit&pagemode=none.

[23] Puuska, H.-M., Muhonen, R. and Leino, Y. (2014). International and domestic co-publishing and their citation impact in different disciplines. *Scientometrics*, 98: 823-839.

[24] See footnote 23 above.

[25] **Methodological remark:** The relative citation (RC) scores of individual papers used in computing the ARC were computed with or without self-citations (i.e., the number of citations [with or without self-citations] of each paper was normalised by the corresponding average number of citations [i.e., with or without self-citations] of all publications published the same year in the same subfield to account for varying citation windows and differences in the referencing practices of researchers across disciplines, see Section 7.4.6 for details on the ARC). Note that since review articles were excluded throughout Section 5, the analyses were mainly performed on original research articles and conference papers.

authors were excluded. This was achieved for all papers in the Scopus database (for the 1996-2010 period; the years 2011 and 2012 were excluded since the citation window for papers published in those years is short and could potentially lead to biases) using the database unique author identifier (AUID) to allow for the subsequent normalisation of citation scores at the paper level (see later in this section).

Tests were performed to assess the potential downsides of using this approach due to a potential lack of precision and recall of the AUID in attributing publications to a given researcher, especially for papers with hundreds of authors as is the case in particle physics. Considering that the analysis is based on the entire population of papers in Scopus, where the law of large numbers applies well, the results suggest that this approach did not overly reduce or amplify the removal of self-citations for papers with a large number of authors or for specific subfields. For instance, there do not seem to be significant outliers when plotting the average number of authors on a publication with the average percentage of self-citations for various author size bins (Figure 41A), or when plotting the average number of authors on a publication with the average percentage of self-citations for various subfields (Figure 41B). In fact, data points in Figure 41B form a random cloud with the average rate of self-citations ranging from a low of 22% to a high of 43%, and the subfield with the largest average number of authors per paper, i.e., Nuclear & Particle Physics, does not exhibit a rate that stands out from the variation observed for the remaining subfields.

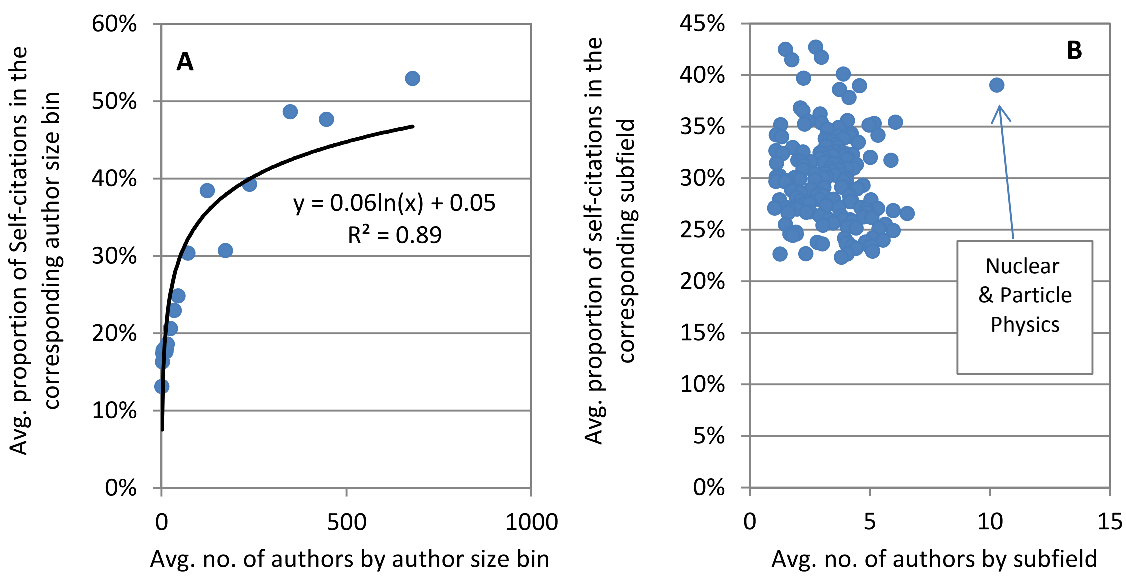

Figure 41 Relationship between the number of authors on a paper and the percentage of author self-citations in Scopus for (A) various author size bins and (B) scientific subfields (1996-2010)

Note: The analysis is based on the entire Scopus database. The years 2011 and 2012 were excluded since the citation window for papers published in those years is short and could potentially lead to biases. The papers were categorised in 23 bins based on their absolute number of authors (i.e., no normalisation by publication year and scientific subfield) and in 176 subfields based on Science-Metrix' journal-based classification of science.[26] See Companion Excel Data Book for information on bin ranges. The number of authors and the percentage of self-citations are computed based on the raw scores of papers (no normalisation by publication year and scientific subfield).

[26] Archambault É., Caruso J., and Beauchesne O. (2011). Towards a Multilingual, Comprehensive and Open Scientific Journal Ontology, in Noyons, B., Ngulube, P. and Leta, J. *Proceedings of the 13th International Conference of the International Society for Scientometrics and Informetrics (ISSI)*, Durban, South Africa, pp 66-77.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Figure 42 confirms that factors other than author self-citations play a role in increasing the citation impact of various types of publications. For instance, it shows that the larger impact of international versus domestic only co-publications versus single author publications persists when excluding author self-citations (SC). Indeed, although the scientific impact (ARC) of international co-publications decreases (from 1.42 to 1.36) when self-citations are eliminated, remains roughly stable for domestic co-publications (0.94 vs. 0.93) and increases slightly for single author publications (0.64 vs. 0.67), important gaps between publication categories remain once self-citations have been removed.

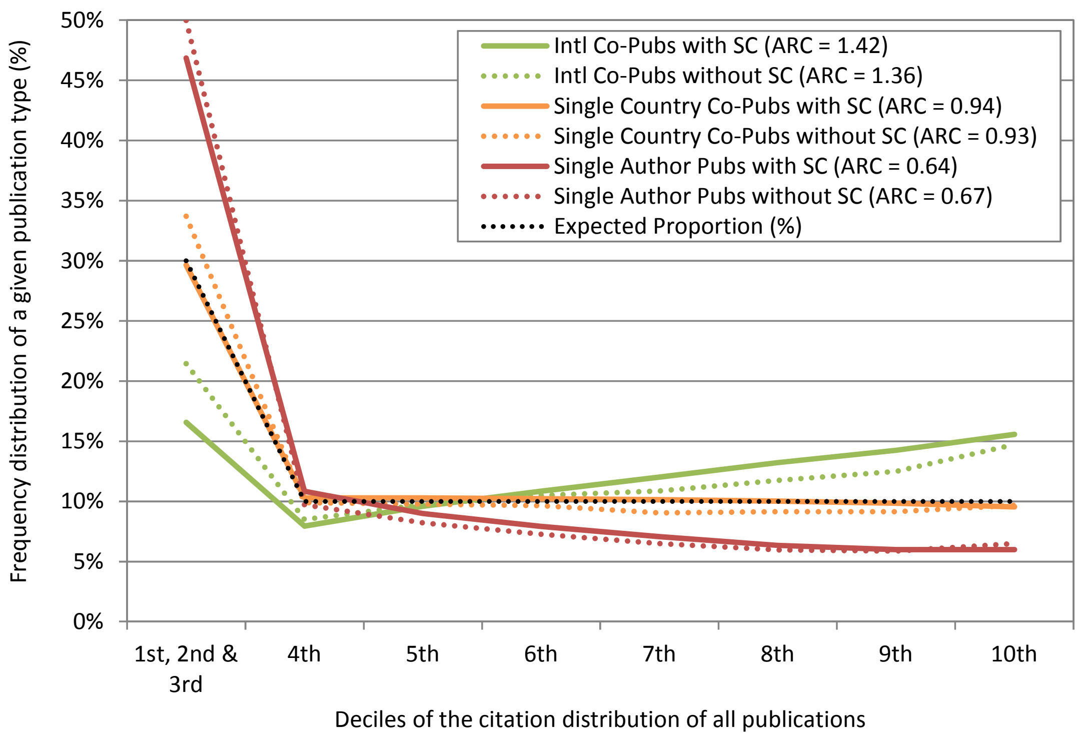

Figure 42 Frequency distribution of various types of publications/co-publications across deciles of the citation distribution of all publications in Scopus (1996-2010)

Note: See methodological remark below (footnote 27). The first three deciles were merged since they all include papers with relative citation (RC) scores of 0.

Source: Computed by Science-Metrix using Scopus (Elsevier)

The observed pattern of change in the ARC of the three different types of publications when self-citations are eliminated can be explained by the fact that the relationship between the number of authors on a paper and its rate of self-citations seems to follow a logarithmic curve (Figure 41A). Thus, the rate of self-citations increases rapidly from single author publications to co-publications with multiple authors, and subsequently slows down as the number of authors on a paper reaches 100. As a result, the citation counts of single author publications are likely less penalised than those of domestic only co-publications (4.14 authors per paper on average). Domestic only co-publications are also less affected than international co-publications (6.17 authors per paper on average).

In relative terms — i.e., when the citation counts are normalised by subfield and year to obtain the relative citation counts used in computing the ARC (see footnote 25 above) — the score of single author publications can in turn be improved since the citation counts of co-publications is reduced to a greater extent, decreasing the expected citation score for a given publication year and subfield.

This is not to say that a higher rate of self-citations of co-publications is negative per se or that self-citations should be removed in measuring the impact of an entity (i.e., an organisation or a country). Indeed, self-citations are an integral part of the scientific endeavour whereby authors build on their previous work to pursue their investigations. Of course, there comes a point where it is much more difficult for the authors of a publication to receive citations from researchers outside their own set of co-authors (e.g., for authors participating in a very large consortium). This inevitably leads to an increase in the rate of self-citations. An extreme example would be a paper co-authored by all scientists from a given subfield. In such a case, all citations from the corresponding subfield would be self-citations (probably close to 100% of self-citations). In this instance, self-citations could definitely not be omitted in measuring the paper's impact.

Although such extreme cases are still very unlikely, the decision was made not to remove self-citations since they were shown to make a fairly small contribution to the increased impact of international co-publications relative to single author publications. In fact, they account for about 12% of the difference in the ARC of both types of publications.

Figure 42 also shows the frequency distribution of the three publication types across deciles of the citation distribution of all publications.[27] Therefore, assuming a random partitioning of all publications into three groups, the expected frequency of any of the publication types by decile of the citation distribution is 10%; the first three deciles were merged (expectation is thus equal to 30%) since they all include papers with a relative citation (RC) score of 0. In other words, they were not highly discriminant. The pattern of departure from expectations across deciles therefore increases our understanding of the underlying changes in the citations scores of individual papers that result in the gap noted in the ARC of all publications across these three publication categories. For example, it is clear that the higher ARC of international co-publications is not the mere result — relative to the other two publication types — of a lower fraction of uncited papers uniformly redistributed to lower/mid-range deciles (e.g., from the 1st, 2nd and 3rd to the 4th, 5th and 6th deciles), but rather to a sharp decrease in the frequency of the smallest deciles (i.e., 1st, 2nd and 3rd) combined with a sharp increase in the frequency of the highest decile (i.e., 10th). Consequently, a larger fraction of international co-publications is cited at least once and a larger fraction of these papers achieves very high impact scores compared to domestic only co-publications and single author publications. The same conclusion holds true when self-citations are removed and when domestic co-publications are compared to single author publications. These results therefore point to a strong incentive for countries to promote scientific partnerships nationally and especially internationally.

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[27] **Methodological remark:** Note that the deciles used for drawing the frequency distributions with and without author self-citations (SC) are the same so that they are directly comparable. They were established on the basis of the relative citation (RC) scores, including self-citations, of all papers published from 1996 to 2010 in Scopus. The years 2011 and 2012 were excluded since the citation window for papers published in those years is short and could potentially lead to biases.

5.2 Effect of the Number of Authors/Countries on the Citation Impact of Co-Publications

In spite of the above findings, it remains unknown to what extent the higher citation impact of international versus domestic co-publications is attributable to the increased size of teams (i.e., number of co-authors; through mechanisms other than the strict effect of self-citations) on individual papers or to the actual geographic location of the co-authors (i.e., number of countries involved). Accordingly, additional analyses have been performed to investigate how the citation impact of various types of co-publications, with and without self-citations, scale with the size of teams, as well as with the number of countries involved. These analyses should shed further light on which types of collaboration (i.e., domestic vs. international and bi-lateral vs. multilateral at the researcher or country level) are the most beneficial to scientific impact and whether there is any cut-off point beyond which further increases in the number of authors and/or countries no longer increase the scientific impact of publications.

Team size is known to vary greatly across scientific disciplines. From 1996 to 2012, for example, it varied from one to two authors in most subfields of the SSH and in Mathematics to about 10 authors in Nuclear & Particle Physics (see companion Excel data book). The much larger size of teams in Nuclear & Particle Physics is explained by experimental physicists' specific requirements for very large and expensive infrastructures (e.g., particle accelerator such as the large hadron collider at CERN) in Particle & High-Energy Physics. The monetary and human capital required to achieve these types of projects (e.g., the ATLAS Experiment at CERN) are such that countries often pool resources in these areas to create international consortia for their achievement. Larger teams and consortia are also quite frequent in the field of Genetics & Heredity (about seven authors per paper from 1996 to 2012). For instance, the Human Genome Project, completed in 2003, was achieved by an international consortium. As the following analysis, which links the number of authors involved on individual papers to their corresponding citation scores, is presented in aggregate for all subfields combined, the number of authors is normalised by subfield to account for differences in team size across subfields. This enables the comparison of countries exhibiting very different specialisation patterns across scientific subfields.

All indicators are also normalised by publication year to ensure their comparability. This normalisation is crucial for the citation scores of papers to account for differences in their citation windows (i.e., older papers have accumulated citations over a longer timeframe). In other words, the number of authors on a paper is normalised by dividing it by the average number of authors in the same year and subfield for all papers in the Scopus database. This is the same approach as that used in computing the relative citation (RC) score of papers with and without self-citations (see Section 5.1).

To also assess the effect of the number of countries on the citation impact of co-publications, international co-publications were disaggregated into international only co-publications (i.e., papers authored by researchers located in at least two countries and without more than one author per country; the number of authors on such a co-publication is equal to the number of countries) and co-publications involving both international and domestic partnerships, hereafter "international/domestic co-publications" (i.e., papers authored by researchers located in at least two countries and with at least two authors from the same country). Because international only co-publications with the same number of authors as international/domestic co-publications and domestic only co-publications necessarily involve more countries, such a comparison enables us to gauge the effect of the number of countries on the citation impact of publications. Thus, four categories are considered:

- International co-publications;
- International only co-publications (account for only 12% of all international co-publications);
- International/domestic co-publications (account for 87% of all international co-publications; as such, results for this category are highly similar to those for all international co-publications; therefore the "International co-publications" category is not always presented in the subsequent figures/tables);
- Domestic only co-publications.

To investigate the association between the numbers of authors on publications and their corresponding citation impact (with and without self-citations), it was first attempted to regress the relative citation scores of papers (with and without self-citations) with their corresponding relative number of authors. This analysis revealed substantial variability in the citation scores of individual papers for any given number of co-authors; the coefficient of determination of a regression model linking the relative number of authors to the relative number of citations was very low (data not shown). As such, the number of authors is not, on its own, a sound predictor of the citation impact of a *specific* paper. It is assumed that the same holds true for the effect of the relative number of countries on the relative number of citations of individual papers. However, these two variables might still have an effect at an aggregated level; i.e., the citation distribution of different co-publication types might differ across different numbers of authors/countries in very specific citation deciles (i.e., blocks of 10% from 0% to 100%).

In other words, the effect of these variables would only impact a small fraction of publications for a given number of authors/countries in the upper citation deciles (i.e., an increase in the likelihood of producing very high impact papers with an increase in the number of authors). Because citation distributions are highly skewed with heavy tails, such an effect could increase the average citation impact of publications as the number of authors/countries increases, even if most publications with the corresponding number of authors do not exhibit such an increase.

To investigate further in this direction, a similar approach to that presented in Figure 42 using deciles of the citation distribution of all publications was applied. The first step consisted in building deciles of the distribution of the relative number of authors for all publications among the selected types of co-publications to build samples of co-publications with a comparable number of authors for each publication type.

Based on these deciles, 10 samples were constructed for each co-publication type by randomly sampling 10,000 papers of the corresponding publication type and corresponding decile's range of the relative number of authors.[28] Therefore, for each co-publication type, 100,000 papers were sampled (10,000 per decile). The only exception is international only co-publications for which it was not possible to create samples for the 8th, 9th and 10th deciles (70,000 papers were sampled). This is because this type of co-publication seldom has as many authors as co-publications in these deciles. This is not surprising since it is much more difficult to increase the number of countries

[28] **Methodological remark:** Note that only co-publications for which a relative citation score could be computed both with and without self-citations were sampled. The years 2011 and 2012 were excluded since the citation window for papers published in those years is short and could potentially lead to biases.

without having more than one author per country than it is to increase the number of authors regardless of their location (i.e. a few countries with multiple authors from each). In fact, the average number of authors for international only co-publications is equal to 2.15 versus 4.14 for domestic only co-publications, 6.71 for international/domestic co-publications and 6.17 for all international co-publications. Although international only co-publications result in a higher citation impact than international/domestic co-publications when controlling for the number of authors (see later in this section), when all co-publications are merged (i.e., irrespective of the number of authors) they actually have a lower ARC score simply because there are generally not as many papers with as many authors for this type as compared to the latter type.

In a second step, deciles of the distribution of the relative number of citations of all co-publications found in the samples constructed in the first step (i.e., 370,000 co-publications) were built to subsequently partition the sampled co-publications across citation deciles. This partitioning of the sampled co-publications was performed twice: once based on the relative citation scores of the sampled co-publications including self-citations, and once excluding self-citations. Note that the citation deciles were established on the basis of the relative citation scores including self-citations. Therefore, the citation deciles are the same for all co-publication types and author deciles, with or without self-citations. This ensures comparability — across co-publication types, author deciles and methods for counting citations (i.e., with or without self-citations) — of the frequency distributions of co-publications over citation deciles. Assuming a random partitioning of co-publications, the expected frequency of any of the co-publication types and author deciles — using either citation scores with or without self-citations — should equal 10% by decile of the citation distribution.

The first two deciles were merged (expectation is thus equal to 20%) since they both include papers with a relative citation (RC) score of 0 (i.e., they were not highly discriminant). The pattern of departure from expectations over citation deciles increases our understanding of the underlying changes in the citation distributions of the various types of co-publications with a comparable number of authors as their number of authors increases (i.e., across author deciles), with or without self-citations. In turn, this analysis helps clarify differences in the ARC of the various co-publication types, while controlling for the number of authors and self-citations. By including international only co-publications, the analysis also controls for the effect of the number of countries on the citation impact of a co-publication (see above discussion).

The above steps were bootstrapped 50 times to allow convergence of the various indicators computed from these samples, as well as to assess the reliability of the findings by computing 95% confidence intervals. As a result, a total of 18,500,000 co-publications were randomly sampled (50 times 370,000 co-publications). Table XXIX, Table XXX and Table XXXI show that the average of the relative number of authors across co-publication types, author deciles, methods for counting citations (i.e., with or without self-citations) and citation deciles are highly comparable with narrow 95% confidence intervals. This indicates that the following comparative analysis of the various co-publication types provides reliable results.

Effect of the number of countries

Table XX shows — for all countries and subfields grouped — the frequency distribution for each combination of co-publication type, author decile and method for counting citations across deciles of the citation distribution of all co-publications. The average citation impact (based on ARC) of each combination of co-publication type, author decile and method for counting citations is presented alongside these frequency distributions. The worst performances are characterised by frequency distributions with greener scores in the lower citation deciles and redder scores in the upper citation deciles. The opposite pattern illustrates the best performances. Note that this table does not present the "international co-publications" category since the results for this type of co-publication are very similar to those for international/domestic co-publications, which account for about 87% of the former category.

Firstly, when controlling for the number of authors on a co-publication, it can be seen that international only co-publications generally achieve the highest average citation impact. Indeed, the ARC scores of this type of co-publication are nearly always slightly higher than those of international/domestic co-publications and always higher than those of domestic only co-publications when comparing the same author decile across co-publication types. Only in the first author decile do international/domestic co-publications score higher than international only co-publications. In fact, the stronger ARC scores of international only co-publications relative to international/domestic co-publications in the other author deciles are mainly due to the higher frequency of the former type in the highest citation decile (i.e., in the 10th decile or the 10% most frequently cited papers) rather than to a lower frequency of uncited papers (i.e., in the 1st and 2nd deciles).

These high impact papers have a strong effect on the ARC since citation distributions are highly skewed; for instance, international only co-publications are, on average across author deciles, cited 11% more often relative to the world average than international/domestic co-publications (the gains range from 1 to 24 percentage points across author deciles with the largest gains observed in the 3rd and 4th deciles; ARC of 1.34 minus ARC of 1.10 in the 3rd author decile provides a gain of 24% points). This indicates that the number of countries involved has a positive effect on the production of very high impact papers, which in turn increases the average impact (i.e., ARC) of international only co-publications. In fact, for a given number of authors, there are always more countries on an international only than on an international/domestic co-publication.

Compared to domestic only co-publications, both international only and international/domestic co-publications stand out with a higher average citation impact, irrespective of the number of authors, due to their lower frequency of occurrence, which is generally below expectations (in red) in the lower citation deciles (i.e., uncited papers are less common) and to their higher frequency of occurrence, which is generally above expectations (in green) in the upper citation deciles (e.g., very high impact papers are more common). The opposite pattern is observed for domestic only co-publications with frequencies generally well above expectations in the lower citation deciles (i.e., more uncited papers than expected) and generally below expectations in the upper citation deciles (i.e., less highly cited papers than expected). As a result, international only co-publications are, on average across author deciles, cited 40% more often relative to the world average than domestic only co-publications (the gains range from 30 to 49 percentage points across author deciles with the largest gains observed in the 3rd and 4th deciles). For international/domestic co-publications, the gains relative to domestic only co-publications are, on average across author deciles, of 38 percentage points. Accordingly, moving from only one to at least two countries on a co-publication for a given number of authors has a positive effect by reducing the frequency of low impact papers, as well as by increasing the frequency of high impact papers.

Note that the above patterns remain unchanged when self-citations are excluded. The only difference is that the ARCs of the various co-publication types are slightly better in the first two to three author deciles and progressively worsen as the number of authors increases. This is consistent with the findings in Section 5.1, where it was shown that with fewer authors, the impact of publications without self-citations could be increased, whereas it can decrease as the number of authors on a publication increases. This is due to the fact that the rate of self-citations appears to increase logarithmically with the number of authors.

Similar findings were observed for Norway. The main difference is that the gap in the impact (ARC) of international only and international/domestic co-publications relative to domestic only co-publications is smaller when controlling for the number of authors. Still, an important effect is present with or without self-citations. For example, international only co-publications are, on average across author deciles, cited 34% more often relative to the world average than domestic only co-publications (the gains ranging from 13 to 50 percentage points). For international/domestic co-publications, the gains relative to domestic only co-publications are, on average across author deciles, 26 percentage points (data not shown). Note that for the upper author deciles (i.e., 10th), the number of authors was not comparable across the three co-publication types and was thus not considered in the analysis for Norway.

Effect of the number of authors

It is also worth noting that, regardless of the co-publication type, the average citation impact increases progressively with the number of authors involved. As we move from the lower to the upper author deciles, the ARC increases for all co-publication types, especially for international/domestic co-publications (i.e., average increase of 8 percentage points relative to the world level of impact from one author decile to the next for an overall increase of 75 percentage points between the 1st and 10th author deciles) and domestic only co-publications (i.e., average increase of 7 percentage points relative to the world level of impact from one author decile to the next for an overall increase of 60 percentage points between the 1st and 10th author deciles; Table XX).

The effect of the number of authors on the citation impact of the various types of co-publications is best appreciated by examining Table XXI. This table illustrates the gains and losses in the frequency of occurrence of co-publications moving (in ascending order) from one author decile to the next (expressed as a percentage of deviation from the previous score) for each combination of co-publication type, citation decile and method for counting citations.

A positive effect of the number of authors on the impact of a given co-publication type should translate into the diminishing of the frequency of occurrence of co-publications in the lower citation deciles (red cells in the table) and in the increasing frequency of occurrence of co-publications in the upper citation deciles (green cells in the table). This pattern is observed for all co-publication types and is most pronounced for the upper author decile (i.e., 10th), except for international only co-publications. Thus, the largest gains in impact are generally observed for co-publications with the largest number of authors. The increased ARC of all co-publication types appear to be the result of a reduction in the frequency of papers in the lower citation deciles (i.e., the 1st and 2nd deciles; i.e., the papers in the 20% less cited papers) combined with an increase in the frequency of papers in the upper citation deciles (i.e., mainly highly cited papers in the 10th decile; in other words papers in the 10% most cited). Hence, the more authors on a paper, the more likely it will become a very high impact paper. Yet, given the pattern of frequency change across citation deciles (i.e., changes occur primarily in the extremes of the citation distribution), more authors on a paper do not guarantee a higher impact. These findings hold true without self-citations.

Similar findings were observed for Norway, with or without self-citations. For example, as we move from the lower to the upper author deciles, the ARC increases for all co-publication types, especially for international/domestic co-publications (i.e., average increase of 9 percentage points relative to the world level of impact from one author decile to the next for an overall increase of 71 percentage points between the 1st and 9th author deciles) and domestic only co-publications (i.e., average increase of 8 percentage points relative to the world level of impact from one author decile to the next for an overall increase of 65 percentage points between the 1st and 9th author deciles; data not shown). Note again that for the upper author deciles (i.e., 10th), the number of authors was not comparable across the three co-publication types and was thus not considered in the analysis for Norway.

Which mechanisms other than self-citations can explain the larger impact of co-publications as the number of authors/countries involved increases?

One mechanism that may explain the observed increase in the citation impact of co-publications as the number of authors and/or countries increases is the visibility of the publications through the collaboration network of co-authors. It is assumed that a paper's visibility increases with the number of authors through the connections of each of the authors within the scientific community. In other words, a publication would generally receive more citations as the number of authors increases by tapping into the networks of each of them not only through *direct* self-citations but also through citations of each authors' connections. Because scientific collaboration networks are often characterised by a strong geographic clustering of researchers, increasing the diversity of countries and/or world regions involved in a scientific publication is likely to further expand its impact by tapping into disconnected networks. The networks would have been unlikely to have influenced each other had the cooperation not taken place. This hypothetical scenario will be the subject of future research by Science-Metrix that will compare the frequency distribution of each combination of co-publication type and author decile across deciles of the distribution of the average shortest path length[29] between the citing and cited authors of a publication. This is currently beyond the scope of the present project.

[29] Computed from Scopus' entire co-authorship network,

Table XX Frequency distribution, for all countries and fields grouped, for each combination of co-publication type, author decile and method for counting citations across deciles of the citation distribution of all co-publications (1996-2010)

With Self-Citations

Co-pub type	Author/ Cit. decile	1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th	ARC
Intl./Domestic Co-Pubs*	1st	17.3%	11.5%	10.4%	10.5%	9.7%	10.3%	9.8%	10.1%	10.4%	1.26
	2nd	17.3%	11.5%	11.0%	11.0%	10.6%	10.3%	9.9%	9.5%	8.8%	1.14
	3rd	17.7%	10.9%	11.6%	11.0%	10.6%	10.9%	9.9%	9.4%	8.1%	1.10
	4th	16.1%	10.9%	10.8%	11.2%	10.9%	10.8%	10.5%	10.1%	8.7%	1.16
	5th	18.7%	9.4%	10.1%	10.2%	10.9%	10.7%	10.4%	10.0%	9.6%	1.22
	6th	16.2%	9.7%	10.3%	10.8%	10.6%	10.9%	10.9%	10.7%	9.9%	1.25
	7th	14.4%	8.7%	9.9%	10.6%	11.1%	11.6%	11.8%	11.5%	10.4%	1.30
	8th	15.2%	8.2%	9.6%	10.0%	10.8%	11.4%	11.6%	11.8%	11.5%	1.39
	9th	13.1%	7.6%	8.8%	9.9%	10.9%	11.6%	12.4%	13.0%	12.8%	1.47
	10th	10.9%	6.2%	7.4%	8.5%	9.8%	11.2%	12.8%	14.9%	18.3%	2.01
Intl. Only Co-Pubs	1st	23.0%	12.4%	11.1%	10.0%	9.4%	9.1%	8.5%	8.2%	8.3%	1.06
	2nd	23.5%	10.9%	10.3%	9.9%	9.5%	9.3%	8.5%	8.7%	9.3%	1.20
	3rd	25.4%	9.8%	9.5%	9.1%	9.0%	8.4%	8.9%	9.0%	10.8%	1.34
	4th	18.7%	9.3%	10.3%	10.3%	10.6%	9.5%	10.5%	10.2%	10.5%	1.32
	5th	16.9%	11.6%	11.4%	10.7%	10.1%	10.1%	9.6%	9.8%	9.8%	1.23
	6th	19.5%	8.6%	7.9%	10.6%	10.0%	10.0%	11.1%	10.5%	11.8%	1.34
	7th	15.0%	8.9%	10.6%	10.2%	11.5%	10.4%	11.3%	10.9%	11.3%	1.38
	8th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	9th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	10th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Domestic Only Co-Pubs	1st	31.2%	13.4%	11.0%	9.6%	8.5%	7.8%	6.9%	6.3%	5.2%	0.77
	2nd	32.2%	11.9%	10.3%	9.1%	8.5%	7.9%	7.3%	6.7%	6.1%	0.84
	3rd	31.8%	11.8%	10.5%	9.3%	8.6%	7.9%	7.3%	6.8%	6.0%	0.85
	4th	28.1%	12.6%	10.7%	9.9%	8.9%	8.4%	7.8%	7.4%	6.2%	0.87
	5th	30.3%	10.9%	10.3%	9.2%	9.2%	8.4%	7.8%	7.3%	6.5%	0.89
	6th	28.3%	11.8%	10.3%	9.8%	8.8%	8.5%	8.0%	7.6%	6.9%	0.92
	7th	26.2%	11.3%	10.4%	9.7%	9.5%	9.0%	8.6%	8.2%	7.1%	0.95
	8th	26.7%	10.7%	10.3%	9.5%	9.3%	8.9%	8.5%	8.4%	7.7%	0.99
	9th	24.5%	10.6%	9.8%	9.5%	9.5%	9.2%	9.1%	9.1%	8.7%	1.07
	10th	21.5%	9.7%	8.9%	9.0%	9.2%	9.4%	9.9%	10.6%	11.7%	1.36

Without Self-Citations

Co-pub type	Author/ Cit. decile	1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th	ARC
Intl./Domestic Co-Pubs*	1st	23.1%	11.3%	10.6%	9.3%	8.8%	8.3%	8.9%	8.9%	10.9%	1.28
	2nd	22.5%	11.4%	10.5%	10.2%	9.5%	9.2%	8.9%	8.7%	9.1%	1.14
	3rd	22.6%	11.4%	10.9%	10.3%	9.5%	9.5%	8.8%	8.5%	8.3%	1.08
	4th	21.5%	10.9%	10.7%	10.2%	9.8%	9.6%	9.3%	9.1%	9.0%	1.14
	5th	24.0%	9.7%	9.8%	9.9%	9.1%	10.0%	8.9%	9.1%	9.5%	1.19
	6th	21.7%	9.9%	10.3%	10.1%	9.7%	9.6%	9.5%	9.5%	9.8%	1.21
	7th	19.7%	9.3%	10.0%	10.2%	9.9%	10.4%	10.2%	10.0%	10.3%	1.25
	8th	20.3%	8.9%	9.6%	9.8%	9.7%	10.2%	10.1%	10.3%	11.0%	1.33
	9th	18.2%	8.4%	9.4%	9.6%	10.0%	10.6%	10.6%	11.2%	12.0%	1.39
	10th	15.8%	7.5%	8.1%	8.9%	9.3%	10.3%	11.1%	12.5%	16.3%	1.86
Intl. Only Co-Pubs	1st	28.1%	11.9%	10.8%	9.1%	8.3%	7.8%	7.7%	7.5%	8.9%	1.09
	2nd	29.2%	10.5%	9.0%	9.4%	8.2%	8.4%	7.7%	8.0%	9.7%	1.23
	3rd	31.5%	8.9%	8.6%	8.6%	7.7%	8.3%	7.3%	8.4%	10.7%	1.34
	4th	25.8%	8.0%	10.0%	9.2%	8.7%	9.0%	9.1%	9.4%	10.7%	1.32
	5th	22.6%	11.9%	10.2%	9.9%	9.0%	8.9%	8.7%	8.9%	9.9%	1.21
	6th	28.5%	6.5%	9.5%	6.7%	10.2%	8.4%	8.7%	9.7%	11.8%	1.32
	7th	24.2%	7.4%	9.1%	10.8%	9.0%	9.8%	8.6%	9.8%	11.3%	1.36
	8th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	9th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	10th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Domestic Only Co-Pubs	1st	35.6%	12.5%	10.3%	8.7%	7.6%	7.0%	6.5%	6.0%	5.8%	0.79
	2nd	36.8%	11.1%	9.1%	8.6%	7.4%	7.4%	6.7%	6.4%	6.5%	0.86
	3rd	36.3%	10.9%	9.6%	8.9%	7.4%	7.4%	6.6%	6.5%	6.4%	0.86
	4th	32.8%	11.7%	10.1%	8.9%	8.1%	7.6%	7.2%	7.0%	6.6%	0.87
	5th	34.9%	10.4%	9.2%	8.9%	7.6%	8.1%	7.0%	6.9%	6.8%	0.89
	6th	33.4%	10.6%	9.8%	9.1%	8.0%	7.6%	7.2%	7.1%	7.1%	0.91
	7th	30.9%	10.8%	9.9%	9.2%	8.3%	8.3%	7.8%	7.6%	7.3%	0.94
	8th	31.5%	10.2%	9.5%	9.1%	8.2%	8.2%	7.7%	7.7%	7.8%	0.97
	9th	29.1%	10.2%	9.4%	9.2%	8.4%	8.5%	8.2%	8.3%	8.7%	1.05
	10th	26.2%	9.6%	8.9%	8.7%	8.3%	8.7%	8.9%	9.4%	11.3%	1.31

Note: *International/domestic co-publications account for about 87% of all international co-publications. Results for this latter category are therefore highly similar to those for international/domestic co-publications and the conclusions remain unchanged. The latter type is therefore not presented here to save space. Values in the table are highlighted using a colour gradient based on the level of departure from expectations (red = below; white = near; green = above). For each combination of any author decile with the 1st and 2nd citation deciles, which were merged, expectation is at 20% under the hypothesis of a random distribution of citations across co-publication types and number of authors (see above description of the approach). For each combination of any author decile with any of the remaining citation deciles, expectation is at 10%. Expectation for the ARC is the world level which equals one. n/a = not applicable (see above description of the approach.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Table XXI Gains/losses in the frequency of occurrence of co-publications moving (in ascending order) from one author decile to the next (expressed as a % of deviation from the previous score) for each combination of co-publication type, citation decile and method for counting citations (1996-2010)

	Author/ Cit. decile	With Self-Citations 1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th	ARC	Without Self-Citations 1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th	ARC
Intl./Domestic Co-Pubs*	1st										1.26										1.28
	2nd	0.1%	-0.2%	5.3%	4.9%	9.7%	0.3%	1.4%	-5.9%	-15.3%	1.14	-2.5%	1.1%	-0.8%	9.0%	8.4%	11.5%	-0.2%	-2.4%	-16.2%	1.14
	3rd	2.1%	-4.9%	5.3%	-0.3%	-0.5%	5.1%	0.1%	-1.3%	-8.1%	1.10	0.4%	-0.2%	4.5%	1.6%	-0.2%	3.1%	-0.5%	-1.3%	-8.9%	1.08
	4th	-8.6%	-0.8%	-6.6%	2.1%	2.8%	-0.1%	5.6%	7.1%	7.8%	1.16	-4.8%	-4.7%	-2.3%	-1.4%	3.4%	0.4%	5.1%	6.4%	8.0%	1.14
	5th	15.7%	-13.5%	-6.3%	-8.7%	-0.3%	-1.3%	-0.8%	-0.1%	9.9%	1.22	11.3%	-10.4%	-8.1%	-3.1%	-7.6%	4.8%	-4.4%	0.1%	6.1%	1.19
	6th	-13.4%	3.1%	2.0%	5.1%	-2.4%	2.0%	5.0%	6.9%	3.2%	1.25	-9.4%	2.0%	4.4%	2.1%	6.5%	-4.2%	6.8%	3.9%	3.2%	1.21
	7th	-11.2%	-10.0%	-4.1%	-1.5%	5.1%	6.1%	7.9%	7.5%	4.8%	1.30	-9.5%	-6.0%	-2.4%	1.0%	2.1%	8.5%	8.3%	6.2%	4.3%	1.25
	8th	5.6%	-6.2%	-3.1%	-5.8%	-3.0%	-1.3%	-1.6%	2.0%	10.6%	1.39	3.4%	-4.8%	-4.6%	-3.9%	-1.2%	-1.9%	-1.1%	2.9%	7.7%	1.33
	9th	-13.8%	-7.5%	-8.1%	-0.3%	0.4%	1.8%	7.0%	10.2%	10.9%	1.47	-10.3%	-5.4%	-1.8%	-1.3%	2.3%	3.4%	4.5%	8.3%	8.9%	1.39
	10th	-16.5%	-18.2%	-16.1%	-14.2%	-10.0%	-4.0%	3.4%	15.1%	43.4%	2.01	-13.1%	-10.6%	-13.5%	-7.5%	-6.3%	-2.2%	5.0%	11.7%	35.7%	1.86
Intl. Only Co-Pubs	1st										1.06										1.09
	2nd	2.5%	-12.2%	-7.1%	-1.4%	1.0%	1.9%	0.5%	6.4%	12.7%	1.20	3.9%	-11.8%	-16.5%	3.9%	-1.3%	7.0%	-0.6%	6.9%	9.3%	1.23
	3rd	7.9%	-10.0%	-7.6%	-7.7%	-5.6%	-9.6%	4.8%	3.3%	16.2%	1.34	7.9%	-14.9%	-4.1%	-8.7%	-5.9%	-1.2%	-5.0%	5.8%	9.9%	1.34
	4th	-26.4%	-5.4%	8.1%	13.7%	17.8%	13.4%	17.6%	13.1%	-2.3%	1.32	-18.0%	-9.9%	15.6%	6.7%	14.0%	8.7%	24.2%	11.8%	0.7%	1.32
	5th	-9.4%	24.8%	10.0%	3.8%	-5.0%	5.8%	-8.4%	-3.4%	-7.3%	1.23	-12.7%	48.5%	2.4%	7.9%	3.3%	-1.2%	-4.3%	-5.2%	-8.1%	1.21
	6th	15.0%	-26.2%	-30.2%	-1.2%	-0.4%	-1.2%	16.1%	6.7%	20.6%	1.34	26.2%	-45.4%	-7.2%	-31.9%	12.6%	-5.4%	0.0%	8.8%	19.6%	1.32
	7th	-22.9%	4.2%	33.2%	-4.0%	14.3%	3.8%	1.8%	3.6%	-4.2%	1.38	-15.2%	13.8%	-3.6%	60.4%	-11.1%	16.7%	-1.0%	0.6%	-4.7%	1.36
	8th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	9th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	10th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Domestic Only Co-Pubs	1st										0.77										0.79
	2nd	3.3%	-11.5%	-6.7%	-5.1%	0.3%	0.8%	5.6%	5.7%	18.0%	0.84	3.5%	-11.2%	-11.9%	-1.4%	-3.3%	6.7%	2.3%	6.2%	13.5%	0.86
	3rd	-1.5%	-0.6%	2.4%	1.7%	1.2%	0.2%	-0.7%	1.9%	-0.8%	0.85	-1.5%	-1.1%	5.5%	3.0%	1.1%	-1.0%	-0.6%	1.5%	-2.2%	0.86
	4th	-11.5%	6.7%	1.3%	6.4%	3.6%	6.0%	7.6%	8.8%	3.1%	0.87	-9.6%	6.6%	5.4%	0.5%	8.3%	3.6%	9.0%	7.4%	3.8%	0.87
	5th	7.9%	-13.7%	-3.3%	-6.6%	2.5%	0.6%	-0.1%	-1.1%	4.9%	0.89	6.5%	-10.7%	-8.9%	0.4%	-5.7%	6.6%	-3.1%	-0.6%	2.8%	0.89
	6th	-6.7%	8.6%	-0.6%	6.6%	-3.9%	0.6%	2.5%	4.0%	5.6%	0.92	-4.5%	2.2%	5.7%	2.1%	5.7%	-6.2%	3.3%	2.6%	4.3%	0.91
	7th	-7.4%	-3.9%	1.4%	-1.0%	8.2%	5.9%	7.2%	7.1%	2.7%	0.95	-7.5%	1.1%	1.1%	1.1%	2.8%	9.1%	7.5%	7.0%	3.1%	0.94
	8th	1.8%	-5.4%	-1.1%	-2.4%	-2.3%	-1.0%	-0.8%	2.4%	9.3%	0.99	2.2%	-5.1%	-4.1%	-1.3%	-0.5%	-1.8%	-0.3%	1.7%	6.6%	0.97
	9th	-8.1%	-1.6%	-4.4%	0.4%	1.7%	3.5%	7.0%	8.6%	12.3%	1.07	-7.6%	0.3%	-0.6%	0.5%	1.7%	4.3%	6.0%	7.6%	10.6%	1.05
	10th	-12.4%	-7.7%	-9.2%	-5.2%	-2.5%	2.5%	8.2%	16.1%	35.2%	1.36	-10.2%	-5.9%	-4.8%	-4.6%	-0.8%	1.5%	8.0%	13.4%	30.1%	1.31

Note: *International/domestic co-publications account for about 87% of all international co-publications. Results for this latter category are therefore highly similar to those for international/domestic co-publications and the conclusions remain unchanged. The latter type is therefore not presented here to save space. Values in the table are highlighted using a colour gradient (the redder the cells, the stronger the losses; the greener the cells the stronger the gains). For the ARC, cells are highlighted based on their departure from the world level of one (red = below; white = near; green = above). n.a. = not applicable (see above description of the approach.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Contradictory Findings

Contrary to the current study, a recent paper focusing specifically on Finland's scientific output reported that international co-publications did not present important gains in citation impact relative to domestic only co-publications when controlling for the number of authors, except for papers with more than 10 authors for which significant gains were registered.[30]

Firstly, where the authors reported a significant gain in the impact of international co-publications relative to domestic only co-publications, i.e., for papers with more than 10 authors, they did not adequately control for the number of authors in their analysis. Indeed, the present study found that the average number of authors per paper for those with more than 10 contributors is much higher for Finland's international co-publications (99 authors based on Scopus) than it is for its domestic only co-publications (13 authors) (see Figure 4 in *Scientometrics*, 98: 823-839). The substantial difference they observed in the impact of both co-publication types for papers with more than 10 authors is therefore not adequately controlled for the actual variation in the number of authors in both groups. The present study found that the average of the relative number of authors of international co-publications is much larger than it is for domestic only co-publications in the upper author decile for Finland (i.e., among the 10% co-publications with the largest relative number of authors). Not surprisingly, the citation impact of international co-publications in this author decile is much greater than it is for domestic only co-publications. However, the number of authors of these two publication types is not comparable in this decile and cannot therefore be used in interpreting the effect of the number of authors on the citation impact of both publication types.

Secondly, the gains Puuska, Muhonen and Leino (2014) report between the two co-publication types are slightly undervalued for lower categories of number of authors due to the inclusion of international/domestic co-publications in their pool of international co-publications. The gains would have been larger if they had used international only co-publications in their comparisons. Based on the current study, the international only co-publications of Finland are, on average across author deciles (excluding the upper category which is problematic), cited 28% more often relative to the world average than domestic only co-publications, compared to 16% when all Finland's international co-publications are included. Still these gains are smaller than when all countries are pooled together or than for Norway.

Another limitation of the Finnish study is that the authors normalised only the citation scores of papers and not the number of authors of papers for field differences. However, there are also important differences across fields in the average number of authors per paper. If a connection exists between the number of authors on a paper and its citation rate, then they might have masked an important signal by normalising the citation score and not the number of authors. In fact, a paper in a field with a large average number of authors per paper would be characterised by a higher average citation rate such that the relative citation score of the paper would be reduced importantly (e.g., number of citations/field average citation rate), while its number of authors would remain high. Other than that, the Finish study found similar results to the present report.

[30] Puuska, H.-M., Muhonen, R. and Leino, Y. (2014). International and domestic co-publishing and their citation impact in different disciplines. *Scientometrics*, 98: 823-839.

6 Regional Analysis

To complement the analysis performed at the national level presented above, Science-Metrix computed various bibliometric indicators at the regional level for the following countries: Brazil, China, India, Japan, France, Germany, Italy, the UK and the US. Table XXII summarises the number of regions (i.e., states, provinces, NUTS or other types of entities) analysed per country.

Table XXII Number and type of regions included in the analysis

Country	No. of regions	Type of regions
Brazil	27	States
China	34	Province, Municipality and Autonomous regions
India	34	States and Union territory
Japan	7	Region
United States	62	States and Territories
France	26	NUTS2
Germany	41	NUTS2
Italy	21	NUTS2
United Kingdom	37	NUTS2

The two tables below focus on the following key regions: Sao Paulo and Rio de Janeiro (Brazil), Beijing and Shanghai (China), Tamil Nadu and Maharashtra (India), Kanto and Kansai (Japan), California and New York State (United States), FR10 (Île de France, France), FR71 (Rhône-Alpes, France), DE21 (Oberbayern, Germany), DE30 (Berlin, Germany), ITC4 (Lombardy, Italy), ITE4 (Lazio, Italy), UKI1 (Inner London, UK) and UKH1 (East Anglia, UK). See Section 9.6 for a description of the methods used to match author addresses on scientific papers to their corresponding regions.

Table XXIII shows the main results of the regional analysis with regard to output and specialisation indicators (number of papers, GR, SI). The GR and SI indicators can be used to compare each region in terms of the relative emphasis they place on any given thematic area. As in other sections of this report, each value is assigned a colour; the darker the green, the higher the result relative to the world average; the darker the red, the lower the result relative to the world average.

For example, the results indicate that in the Sao Paolo region, all the thematic areas, except area 14 (Nanotechnology & New Materials), have a higher GR than San Paolo's total scientific output (GR = 1.47). This suggests that these areas are of particular recent interest to this region. Within the subject areas, Welfare & Working Life (area 15), followed by Fisheries & Aquaculture (area 5), experienced the fastest growth in Sao Paolo. Since the colour coding in this row is relative to the world average (rather than to the Sao Paolo average), it can be seen that Sao Paolo's growth was more rapid than the world average in a few subject areas, such as 1, 2, 5, 9, 10, 12, 13 and 15. Sao Paolo had a lower GR than the world average in areas 4, 5, 11, and especially in area 14.

However, the findings also indicate that the only thematic area where Sao Paolo is significantly more *specialised* than the world average is area 9 (Food Sciences). In other words, although Sao Paolo may be increasing its scientific production in most of the areas shown, it is still not particularly specialised in any of these areas compared to the world average.

In this table, a clear demarcation can be observed between regions in developed and in developing countries. The regions in developed countries (France, Germany, Italy, Japan, the UK and the US) all tend to have low GR and SI scores relative to the world level, while the opposite is true for the regions in developing countries (Brazil and especially China and India). This implies that developing countries place more emphasis on these thematic areas than developed countries.

Table XXIII Comparative analysis of the scientific output and specialisation of 18 regions by thematic area (2003–2012)

Country & region			Theme 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Scopus
Brazil	Sao Paulo	Paper	346	26,372	2,928	4,193	1,369	9,063	2,328	2,672	19,939	66,388	6,433	4,346	391	7,144	2,067	138,171
		GR	1.55	1.58	1.89	1.89	2.08	1.82	1.89	1.81	1.86	1.60	1.63	1.78	1.89	1.37	2.43	1.47
		SI	0.51	1.19	0.93	0.84	1.36	1.06	0.93	1.02	2.31	1.25	0.43	1.33	0.64	0.80	0.62	1.00
	Rio de Janeiro	Paper	178	8,148	969	2,747	574	3,501	817	1,035	4,251	20,050	3,703	2,307	545	1,723	994	49,923
		GR	1.53	1.46	1.86	1.70	2.09	1.73	2.66	1.55	1.89	1.67	1.39	1.93	1.54	1.70	2.07	1.50
		SI	0.72	0.99	0.89	1.56	1.67	1.17	0.97	1.11	1.33	1.04	0.72	2.12	2.57	0.48	0.88	1.00
China	Beijing	Paper	1,786	71,995	3,180	39,740	1,705	45,031	12,496	16,327	33,215	86,108	106,291	10,926	1,975	52,519	3,876	566,584
		GR	2.33	1.80	4.09	2.24	2.90	2.52	2.67	2.70	2.26	2.01	2.13	2.24	2.72	1.81	3.22	1.92
		SI	0.53	0.75	0.24	1.81	0.26	1.20	1.18	1.42	0.87	0.38	1.77	0.67	0.63	1.44	0.27	1.00
	Shang-hai	Paper	472	42,778	1,425	13,009	975	13,398	2,061	6,252	7,430	60,647	33,923	3,405	2,244	29,406	1,406	247,709
		GR	2.34	2.08	4.61	2.58	3.92	2.87	3.26	3.41	2.33	2.33	1.83	2.92	2.24	1.98	3.57	1.88
		SI	0.29	1.05	0.23	1.40	0.47	0.86	0.42	1.27	0.44	0.63	1.23	0.53	1.93	1.93	0.20	1.00
France	FR10	Paper	1,967	57,706	2,136	7,039	1,044	16,463	6,451	3,721	13,308	141,350	27,389	5,486	889	17,622	5,771	326,989
		GR	1.15	1.03	1.54	1.42	1.17	1.35	1.46	1.33	1.12	1.04	1.41	1.21	1.29	1.47	1.28	1.12
		SI	0.91	1.05	0.29	0.52	0.32	0.71	0.96	0.54	0.57	1.18	0.78	0.59	0.48	0.78	0.79	1.00
	FR71	Paper	1,109	19,285	919	4,287	464	6,857	2,225	1,819	4,268	43,358	11,584	2,311	226	14,105	1,190	130,432
		GR	1.11	1.06	1.62	1.79	1.11	1.38	1.38	1.37	1.10	1.09	1.32	1.21	1.36	1.44	1.28	1.15
		SI	1.49	0.88	0.34	0.90	0.46	0.82	0.87	0.75	0.45	0.86	0.93	0.71	0.35	1.64	0.41	1.00
Germany	DE21	Paper	527	25,304	1,078	2,494	258	6,573	2,414	1,356	6,926	56,293	11,981	1,834	296	5,984	1,747	132,496
		GR	1.22	1.17	1.95	1.62	0.89	1.34	1.41	1.41	1.05	1.13	1.39	1.36	1.46	1.34	1.27	1.18
		SI	0.67	1.14	0.38	0.51	0.27	0.77	1.00	0.57	0.85	1.10	0.93	0.55	0.43	0.68	0.55	1.00
	DE30	Paper	393	21,713	1,361	2,740	614	5,560	1,722	1,557	5,024	53,675	8,527	2,435	221	8,826	2,360	113,951
		GR	1.31	1.12	1.41	1.68	0.97	1.35	1.77	1.39	1.21	1.09	1.38	1.16	1.38	1.30	1.54	1.15
		SI	0.50	1.07	0.54	0.66	0.65	0.77	0.81	0.71	0.68	1.17	0.74	0.86	0.40	1.15	0.92	1.00
India	Tamil nadu	Paper	60	13,743	614	4,805	1,048	6,622	738	3,236	6,986	22,356	12,434	2,533	385	7,089	677	77,301
		GR	2.63	2.77	3.60	2.84	2.30	2.61	4.99	2.66	2.18	2.37	4.36	2.76	1.32	3.81	2.53	2.41
		SI	0.13	1.12	0.33	1.61	1.84	1.43	0.57	2.19	1.50	0.74	1.47	1.46	0.99	1.39	0.34	1.00
	Mahar-ashtra	Paper	123	11,364	680	3,353	456	6,086	984	2,761	5,666	24,442	5,805	1,441	229	7,493	879	74,664
		GR	2.28	2.09	3.44	2.56	1.45	1.85	2.73	2.01	1.88	2.05	3.27	1.94	1.86	2.34	1.82	1.79
		SI	0.31	0.99	0.37	1.18	0.85	1.37	0.72	1.99	1.28	0.88	0.69	0.88	0.63	1.56	0.48	1.00
Italy	ITC4	Paper	512	26,377	1,001	3,316	486	6,894	2,019	1,679	6,496	70,291	9,777	1,926	353	5,825	2,238	130,288
		GR	1.07	1.25	1.90	1.99	1.07	1.63	1.95	1.49	1.34	1.18	1.46	1.38	1.98	1.73	1.75	1.24
		SI	0.68	1.20	0.35	0.71	0.49	0.84	0.82	0.69	0.79	1.36	0.75	0.60	0.54	0.70	0.74	1.00
	ITE4	Paper	804	22,025	1,082	3,002	647	6,983	2,248	1,749	6,376	58,465	8,880	2,286	517	4,996	2,149	119,498
		GR	1.01	1.23	1.64	1.55	1.19	1.37	1.50	1.36	1.30	1.23	1.35	1.29	1.58	1.49	1.46	1.21
		SI	1.16	1.13	0.44	0.71	0.72	0.97	1.03	0.84	0.86	1.29	0.73	0.83	0.95	0.64	0.79	1.00
Japan	kanto	Paper	3,315	103,151	3,232	20,181	3,643	24,384	7,388	8,017	25,713	184,473	48,654	10,362	2,095	54,150	4,100	531,665
		GR	1.00	1.00	1.62	1.30	1.08	1.20	1.25	1.20	1.09	1.06	1.23	1.09	1.05	1.00	1.39	1.02
		SI	1.11	1.14	0.25	1.02	0.83	0.71	0.76	0.77	0.72	0.88	0.87	0.75	0.79	1.62	0.32	1.00
	Kansai	Paper	915	54,711	1,436	7,929	1,831	9,066	2,137	2,908	11,491	99,558	17,999	4,694	842	26,438	1,692	256,990
		GR	1.19	0.98	1.65	1.21	1.01	1.13	1.27	1.21	1.02	1.00	1.21	1.05	1.49	1.01	1.42	0.99
		SI	0.66	1.25	0.23	0.84	0.92	0.55	0.44	0.58	0.67	0.98	0.66	0.70	0.65	1.68	0.26	1.00
UK	UKI1	Paper	1,103	46,835	6,119	4,611	769	11,071	3,724	2,453	7,465	158,489	16,558	3,841	874	7,225	12,072	251,694
		GR	1.27	1.05	1.56	1.55	1.10	1.33	1.85	1.18	1.11	1.08	1.28	1.14	1.05	1.70	1.29	1.11
		SI	0.68	1.05	1.15	0.49	0.33	0.68	0.81	0.50	0.41	1.62	0.61	0.51	0.77	0.42	2.15	1.00
	UKH1	Paper	2,890	24,985	1,433	2,210	1,162	7,935	3,849	1,209	7,522	44,818	7,233	3,830	520	6,413	2,778	105,300
		GR	1.05	1.08	1.71	1.66	0.88	1.17	1.33	1.09	0.95	1.14	0.94	1.04	1.04	1.31	1.33	1.07
		SI	5.39	1.35	0.68	0.56	1.27	1.11	1.95	0.60	1.05	1.06	0.64	1.41	1.03	1.00	1.19	1.00
United States	Califo-rnia	Paper	4,871	135,234	13,845	19,196	4,676	41,709	15,687	9,742	28,548	308,812	69,863	18,754	3,538	41,189	17,227	694,379
		GR	1.07	1.09	1.32	1.57	1.01	1.27	1.47	1.36	1.11	1.11	1.06	1.16	0.88	1.32	1.28	1.07
		SI	1.13	1.17	0.88	0.76	0.93	0.93	1.24	0.73	0.62	1.13	0.94	1.10	1.07	1.00	1.06	1.00
	New York	Paper	1,873	82,153	11,416	7,766	1,874	18,900	6,849	3,881	16,232	230,221	33,653	6,883	1,160	19,959	14,024	415,979
		GR	0.90	1.09	1.33	1.68	1.30	1.28	1.47	1.27	1.08	1.10	1.02	1.16	0.99	1.37	1.28	1.08
		SI	0.66	1.17	1.23	0.51	0.54	0.67	0.85	0.47	0.57	1.42	0.75	0.59	0.55	0.79	1.44	1.00

Theme Legend

1 - Arctic & Antarctic	6 - Environment	11 - Inform. & Comm. Tech.
2 - Biotechnology	7 - Climate Change	12 - Marine & Freshwater Biol.
3 - Education	8 - Environment Technology	13 - Maritime Research
4 - Energy	9 - Food Research	14 - Nanotech & New Materials
5 - Fisheries & Aquaculture	10 - Health & Care	15 - Welfare &Working Life

Note: Paper is the total number of papers (full counting), GR and SI are the growth ratio and the specialisation index, respectively, both calculated from fractional counting.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Table XXIV compares each region in terms of three indicators: ARC, ARC as computed for papers co-published with Norwegian authors, and the collaboration rate with Norwegian researchers. This can be used to assess each region in terms of ARC scores for the 15 thematic research areas considered in this study and for its paper output as a whole. In addition, the table shows which regions collaborate the most with Norway, and which clusters benefit the most from such collaboration.

As can be seen, ARC scores tend to be higher for regions in developed countries, apart from Japan. Although regions in developing countries have been increasing their research output in most of the subject areas of interest (as shown above), they have not caught up with developed regions in terms of scientific impact.

Interestingly, ARC scores are significantly higher when developing regions collaborate with Norway. However, ARC indicators for Norwegian collaborations can only be computed for a limited number of subject areas due to the small number of such papers. This finding, i.e. collaborating with Norway increases ARC scores, also applies to developed regions.

In addition, this data can be used to identify the thematic areas where collaborating with Norway has the most impact. For example, Sao Paolo has an ARC of 0.86 for research on Health & Care (subject area 10), but this score rises to 7.49 when papers are co-authored with Norwegian researchers. Since the average ARC for all papers co-authored by Sao Paolo and Norwegian researchers is 6.99, this means that that collaborating with Norway has an especially strong impact in Health & Care.

Table XXIV Comparative analysis of the scientific impact and Norwegian collaborations of 18 regions by thematic area (2003–2012)

Country & region			Theme 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Scopus
brazil	Sao Paulo	Coll rate	0.58%	0.26%	0.24%	0.14%	0.29%	0.25%	0.60%	0.04%	0.04%	0.29%	0.19%	0.32%	0.26%	0.07%	n.c.	0.33%
		ARC Paper	0.85	0.84	0.61	1.07	0.80	0.90	0.94	0.84	0.79	0.86	0.87	0.84	0.76	0.79	0.66	0.90
		ARC Coll	n.c.	3.68	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	7.49	n.c.	n.c.	n.c.	n.c.	n.c.	6.99
	Rio de Janeiro	Coll rate	2.2%	0.4%	0.1%	0.8%	0.3%	0.4%	1.1%	0.4%	0.2%	0.3%	0.4%	0.3%	2.4%	0.1%	n.c.	0.8%
		ARC Paper	0.63	0.89	0.47	0.71	0.96	0.86	0.78	0.82	0.92	0.90	0.75	0.84	0.57	0.75	0.73	0.91
		ARC Coll	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	2.65	n.c.	n.c.	n.c.	n.c.	n.c.	3.25
China	Beijing	Coll rate	2.6%	0.1%	0.3%	0.2%	1.3%	0.4%	0.8%	0.2%	0.1%	0.2%	0.1%	0.2%	0.5%	0.1%	0.3%	0.2%
		ARC Paper	0.82	0.75	0.59	0.81	1.05	0.87	0.82	0.86	0.94	0.75	0.65	0.79	0.77	1.00	0.90	0.82
		ARC Coll	0.91	1.97	n.c.	1.33	n.c.	1.66	1.27	n.c.	2.11	8.18	1.33	n.c.	n.c.	n.c.	n.c.	3.31
	Shang-hai	Coll rate	2.3%	0.1%	0.1%	0.1%	0.5%	0.2%	0.5%	0.1%	0.2%	0.2%	0.1%	0.2%	0.5%	0.2%	0.3%	0.1%
		ARC Paper	0.65	0.76	0.70	0.92	0.75	0.83	0.73	0.83	1.01	0.77	0.70	0.82	0.81	0.98	0.80	0.83
		ARC Coll	n.c.	1.26	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	2.47	n.c.	n.c.	n.c.	0.83	n.c.	1.89
France	FR10	Coll rate	5.6%	1.0%	0.9%	1.5%	4.4%	2.3%	3.2%	0.8%	1.9%	0.9%	0.7%	1.6%	3.4%	0.4%	1.0%	1.0%
		ARC Paper	1.46	1.31	0.97	1.22	1.30	1.36	1.41	1.21	1.46	1.28	1.35	1.44	1.71	1.16	0.97	1.33
		ARC Coll	2.71	2.61	n.c.	1.44	1.76	2.75	2.80	n.c.	2.68	4.17	2.67	2.95	n.c.	1.38	3.81	3.21
	FR71	Coll rate	6.0%	1.7%	0.9%	1.8%	2.4%	2.4%	4.0%	1.4%	3.7%	1.6%	0.4%	1.8%	1.8%	0.6%	2.4%	1.6%
		ARC Paper	1.42	1.30	1.14	1.29	1.30	1.34	1.45	1.11	1.50	1.33	1.40	1.46	1.39	1.05	0.99	1.34
		ARC Coll	2.43	2.22	n.c.	1.37	n.c.	2.80	3.05	n.c.	3.12	3.30	1.71	2.00	n.c.	1.36	n.c.	2.88
Germany	DE21	Coll rate	5.7%	1.1%	0.7%	1.0%	1.9%	2.5%	3.7%	0.7%	1.0%	1.0%	0.4%	2.5%	5.7%	0.7%	1.1%	1.0%
		ARC Paper	1.30	1.48	1.56	1.29	1.14	1.40	1.42	1.10	1.50	1.42	1.27	1.38	1.84	1.32	1.12	1.46
		ARC Coll	n.c.	3.54	n.c.	n.c.	n.c.	2.49	2.37	n.c.	2.88	3.79	2.12	1.75	n.c.	0.88	n.c.	3.25
	DE30	Coll rate	4.8%	0.9%	0.7%	0.6%	3.4%	1.6%	2.6%	1.2%	1.0%	1.1%	0.6%	1.4%	4.5%	0.2%	0.8%	1.1%
		ARC Paper	1.51	1.41	1.32	1.28	1.41	1.27	1.18	1.43	1.32	1.44	1.61	1.38	1.62	1.20	1.14	1.39
		ARC Coll	n.c.	2.86	n.c.	n.c.	n.c.	3.36	3.35	n.c.	4.06	4.68	8.27	n.c.	n.c.	n.c.	n.c.	4.09
India	Tamil nadu	Coll rate	2.4%	0.1%	0.1%	0.4%	0.7%	0.2%	0.7%	0.1%	0.1%	0.1%	0.1%	0.1%	0.9%	0.0%	0.2%	0.1%
		ARC Paper	0.39	0.69	0.53	0.98	0.56	0.72	0.75	0.83	0.62	0.65	0.66	0.57	1.23	0.96	0.51	0.78
		ARC Coll	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	2.08
	Mahar ashtra	Coll rate	n.c.	0.2%	n.c.	0.2%	0.5%	0.1%	0.3%	0.0%	0.1%	0.1%	0.4%	0.2%	0.8%	0.2%	0.3%	0.2%
		ARC Paper	0.75	0.65	0.51	1.02	0.74	0.72	0.51	0.78	0.65	0.72	0.61	0.74	0.89	0.94	0.65	0.84
		ARC Coll	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	5.54
Italy	ITC4	Coll rate	6.3%	1.2%	1.3%	1.5%	4.5%	2.6%	3.7%	1.0%	2.1%	1.3%	0.6%	2.0%	3.1%	0.3%	1.7%	1.6%
		ARC Paper	1.30	1.32	1.06	1.20	1.15	1.37	1.42	1.29	1.34	1.47	1.29	1.29	1.61	1.04	1.15	1.42
		ARC Coll	n.c.	2.79	n.c.	1.10	n.c.	3.62	4.13	n.c.	3.76	4.72	3.04	2.73	n.c.	n.c.	n.c.	3.70
	ITE4	Coll rate	3.7%	0.7%	0.6%	1.2%	3.6%	1.5%	1.8%	0.7%	1.0%	0.8%	0.6%	1.2%	3.7%	0.1%	1.0%	1.3%
		ARC Paper	0.98	1.15	1.00	1.38	1.23	1.24	1.36	1.16	1.26	1.24	1.20	1.17	1.48	0.96	1.05	1.26
		ARC Coll	n.c.	2.39	n.c.	n.c.	n.c.	2.86	3.46	n.c.	3.79	5.43	1.89	n.c.	n.c.	n.c.	n.c.	3.50
Japan	Kansai	Coll rate	1.4%	0.1%	0.2%	0.3%	0.6%	0.2%	0.4%	0.1%	0.2%	0.1%	0.1%	0.3%	1.1%	0.1%	0.2%	0.2%
		ARC Paper	0.49	0.97	0.70	1.13	0.71	0.88	0.77	0.87	0.94	1.01	0.74	0.84	1.13	0.83	0.78	0.98
		ARC Coll	n.c.	2.52	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	2.93	n.c.	n.c.	n.c.	n.c.	n.c.	3.46
	kanto	Coll rate	3.6%	0.2%	0.3%	0.2%	0.8%	0.6%	1.3%	0.2%	0.2%	0.2%	0.1%	0.5%	1.1%	0.1%	0.3%	0.2%
		ARC Paper	0.87	0.96	0.65	1.05	0.72	0.95	0.93	0.95	1.00	0.95	0.81	0.89	0.93	0.88	0.77	0.97
		ARC Coll	2.16	2.32	n.c.	1.04	n.c.	2.65	2.68	n.c.	3.24	5.41	1.23	3.22	n.c.	1.22	n.c.	3.80
UK	UKH1	Coll rate	7.2%	1.7%	0.8%	2.2%	8.9%	3.8%	5.1%	1.9%	2.4%	1.6%	0.7%	3.8%	7.3%	0.4%	1.5%	1.6%
		ARC Paper	1.63	1.96	1.72	2.16	1.83	1.81	1.76	1.69	1.80	1.85	2.93	1.72	1.76	1.55	1.57	1.93
		ARC Coll	2.39	3.03	n.c.	1.70	2.45	3.42	3.10	n.c.	3.23	4.60	1.57	2.92	3.06	n.c.	n.c.	3.92
	UKI1	Coll rate	7.4%	1.2%	0.6%	1.6%	3.3%	2.2%	4.0%	0.9%	2.1%	1.1%	0.4%	2.6%	3.3%	0.3%	1.0%	1.3%
		ARC Paper	1.38	1.64	1.68	1.74	1.48	1.50	1.49	1.51	1.66	1.71	1.61	1.62	1.27	1.48	1.50	1.67
		ARC Coll	2.27	2.93	1.56	1.56	n.c.	2.15	1.92	n.c.	3.93	4.13	1.20	2.44	n.c.	n.c.	2.31	3.44
United States	Calif-ornia	Coll rate	3.9%	0.6%	0.4%	0.4%	1.4%	0.8%	1.3%	0.3%	0.5%	0.5%	0.3%	0.9%	0.8%	0.2%	0.4%	0.5%
		ARC Paper	1.72	1.72	1.61	1.87	1.41	1.60	1.61	1.31	1.69	1.81	2.29	1.65	1.55	1.68	1.50	1.82
		ARC Coll	2.11	2.52	1.64	1.53	2.22	3.64	3.71	n.c.	2.74	3.50	4.69	2.96	n.c.	1.44	3.02	3.16
	New York	Coll rate	4.2%	0.5%	0.3%	0.6%	1.3%	0.9%	1.6%	0.2%	0.6%	0.4%	0.2%	0.8%	0.9%	0.2%	0.2%	0.5%
		ARC Paper	1.90	1.57	1.33	1.59	1.43	1.56	1.55	1.35	1.82	1.66	1.82	1.65	1.67	1.49	1.36	1.66
		ARC Coll	2.70	3.22	n.c.	2.35	n.c.	3.72	3.58	n.c.	3.81	4.62	2.25	4.23	n.c.	n.c.	n.c.	3.72

Theme Legend

1 - Arctic & Antarctic	6 - Environment	11 - Inform. & Comm. Tech.
2 - Biotechnology	7 - Climate Change	12 - Marine & Freshwater Biol.
3 - Education	8 - Environment Technology	13 - Maritime Research
4 - Energy	9 - Food Research	14 - Nanotech & New Materials
5 - Fisheries & Aquaculture	10 - Health & Care	15 - Welfare & Working Life

Note: ARC paper is the ARC calculated from the total number of papers (full counting) while ARC Coll is calculated from the collaboration papers (full counting).

Source: Computed by Science-Metrix using Scopus (Elsevier)

7 Cluster Analysis

This section presents the results of a bibliometric analysis conducted to assess and compare the scientific performance of 20 research clusters that the RCN selected following suggestions by Science-Metrix. Measuring the output and performance of such clusters was a major challenge for this study since each cluster is formed of a range of public and private actors that are difficult to identify given the lack of formal membership structures. Although clusters can often be associated to a number of core members (e.g., universities), focusing publication counts on the latter would exclude informal partners, such as local SMEs, from the analysis. Geographic location rather than institutional affiliation was therefore used to determine membership in any given cluster. For example, the publication count of the Bergen Marine Forskningsklynge cluster was not limited to the core members of this cluster (University of Bergen, Institute of Marine Research, Christian Michelsen Research AS, etc.). Instead, all publications authored by researchers based in relevant areas (in this case, institutions based in Bergen, Breivika, Troms, Tromsø, Ås, Stavanger, Sunndalsøra and Averøy) were included. The cities included in each cluster are set out in Table XXVII in Section 9.6.

According to this approach, cluster publications are not limited to those of researchers who consider themselves part of a given cluster, or even publications that address related subjects (e.g., marine related subjects in the case of the Bergen cluster). To mitigate this last limitation, bibliometric indicators were computed for each of the 15 research themes presented in this study. When analysing results, only relevant research themes should thus be considered.

Table XXV shows the main results of the analysis with regard to output and specialisation indicators (number of papers, GR, SI). As usual, the darker the green, the higher the result relative to the world average; the darker the red, the lower the result relative to the world average.

One of the main findings here is that few of the clusters are growing their output faster than the world average. Only the CalValleyTech iHub (CVTi) and Hedmark-Dalarna (HD) clusters have relatively high GR scores in a number of subject areas.

As expected, each cluster tends to specialise in a limited number of thematic areas (i.e., the green areas along the SI rows). For example, the Bergen Marine Forskningsklynge cluster is highly specialised in Arctic & Antarctic Research (subject area 1) and Fisheries & Aquaculture (subject area 5). It is also considerably specialised in Climate Change, Marine & Freshwater Biology and Maritime Research. These results confirm that the Bergen Marine Forskningsklynge cluster is actively contributing to making associated cities global players in marine related subjects (since, as noted, indicators are computed with regard to the total output of the cities associated to each cluster). A similar interpretation can be made for the indicators computed for Future Ocean, Kiel Marine Science (FO KMS).

Overall, the most popular subjects in terms of SI are subject areas 1 (Arctic & Antarctic Research), 6 (Environment), 7 (Climate Change), 10 (Health & Care), and 15 (Welfare & Working Life). In other words, these are the areas that tend to be the most popular across the clusters concerned (among the 15 thematic areas considered).

Table XXV Comparative analysis of the scientific output and specialisation of 20 leading research clusters by thematic area (2003–2012)

		Theme															
Cluster		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Scopus
AAFC	Paper	4,235	59,381	7,136	8,610	3,014	22,021	7,103	6,190	19,027	160,393	34,322	7,355	1,067	12,740	11,213	320,646
	GR	1.29	1.21	1.58	1.63	1.24	1.36	1.55	1.39	1.20	1.24	1.18	1.30	1.25	1.68	1.52	1.22
	SI	2.44	1.13	0.96	0.70	1.07	1.05	1.20	0.97	0.92	1.27	1.03	0.86	0.64	0.66	1.49	1.00
BMF	Paper	3,088	5,792	773	1,534	2,878	3,483	1,889	373	2,933	14,505	1,836	2,859	514	333	1,166	30,894
	GR	1.27	1.36	1.53	1.49	1.25	1.56	1.71	1.21	1.36	1.31	1.47	1.40	1.34	2.28	1.85	1.34
	SI	21.41	1.14	1.18	1.44	14.59	1.63	3.29	0.52	1.56	1.21	0.57	4.05	3.59	0.17	1.78	1.00
BA	Paper	280	2,746	255	495	124	1,187	350	421	643	6,287	2,753	319	25	644	407	15,666
	GR	1.62	0.98	1.89	1.77	1.31	1.25	1.45	1.11	1.26	1.06	1.16	1.16	1.14	1.57	1.30	1.11
	SI	3.24	0.91	0.74	0.93	0.88	1.28	1.32	1.61	0.56	0.84	1.93	0.75	0.29	0.64	1.14	1.00
CVTi	Paper	36	556	211	162	35	426	184	91	426	1,473	342	187	12	224	188	4,249
	GR	1.48	3.18	1.58	3.82	1.26	2.13	3.78	1.85	1.14	1.34	3.30	3.05	0.62	3.18	1.92	1.93
	SI	0.76	0.67	2.47	1.18	1.01	1.40	1.88	1.02	1.46	0.91	0.87	1.50	0.55	0.95	2.23	1.00
DSP	Paper	627	24,506	1,884	2,426	873	7,100	1,937	1,976	7,341	60,963	9,065	3,354	332	5,912	2,640	120,826
	GR	1.39	1.19	1.91	1.79	1.04	1.50	1.62	1.52	1.31	1.18	1.46	1.15	1.96	1.67	1.86	1.25
	SI	0.81	1.21	0.71	0.55	0.91	0.92	0.84	0.87	0.96	1.27	0.76	1.12	0.56	0.77	0.94	1.00
EBGCi	Paper	632	17,454	2,198	3,854	413	8,394	3,071	1,929	5,036	32,969	8,786	2,373	440	8,496	3,601	101,159
	GR	1.10	1.05	1.29	1.74	0.99	1.42	1.79	1.49	1.20	1.06	0.97	1.01	0.79	1.37	1.23	1.08
	SI	0.92	1.02	1.02	1.14	0.46	1.31	1.70	1.00	0.75	0.79	0.83	0.86	0.90	1.49	1.65	1.00
EST	Paper	612	10,421	1,015	1,376	241	3,869	1,795	657	3,939	21,209	4,224	1,260	216	1,801	1,654	48,656
	GR	1.04	1.09	1.53	1.45	1.41	1.39	1.75	1.38	1.00	1.09	1.18	1.16	1.45	1.92	1.24	1.13
	SI	2.18	1.28	1.05	0.84	0.54	1.16	1.86	0.73	1.22	1.14	0.88	0.92	1.04	0.56	1.56	1.00
ENC	Paper	1,498	12,865	1,883	4,990	511	6,022	2,304	1,639	5,822	35,007	7,865	2,097	258	2,891	2,268	76,730
	GR	1.22	1.24	1.76	1.56	1.08	1.38	1.58	1.40	1.26	1.21	1.10	1.27	0.86	1.60	1.52	1.20
	SI	3.41	1.01	1.10	1.84	0.80	1.19	1.61	1.10	1.15	1.14	0.99	1.04	0.59	0.71	1.24	1.00
ELAT	Paper	425	24,394	2,557	5,060	567	7,513	2,031	2,553	6,290	65,697	15,975	2,411	281	10,867	3,233	153,362
	GR	0.87	1.17	1.69	1.67	1.21	1.49	1.62	1.51	1.16	1.17	1.32	1.10	1.53	1.52	1.65	1.18
	SI	0.45	0.92	0.73	0.97	0.43	0.78	0.71	0.90	0.64	1.03	1.05	0.61	0.34	1.13	0.86	1.00
FO KMS	Paper	718	4,723	281	488	366	2,095	1,283	239	1,741	9,237	1,101	1,840	217	858	294	19,874
	GR	1.00	1.17	1.92	1.87	1.46	1.34	1.48	1.11	1.05	1.09	0.99	1.39	1.06	2.05	1.38	1.17
	SI	6.25	1.31	0.64	0.70	2.07	1.60	3.52	0.68	1.55	1.12	0.61	3.75	2.31	0.75	0.65	1.00
GT	Paper	2,274	36,860	3,351	3,471	617	9,272	3,965	1,754	6,658	96,537	10,684	3,930	554	9,377	6,986	186,936
	GR	0.93	0.91	1.02	1.43	1.10	1.14	1.43	1.04	0.92	0.88	0.99	1.07	0.79	1.43	1.03	0.94
	SI	2.34	1.16	0.81	0.52	0.38	0.77	1.18	0.49	0.52	1.28	0.56	0.79	0.68	0.81	1.69	1.00
HD	Paper	6	135	20	167	17	128	28	42	142	354	65	29	0	23	42	1,198
	GR	1.78	1.95	4.90	1.02	2.56	1.10	2.02	0.43	1.33	1.29	1.59	5.59	n.c.	0.99	1.83	1.33
	SI	0.40	0.40	0.97	3.32	1.17	1.90	1.49	2.08	1.35	0.55	0.64	0.64	n.c.	0.38	1.40	1.00
HT	Paper	817	10,339	983	1,188	483	4,808	1,861	880	3,649	24,386	3,716	1,694	245	1,921	1,909	48,446
	GR	1.10	1.05	1.91	1.44	0.83	1.13	1.39	1.28	1.00	1.00	1.31	0.94	1.93	1.39	1.61	1.07
	SI	3.29	1.21	0.95	0.68	1.36	1.64	2.18	1.03	1.26	1.21	0.77	1.51	1.13	0.64	1.87	1.00
128C	Paper	1,018	65,152	4,800	4,275	1,136	10,515	3,682	2,070	6,656	172,877	18,027	4,183	642	13,723	7,338	274,224
	GR	1.03	1.15	1.38	1.79	0.95	1.26	1.37	1.26	1.18	1.18	1.08	1.13	1.23	1.70	1.34	1.16
	SI	0.57	1.44	0.74	0.44	0.51	0.57	0.69	0.39	0.35	1.62	0.62	0.59	0.46	0.88	1.08	1.00
MC	Paper	2,408	22,808	1,137	3,989	872	8,733	3,353	2,389	7,079	51,727	5,259	3,505	481	5,039	3,024	101,119
	GR	1.02	1.05	1.81	1.46	1.12	1.22	1.47	1.15	0.97	1.10	1.33	0.98	1.23	1.63	1.62	1.12
	SI	4.73	1.35	0.55	1.22	1.10	1.38	1.83	1.31	1.07	1.28	0.52	1.38	1.12	0.83	1.40	1.00
OR	Paper	2,256	20,053	1,024	2,659	690	7,029	2,935	1,519	5,963	48,319	4,044	2,940	296	3,244	2,870	86,255
	GR	1.03	1.04	1.73	1.33	1.12	1.17	1.38	0.99	0.96	1.11	1.20	0.99	1.21	1.54	1.62	1.09
	SI	5.25	1.39	0.59	0.91	0.99	1.26	1.87	0.93	1.05	1.43	0.48	1.37	0.73	0.59	1.61	1.00
OCC	Paper	1,100	7,320	932	1,078	1,125	3,057	1,314	526	2,636	22,090	1,859	1,362	283	780	1,861	36,981
	GR	1.21	1.22	1.88	1.49	1.16	1.52	1.71	1.57	1.08	1.14	1.83	1.20	1.59	1.88	1.49	1.25
	SI	5.38	1.17	1.25	0.74	3.89	1.23	2.03	0.69	1.09	1.52	0.46	1.46	1.46	0.32	2.53	1.00
OUR	Paper	353	3,490	280	652	126	1,392	459	420	907	7,165	3,671	389	80	1,272	357	19,237
	GR	1.36	1.01	2.00	1.71	1.15	1.38	1.31	1.56	1.18	1.05	1.29	1.30	3.07	1.50	1.60	1.16
	SI	3.28	0.95	0.66	0.96	0.73	1.14	1.32	1.19	0.66	0.77	2.11	0.73	1.08	1.08	0.75	1.00
RT	Paper	476	28,817	3,445	2,655	1,054	9,002	2,856	2,192	8,385	73,468	7,794	3,692	448	6,173	4,281	129,528
	GR	0.89	1.18	1.45	2.18	0.82	1.34	1.43	1.41	1.06	1.17	1.14	1.18	1.06	1.45	1.28	1.15
	SI	0.52	1.34	1.18	0.58	1.04	1.03	1.10	0.89	0.98	1.42	0.60	1.11	0.68	0.85	1.35	1.00
VBRP	Paper	21	4,632	668	602	94	873	221	250	702	14,426	831	313	50	1,233	900	21,357
	GR	1.57	1.28	1.08	1.34	2.25	1.32	1.69	1.43	1.20	1.14	1.48	1.36	0.73	1.18	1.39	1.15
	SI	0.12	1.33	1.31	0.73	0.41	0.60	0.57	0.55	0.45	1.74	0.35	0.49	0.45	1.00	1.78	1.00

Legend

Cluster Name	Theme Name
AAFC - Agriculture and Agri-Food central canada	1 - Arctic & Antarctic Research
BFM - Bergen Marine Forskningsklynge	2 - Biotechnology
BA - Bothnian Arc	3 - Education
CVTi - CalValleyTech iHub	4 - Energy
DSP - DSP Valley	5 - Fisheries & Aquaculture
EBGCi - East Bay Green Corridor iHub	6 - Environment
EST - Edinburgh Science triangle	7 - Climate Change
ENC - Edmonton nanotechnology cluster	8 - Environmental Technology
ELAT - Eindhoven-Leuven-Aachen triangle	9 - Food Research
FO KMS - Future Ocean, Kiel Marine Science	10 - Health & Care
GT - Golden TriangleHedmark-Dalarna	11 - Information & Communication Tech.
HD - Hedmark-Dalarna	12 - Marine & Freshwater Biology
HT - Helsinki-Tallin	13 - Maritime Research
128C - Massachusetts' Route 128 Corridor	14 - Nanotechbologies & New Materials
MC - Medicon valley	15 - Welfare & Working Life
OR - Oresund Region	
OCC - Oslo Cancer Cluster	
OUR - Oulu Region	
RT - Research Triangle	
VBRP - Virginia Biotechnology Research Park	

Note: Paper is the total number of papers (full counting), GR and SI are the growth ratio and the specialisation index, respectively, both calculated from fractional counting.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Table XXVI compares each cluster in terms of ARC, ARC as computed for papers co-published with Norwegian authors, and the collaboration rate with Norwegian researchers. This table enables the identification of the thematic research areas where each cluster has the most impact, the clusters that collaborate the most Norway, and the clusters that benefit the most from collaborating with Norwegian researchers.

As shown, the clusters tend to have high ARC scores in all or most of the thematic areas examined. This is likely because the selected clusters are all in countries that tend to have an above-average scientific impact (i.e., European and North American countries). Interestingly, the ARC scores for papers co-published with Norwegian authors are not only higher than the world average in each thematic area, but are also almost always higher than the general ARC scores of each cluster, suggesting that collaborations with Norway pay off in terms of citation impact. In other words, even though the clusters generally have high ARC scores, they perform even better when a Norwegian collaborator contributes to a publication.

Similarly to the above regional analysis, the cluster data can also be used to identify the subject areas where collaborating with Norway has the most impact. For example, the AAFC cluster has an ARC of 1.56 for research on Health & Care (area 10), which climbs to 5.23 when papers are co-authored with Norwegian researchers. Since the average ARC for all papers co-authored by AAFC and Norwegian researchers is 3.77, this means that that collaborating with Norway has an especially strong impact in Health & Care.

Table XXVI Comparative analysis of the scientific impact and Norway collaborations of 20 leading research clusters by thematic area (2003–2012)

Cluster		Theme 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Scopus
	Collab rate	5.5%	0.7%	0.5%	0.6%	3.7%	1.3%	2.1%	0.6%	0.7%	0.5%	0.6%	1.7%	2.0%	0.1%	0.5%	0.7%
AAFC	ARC paper	1.46	1.41	1.53	1.52	1.48	1.40	1.33	1.43	1.38	1.56	1.42	1.39	1.40	1.26	1.24	1.51
	ARC Collab	2.54	3.16	n.c.	1.79	2.80	3.33	3.35	3.84	2.95	5.23	1.99	2.78	n.c.	n.c.	3.89	3.77
	Collab rate	61.7%	60.6%	38.0%	44.1%	50.1%	65.0%	67.8%	63.5%	53.1%	49.6%	52.6%	62.4%	42.2%	62.5%	41.3%	54.1%
BMF	ARC paper	1.29	1.34	1.33	1.05	1.47	1.58	1.44	2.03	1.42	1.52	1.42	1.49	1.58	1.14	1.38	1.49
	ARC Collab	1.45	1.56	1.53	1.20	1.68	1.82	1.65	2.52	1.62	1.96	1.81	1.72	2.26	1.28	1.69	1.83
	Collab rate	14.6%	3.1%	8.6%	3.0%	8.1%	4.7%	9.7%	2.9%	4.4%	3.4%	1.2%	6.9%	4.0%	1.4%	4.2%	2.9%
BA	ARC paper	0.83	1.32	1.66	1.30	1.02	1.21	1.14	1.15	1.38	1.51	1.03	1.29	n.c.	1.06	1.26	1.29
	ARC Collab	1.17	3.19	n.c.	n.c.	n.c.	2.52	1.92	n.c.	n.c.	3.16	n.c.	n.c.	n.c.	n.c.	n.c.	2.52
	Collab rate	30.6%	0.4%	0.9%	0.6%	2.9%	2.6%	2.7%	n.c.	0.5%	0.8%	n.c.	2.1%	n.c.	n.c.	n.c.	2.4%
CVTi	ARC paper	2.12	1.22	0.92	1.00	0.90	1.55	1.56	1.03	1.27	1.27	1.88	1.55	n.c.	0.95	1.06	1.48
	ARC Collab	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	7.99
	Collab rate	9.7%	1.4%	1.1%	1.4%	4.4%	2.3%	3.4%	1.1%	1.4%	1.6%	0.6%	1.8%	4.2%	0.2%	1.9%	1.3%
DSP	ARC paper	1.65	1.57	1.77	1.55	1.46	1.54	1.41	1.57	1.58	1.76	1.71	1.41	2.10	1.25	1.49	1.64
	ARC Collab	2.54	2.72	n.c.	1.59	1.65	3.74	3.63	n.c.	2.39	4.78	1.66	2.90	n.c.	n.c.	2.50	3.90
	Collab rate	3.5%	0.6%	0.4%	0.6%	1.5%	0.7%	0.9%	0.2%	0.5%	0.5%	0.4%	0.8%	1.8%	0.2%	0.5%	1.1%
EBGCi	ARC paper	2.12	1.84	1.76	2.33	1.83	1.84	1.87	1.68	1.88	1.82	3.18	1.81	1.52	1.88	1.57	2.04
	ARC Collab	n.c.	3.72	n.c.	n.c.	n.c.	4.38	n.c.	n.c.	n.c.	2.80	n.c.	n.c.	n.c.	n.c.	n.c.	3.07
	Collab rate	8.0%	1.6%	0.6%	3.1%	7.9%	3.0%	3.9%	1.5%	1.6%	1.5%	0.5%	3.7%	4.6%	0.8%	1.0%	2.6%
EST	ARC paper	1.67	1.53	1.47	1.32	1.71	1.70	1.73	1.35	1.61	1.67	1.68	1.70	2.45	1.38	1.36	1.65
	ARC Collab	2.67	4.06	n.c.	1.57	n.c.	3.61	3.21	n.c.	2.51	4.76	n.c.	3.08	n.c.	n.c.	n.c.	3.35
	Collab rate	7.0%	0.9%	0.2%	1.3%	3.7%	1.6%	2.6%	0.7%	0.5%	0.7%	0.3%	2.7%	2.7%	0.2%	0.3%	0.9%
ENC	ARC paper	1.17	1.35	1.46	0.99	1.38	1.29	1.29	1.16	1.36	1.57	1.45	1.24	1.16	1.05	1.14	1.45
	ARC Collab	1.96	2.03	n.c.	1.67	n.c.	3.53	3.29	n.c.	n.c.	5.19	n.c.	3.08	n.c.	n.c.	n.c.	4.29
	Collab rate	4.7%	1.2%	0.7%	0.6%	3.4%	1.4%	2.3%	0.4%	1.1%	1.3%	0.5%	1.3%	4.3%	0.2%	1.0%	0.9%
ELAT	ARC paper	1.60	1.43	1.79	1.76	1.34	1.51	1.45	1.56	1.58	1.64	1.64	1.44	1.83	1.36	1.49	1.58
	ARC Collab	n.c.	2.76	n.c.	n.c.	n.c.	3.70	4.39	n.c.	2.12	4.94	1.56	n.c.	n.c.	n.c.	2.89	4.04
	Collab rate	8.8%	2.2%	0.7%	2.0%	7.1%	4.6%	5.5%	2.1%	2.0%	1.1%	0.5%	5.5%	4.6%	0.7%	1.7%	1.8%
FO KMS	ARC paper	1.70	1.51	1.89	1.39	1.67	1.70	1.57	1.56	1.35	1.60	1.10	1.76	1.79	1.13	1.12	1.53
	ARC Collab	3.07	2.99	n.c.	n.c.	n.c.	2.93	2.71	n.c.	2.04	3.77	n.c.	2.36	n.c.	n.c.	n.c.	2.90
	Collab rate	6.7%	0.7%	0.2%	1.5%	3.2%	2.6%	4.6%	0.9%	1.1%	0.6%	0.4%	2.9%	3.2%	0.4%	0.7%	0.8%
GT	ARC paper	1.48	1.72	1.80	2.14	1.57	1.64	1.65	1.43	1.69	1.66	2.56	1.72	1.61	1.60	1.52	1.76
	ARC Collab	2.03	2.74	n.c.	1.02	n.c.	2.42	2.19	n.c.	5.15	4.46	0.97	2.13	n.c.	n.c.	1.68	3.29
	Collab rate	50.0%	37.0%	20.0%	2.4%	41.2%	11.7%	14.3%	2.4%	38.7%	25.7%	9.2%	41.4%	n.c.	n.c.	16.7%	15.8%
HD	ARC paper	n.c.	1.02	n.c.	1.10	n.c.	0.98	n.c.	1.66	1.27	1.14	1.25	n.c.	n.c.	n.c.	1.17	1.13
	ARC Collab	n.c.	1.22	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	1.47	1.73	n.c.	n.c.	n.c.	n.c.	n.c.	1.50
	Collab rate	13.8%	3.9%	4.3%	4.5%	7.2%	5.7%	8.1%	1.9%	3.3%	4.9%	1.1%	5.8%	10.2%	1.1%	3.2%	3.9%
HT	ARC paper	1.18	1.49	1.60	1.34	1.26	1.45	1.55	1.13	1.52	1.67	1.53	1.32	2.03	1.27	1.38	1.58
	ARC Collab	2.08	2.68	2.64	1.98	n.c.	2.48	2.48	n.c.	3.26	3.60	1.87	2.33	n.c.	n.c.	2.06	3.17
	Collab rate	3.8%	0.7%	0.3%	1.0%	1.6%	0.9%	1.5%	0.4%	0.6%	0.6%	0.2%	0.8%	1.4%	0.2%	0.5%	0.7%
128C	ARC paper	2.00	2.03	1.70	1.96	1.50	1.82	1.75	1.56	2.25	2.18	2.61	1.73	1.85	1.97	1.88	2.19
	ARC Collab	n.c.	3.27	n.c.	1.51	n.c.	2.72	2.06	n.c.	8.76	4.82	3.07	n.c.	n.c.	n.c.	n.c.	3.78
	Collab rate	14.2%	4.1%	3.9%	3.8%	10.6%	5.9%	8.2%	2.3%	4.6%	5.2%	2.1%	6.3%	8.3%	1.7%	4.3%	4.5%
MC	ARC paper	1.39	1.49	1.33	2.06	1.53	1.70	1.62	1.79	1.69	1.70	1.64	1.53	2.10	1.46	1.48	1.70
	ARC Collab	1.79	1.99	1.69	1.67	2.17	2.48	2.17	3.30	3.08	2.75	1.90	1.80	0.78	1.74	1.99	2.69
	Collab rate	14.5%	4.3%	4.1%	4.7%	10.1%	6.9%	8.9%	3.0%	5.0%	5.4%	2.0%	6.5%	4.4%	1.9%	4.3%	4.9%
OR	ARC paper	1.43	1.46	1.39	2.12	1.51	1.71	1.65	1.75	1.72	1.69	1.54	1.51	2.03	1.51	1.46	1.69
	ARC Collab	1.83	2.05	1.69	1.70	2.41	2.54	2.24	3.52	3.19	2.78	1.94	1.90	n.c.	1.10	2.01	2.76
	Collab rate	61.1%	58.3%	31.1%	45.0%	48.3%	57.5%	59.2%	50.2%	50.5%	47.5%	44.2%	58.7%	41.0%	59.5%	32.1%	49.2%
OCC	ARC paper	1.31	1.36	1.54	1.38	1.55	1.69	1.69	1.84	1.61	1.64	1.41	1.50	1.65	1.16	1.32	1.60
	ARC Collab	1.43	1.61	1.90	1.75	1.66	2.02	2.13	2.20	1.90	2.25	1.77	1.69	1.99	1.39	1.77	2.10
	Collab rate	15.0%	2.8%	7.5%	2.5%	7.9%	5.0%	8.7%	1.9%	4.1%	2.7%	1.0%	5.1%	2.5%	0.7%	3.9%	2.3%
OUR	ARC paper	0.95	1.30	1.49	1.33	1.02	1.19	1.21	0.97	1.33	1.45	1.15	1.22	1.57	1.01	1.22	1.28
	ARC Collab	2.17	3.05	n.c.	n.c.	n.c.	2.83	2.75	n.c.	1.65	3.22	1.04	n.c.	n.c.	n.c.	n.c.	2.64
	Collab rate	7.8%	0.7%	0.1%	0.7%	2.0%	0.9%	1.5%	0.3%	0.5%	0.5%	0.3%	0.7%	0.7%	0.2%	0.5%	0.6%
RT	ARC paper	1.80	1.72	1.60	1.46	1.33	1.64	1.72	1.38	1.56	1.95	1.92	1.66	1.82	1.51	1.67	1.85
	ARC Collab	n.c.	3.50	n.c.	n.c.	n.c.	3.68	4.15	n.c.	4.85	6.91	n.c.	n.c.	n.c.	n.c.	n.c.	5.46
	Collab rate	n.c.	0.8%	n.c.	0.2%	n.c.	0.7%	1.4%	0.8%	0.3%	0.5%	0.1%	0.3%	n.c.	n.c.	0.1%	0.4%
VBRP	ARC paper	n.c.	1.63	1.23	1.61	0.93	1.20	1.35	1.01	1.28	1.71	1.32	1.33	1.22	1.36	1.09	1.59
	ARC Collab	n.c.	2.51	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	3.14	n.c.	n.c.	n.c.	n.c.	n.c.	3.48

Legend

Cluster Name	Theme Name
AAFC - Agriculture and Agri-Food central canada	1 - Arctic & Antarctic Research
BFM - Bergen Marine Forskningsklynge	2 - Biotechnology
BA - Bothnian Arc	3 - Education
CVTi - CalValleyTech iHub	4 - Energy
DSP - DSP Valley	5 - Fisheries & Aquaculture
EBGCi - East Bay Green Corridor iHub	6 - Environment
EST - Edinburgh Science triangle	7 - Climate Change
ENC - Edmonton nanotechnology cluster	8 - Environmental Technology
ELAT - Eindhoven-Leuven-Aachen triangle	9 - Food Research
FO KMS - Future Ocean, Kiel Marine Science	10 - Health & Care
GT - Golden TriangleHedmark-Dalarna	11 - Information & Communication Tech.
HD - Hedmark-Dalarna	12 - Marine & Freshwater Biology
HT - Helsinki-Tallin	13 - Maritime Research
128C - Massachusetts' Route 128 Corridor	14 - Nanotechbologies & New Materials
MC - Medicon valley	15 - Welfare & Working Life
OR - Oresund Region	
OCC - Oslo Cancer Cluster	
OUR - Oulu Region	
RT - Research Triangle	
VBRP - Virginia Biotechnology Research Park	

Note: ARC paper is the ARC calculated from the total number of papers (full counting) while ARC Collab is calculated from the collaboration papers (full counting).

Source: Computed by Science-Metrix using Scopus (Elsevier)

8 Conclusion

This report provides the RCN with bibliometric indicators of scientific performance and collaboration patterns focusing on Norway and 57 selected international partners in science in general, as well as in thematic areas of high relevance to Norway. Analyses in this report were based on data for the past decade (2003–2012), taken from the Scopus database of peer-reviewed scientific literature.

This conclusion summarises the findings and highlights the countries of interest in relation to the RCN's objectives of: (a) identifying leading scientific nations and those that co-publish the most with foreign partners and with Norway in particular, and (b) showing how the relative performance of countries is likely to change in the near future.

Findings regarding the scientific performance and collaboration patterns for Norway and selected countries in the sciences in general

General scientific production and future trends

In terms of output for the entire study period, Norway ranks 31st among the 58 selected countries, with 114,000 publications (based on FULL counting). The largest producers of scientific papers are the US, with close to 4.6 million papers (FULL) and China (2.5 million). Completing the top 10 are the UK, Japan, Germany, France, Canada, Italy, India and Spain (from 1.2 million to 541,000 papers respectively).

Of the 15 countries with the highest publication output during the entire 10-year period, China and India show by far the largest increases in the number of papers produced during the study period. In fact, they both overtook many countries during this time period and China likely surpassed the US in 2013 as the leading nation in terms of its share of world output if recent trends continued.

Among the top 15 largest producers of scientific output, Brazil, the Republic of Korea and Taiwan follow, with above 50% increases in output from 2003 to 2012.

Among the smaller producers of scientific papers, Malaysia, currently ranking in 33rd place in terms of production among the 58 countries analysed, increased its publication output by more than fourfold. With an overall publication output of 88,775 publications (FULL), Malaysia could become an important producer of scientific output in the future if this trend continues.

Other small producers of publication output such as Iran, Luxembourg, Romania, Indonesia and Colombia also exhibit high increases in output.

International collaboration

In absolute numbers, the largest producers lead in terms of co-publications with other countries. When taking the volume of their scientific production into account, some countries stand out since they collaborate more than expected. As measured by the collaboration index (CI,) Switzerland leads in this respect, followed by Belgium, Vietnam and Germany.

Norway collaborates about 25% above expectations and ranks 15th among the selected countries. In fact, all the Nordic countries collaborate more than expected.

Of those countries that already collaborate more than expected, Singapore, Spain, the US and Australia show the largest increase in their propensity to collaborate with foreign partners. Of those that currently collaborate less than expected, Pakistan, Egypt and Taiwan show the largest increase in their propensity to collaborate with foreign partners.

Countries' scientific impact

Based on their average of relative citations (ARC), Iceland, Switzerland and Denmark have the highest scientific impact for their overall publications. Even when considering their international co-publications only, they maintain the highest impact, with Iceland in the lead, followed by Denmark and Switzerland. Norway ranks 11th for its overall output and 12th for its international collaborations.

On average, the ARC of international co-publications is 48% higher than that for overall publications, and all countries without exception benefit from international partnerships in terms of scientific impact.

Among countries with overall below average ARCs, China, Croatia, Poland and Russia reap the most benefit from international collaborations. Of those countries that already meet or exceed expectations respecting citation impact, Malta, Italy and Estonia show the highest increase between overall citation rates and the ARCs of their international co-publications.

China as a key scientific partner with which to expand and/or reinforce collaboration

Within the subset of countries identified as key scientific partners with which Norway should expand and/or reinforce collaboration in the future, China heads the list given the rapidly changing nature of its scientific system. If the trends shown in this study continued, China should have had surpassed the United States as the nation with the largest annual scientific production in 2013.

Because China's impact is still relatively low, it does not often appear in the report's recommendations by strategic theme (Section 3.2 to Section 3.16). However, even if its impact remains relatively low in many areas, this is changing and will continue to do so in the future, which means that China should definitely be on the radar screen of any nation planning future international collaboration strategies.

Collaboration profiles with Norway in the sciences in general

Norway's major collaborators in terms of absolute number of co-publication output are the leaders in output at the world level (e.g., the US, the UK and Germany), with the exception of China and Japan. In terms of collaboration rates and pairwise affinities with Norway, all the Nordic countries are noteworthy (in descending order: Iceland, Sweden, Denmark and Finland), as are Estonia and Luxembourg. These findings reflect the strong influence of geographic proximity and cultural similarity on countries' collaboration patterns.

Interestingly, Norway presents a positive affinity for all EU-28 countries, with the exception of Croatia, which only joined the European Union in 2013. This tends to indicate that Norway has integrated the European Union motto — United in Diversity — and has seriously focused on developing strong partnerships within Europe

Norway is also an important collaborator for South Africa, Israel, Russia and Canada, which all have strong affinities for Norway. However, Norway's affinities for these countries are less strong.

Although Norway presents very little affinity for collaborating with China, China shows a certain affinity for Norway, co-publishing 19% more with Norwegian researchers than expected.

Among the Nordic countries, collaboration between Norway and Sweden is increasing, even though it is already significant. The greatest increase within the EU is noted with the Czech Republic, Hungary and Belgium.

International collaboration with Norway leads to a particularly high ARC score of 1.76 on average (all countries pooled). All the 57 selected countries have ARC scores above 2 for their co-publications with Norway.

Of the traditional leaders in science, those with which collaboration with Norway has proven most beneficial include Belgium, Switzerland, Italy, Australia and Canada.

Findings as to the scientific performance and collaboration profile of selected countries with Norway by strategic theme.

General discussion

In each of the 15 themes, strategic partners for Norway were identified as potential candidates for increasing collaborations and impact. While these candidates vary, some are recurrent across the themes. **Singapore** was identified in almost all themes based on its strong impact and the fact that Norway's collaborations with Singapore are infrequent. A global collaboration partnership with Singapore similar to that Norway has achieved with **South Africa** could yield high benefits for both countries.

The other Nordic countries (i.e., **Denmark**, **Sweden**, **Iceland** and **Finland**), especially Denmark and Sweden, were also frequently identified as good selections. These countries have a high impact in most of the themes and share common traits with Norway in their scientific output. Given that Norway already collaborates frequently with these countries, shows strong affinities for them, and that this affinity is reciprocal, it would be important to maintain these privileged relationships.

The **US**, with its generally good impact and the largest output in most themes, should of course be a strong candidate in Norway's strategic plan for collaboration. While the US's impact is rarely the highest, its performance is always among the best, and the sheer size of its output multiplies the possibilities for high quality partnerships in most themes.

From a different perspective, more distant partners with which Norway could collaborate in certain specific areas include **Canada**, **New Zealand** and **Australia**. Partnerships with these countries, with which Norway shares specific interests (e.g., themes relating to aquatic and polar environments), could be beneficial in terms of producing high impact publications and could help expand Norway's already diverse field of collaborators. Since collaborations with these countries were less frequent than with Norway's top collaborators in many themes, developing these links would benefit all parties.

On the European front, although their outputs are smaller than the top publishing countries, **Switzerland** and the **Netherlands** present some of the strongest scientific impact in many themes, which shows great promise for improving Norway's impact if strong partnerships were to be developed. **Belgium** and **Luxembourg** also fall into this same category, but for a more limited set of themes and with slightly less scientific impact. Nevertheless, they present good opportunities for collaboration on the European scene.

While the above-mentioned countries are those that stood out overall in many themes, some strategic partners were also identified in a few themes. A listing of all the strategic partners identified per theme is presented below. Those in bold are countries with which Norway does not actually collaborate frequently and with which it should particularly try to intensify collaboration to promote high impact output. As mentioned previously, China's impact is still relatively low, which explains why it does not often appear as a strategic partner for Norway. Nevertheless, also as mentioned previously, China's performance is growing rapidly and will continue to do so in the future. Accordingly, China should definitely be on the radar screen of any nation planning future international collaboration strategies.

It should also be noted that the analyses were performed at the macro-level (i.e., at the level of nations) and as such do not account for the substantial variability in the underlying data at the institutional/researcher level that characterises bibliometric data (e.g., power law distribution in the production/impact of research institutions/researchers). Consequently, the RCN should consider micro-level data for the nations (especially those with small productions; less than a thousand publications in full counting) identified as potential key partners in developing its collaboration strategies to maximise the beneficial returns of these partnerships. In a subsequent draft of this report, Science-Metrix will highlight potential institutions, based on the data in the companion database, within the nations identified as potentially beneficial partners for Norway. Data at the researcher level will also be made available in the final delivery.

Potential key partners for Norway by strategic theme and for which it should expand and/or reinforce collaboration

- **Arctic & Antarctic Research:** Based on their overall performance in Arctic & Antarctic Research, strategic partners for improving the scientific impact of Norwegian publication output include Iceland, Canada, Switzerland, Denmark, the UK, the US and New Zealand. Of these, Norway's collaborations with **Canada**, the **US** and **New Zealand** are below expectations and could thus be further strengthened. At the micro-level, organisations that stand out in terms of output, specialisation and impact in this thematic include: **University of Iceland** (Iceland), **Laval University** (Canada), **University of Bern** (Switzerland), **University of Aarhus and University of Copenhagen** (Denmark), **University of Southampton and University of Bristol** (UK), **NASA** and **Caltech** (US) and **Victoria University of Wellington** (New Zealand).
- **Biotechnology:** Based on overall performance, Iceland, Luxembourg, the US, Denmark, Switzerland, the Netherlands, Ireland, Belgium and Germany emerge as strategic partners that could improve Norway's scientific impact in Biotechnology. Collaborations with **Ireland** and **Switzerland** should be particularly intensified. At the micro-level, organisations that stand out in Biotechnology include: **DeCODE Genetics** (Iceland), **Public research Center for Health** (Luxembourg), **NIH** and **Harvard University** (US), **University of Copenhagen** (Denmark), **University of Zurich** and **University of Lausanne** (Switzerland), **Erasmus MC** and **WUR** (the Netherlands), **University College of Dublin** (Ireland), **KU Leuven and Ghent University** (Belgium) and **Max Planck Society** (Germany).
- **Education:** Based on their overall performance in the Education theme, strategic partners for improving the scientific impact of Norwegian publication output include Belgium, Luxembourg, the Netherlands, the UK, Cyprus, Canada, Australia, Taiwan and the US. Norway's collaborations are low and should be especially intensified with **Canada**, **Cyprus** and **Luxembourg** due to these countries' high specialisation and impact. At the micro-level, organisations that stand out in Education are: **Ghent University** (Belgium), **Utrecht University** (the Netherlands), **University of Nottingham** and **University of Oxford** (UK), **Near East University** (Cyprus), **University of Toronto** (Canada), **Queensland University of Technology** (Australia), **National Central University** (Taiwan) and **University of Michigan** and **University of Texas at Austin** (the US).
- **Energy:** Considering overall performance in the strategic theme of Energy, Singapore, Denmark, Malaysia, the Republic of Korea, Switzerland, Canada and Taiwan can be identified

as strategic partners to improve Norway's scientific impact. More specifically, Norway's collaborations are low and should especially be strengthened with **Singapore** and **the Republic of Korea**. At the micro-level, institutions that stand out in Energy in these strategic countries include: **Nanyang Technological University** and **National University of Singapore** (Singapore), **DTU** and **Aalborg University** (Denmark), **University of Malaya** (Malaysia), **KAIST** (Korea), **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **National Research Council** (Canada) and **National Cheng Kung University** and **National Chiao Tung University** (Taiwan).

- **Environment:** Strategic partners for improving Norway's scientific impact in Environment include Switzerland, Denmark, Australia, Portugal, the Netherlands, the UK, Canada, Spain and New Zealand, since these countries exhibit high general performance considering all indicators combined. Collaboration with **Australia Portugal, Spain and New Zealand** could be emphasised since it is presently below expectations. Organisations that stand out in terms of output, specialisation and impact in Environment in these strategic countries include: **ETHZ** (Switzerland), **DTU** and **University of Aarhus** (Denmark), **CSIRO** (Australia), **University of Aveiro** (Portugal), **WUR** (the Netherlands), **University of Leeds** (UK), **University of British Columbia** (Canada) and **Spanish National Research Council** (Spain).
- **Climate Change:** Strategic partners for improving Norway's visibility and impact in Climate Change include Switzerland, Australia, Denmark, the UK, the Netherlands, Sweden, Finland, the US, Canada and New Zealand. More specifically, collaboration with **Australia, Canada, New Zealand** and the **US** could be further promoted given that it is currently below expectations. Organisations that stand out in Climate Change in these strategic countries include: **ETHZ** (Switzerland), **CSIRO** (Australia), **DTU** and **University of Aarhus** (Denmark), **University of Oxford** (UK), **WUR** and **Utrecht University** (the Netherlands), **Stockholm University** (Sweden), **University of Eastern Finland** and **University of Helsinki** (Finland), **NASA**, **Columbia University**, **US Department of Energy** and **University of California - Berkeley** (US), **University of British Columbia** (Canada) and **University of Otago** (New Zealand).
- **Environmental Technology:** Strategic partners for improving Norway's impact in Environmental Technology include Switzerland, Malaysia, Portugal, Denmark, Spain, Singapore, Australia, Canada and China, since these countries are frontrunners in this field considering all indicators combined. Collaboration is presently below expectations and efforts should be made to build stronger scientific relations with these countries, especially with **Malaysia Spain, Australia** and **China.** At the micro-level, the top institutions in Environmental Technologies in these countries are: **ETHZ** (Switzerland), **University of Science** (Malaysia), **New University of Lisbon** and **University of Porto** (Portugal), **DTU** and **Aalborg University** (Denmark), **CSIC** and **University of Santiago de Compostela** (Spain), **Nanyang Technological University** (Singapore), **CSIRO** and **University of Queensland** (Australia), **University of Waterloo** (Canada) and **Tongji University** and **Chinese Academy of Sciences** (China).
- **Fisheries & Aquaculture: Norway** is a leader in Fisheries & Aquaculture research considering overall international performance, followed by Iceland, Denmark, Canada, Australia, Portugal, Spain, New Zealand and the UK. **Portugal** can be identified a strategic partner contributing to Norway's relative decline in output. The strong partnership with **Denmark** should be further reinforced to increase citation impact. Organisations that stand out in this strategic field and with which Norway should consider intensifying its collaboration include: **Matís ltd. - Icelandic Food and Biotech R&D** (Iceland), **DTU** (Denmark), **University of British Columbia** and **Dalhousie University** (Canada), **CSIRO** and **Australian Research Council** (Australia), **University of Aveiro** (Portugal), Spanish National Research Council (Spain), and **Imperial College London** (UK).

- **Food Sciences:** Strategic partners for improving the scientific impact of Norway's output in Food Sciences include the Netherlands, Ireland, Denmark, Switzerland, Spain, Luxembourg, the UK, Australia, the US, Belgium, New Zealand and Singapore. Of these, the **US** and **Singapore** post shares of co-publications with Norway below the world level. Organisations that stand out based on output, specialisation or impact in Food Science in these strategic countries include: **WUR** (the Netherlands), **University College Dublin** (Ireland), **University of Aarhus** (Denmark), **Spanish National Research Council** (Spain), **CSIRO** (Australia), **US Department of Agriculture and University of California – Davis** (US), **Ghent University** (Belgium) and **Massey University** (New Zealand).
- **Health & Care:** Strategic partners for improving the scientific impact of Norway's output in Health & Care include the Netherlands, the US, Denmark, Iceland, Switzerland, Canada, the UK, Belgium, Sweden, Australia, Ireland and Singapore. More specifically, Norway collaborates less than expected with the **US**, **Singapore**, **Canada** and **Australia**. Given the robust growth of its output, its strong scientific impact and the mutual affinity between both countries, **Luxembourg** should also be targeted for increasing collaborations. At the micro-level, Norway should consider the following organisations (among many others) that stand out in Health & Care in the above countries: **Academic Medical Centre** and **Erasmus MC** (the Netherlands), **Brigham and Women's Hospital** and **National Institutes of Health** (US), **Copenhagen University Hospital** (Denmark), **DeCODE Genetics** (Iceland), **University Hospital of Zürich** (Switzerland), **University Health Network** (Canada), **Medical Research Council** (UK), **UZ Leuven** (Belgium), **Karolinska Institute** and **Karolinska University Hospital** (Sweden), **University of Melbourne** and **University of Sydney** (Australia), **Trinity College Dublin** (Ireland) and **Singapore National Eye Centre** (Singapore).
- **Information & Communication Technologies:** Strategic partners for improving the scientific impact of Norway's output in ICT include the US, the UK, Israel, Singapore, Switzerland, Iceland, the Netherlands, Denmark, Canada, Turkey, Ireland, Taiwan and Luxembourg. More specifically, **Israel**, the **US**, **Taiwan** and **Turkey** show lower shares of co-publications with Norway than the world average. Finland, Greece and India could also be considered, the first two because of their high impact, specialisation and proven capacity to produce high impact co-publications with Norway, and India because of its high impact co-publications and the tremendous growth of its already substantial output. Institutions that stand out in ICT in these strategic countries include: **Georgia Institute of Technology** and **Massachusetts Institute of Technology** (US), **University of Southampton** (UK), **Technion** (Israel), **Nanyang Technological University** (Singapore), **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **Reykjavik University** (Iceland), **TUDelft** (the Netherlands), **Aalborg University** (Denmark), **University of Waterloo** (Canada), **Middle East Technical University** (Turkey), **National Chiao Tung University** (Taiwan), **University of Luxembourg** (Luxembourg), **Aalto University** (Finland) and **University of Patras** (Greece).
- **Marine & Freshwater Biology:** Strategic partners for improving the scientific impact of Norway's output in Marine & Freshwater Biology include Cyprus, Denmark, the UK, the Netherlands, Switzerland, Estonia, Australia, Sweden, New Zealand, Portugal, Canada and the US. Of these, **Cyprus**, **Australia**, the **US** and **Portugal** have a share of co-publications with Norway below the world level. However, in the case of the US this still results in a positive affinity for Norway. The most important institutions in terms of output, specialisation or impact in this strategic field include: **University of Aarhus** (Denmark), **University of Southampton** (UK), **WUR** (the Netherlands), **ETHZ** (Switzerland), **Estonian University of Life Sciences** (Estonia), **Australian Research Council** and **CSIRO** (Australia), **Stockholm University** (Sweden), **University of Otago** (New Zealand), **University of Aveiro** (Portugal), **Dalhousie University** (Canada) and the **US Department of Agriculture** (US).

- **Maritime Research:** Strategic partners for improving the scientific impact of Norway's output in Maritime Research include Denmark, Portugal, Sweden, Singapore, Belgium, Greece and New Zealand. Even though their impact on their own is slightly below the world average, special attention should also be paid to Canada, Germany and France as potential avenues for increasing Norway's impact since they all present sizable outputs in the field and have an extremely high impact when collaborating with Norway. Of the above, only **New Zealand**'s share of co-publications with Norway is below the world level. In terms of institutions that stand out in Maritime research in these countries, the following are worth mentioning: **DTU** (Denmark), **University of Lisbon** (Portugal), **National University of Singapore** (Singapore) and **National Technical University of Athens** (Greece).
- **Nanotechnology & New Materials:** Strategic partners for improving the scientific impact of Norway's output in Nanotechnology & New Materials include Singapore, Iran, the US, Switzerland, the Netherlands, Denmark, Australia, Germany, China, the Republic of Korea and the UK. More specifically, countries for which the share of co-publications with Norway is below expectations include **Singapore**, **Iran**, the **US**, the **Republic of Korea** and **China**. At the micro-level, the following organisations stand out in this thematic field: **Nanyang Technological University** (Singapore), **Isfahan University of Technology** (Iran), **US Department of Energy** and **Northwestern University** (US), **ETHZ** and **Swiss Federal Institute of Technology in Lausanne** (Switzerland), **University of Groningen** (the Netherlands), **DTU** (Denmark), **Australian Research Council** (Australia), **Max Planck Society** (Germany), **Chinese Academy of Sciences** and **Peking University** (China), **KAIST** (Republic of Korea) and **University of Cambridge** (UK)**.**
- **Welfare & Working Life:** Strategic partners for improving the scientific impact of Norway's output in the Welfare & Working Life theme include the Netherlands, the UK, Denmark, the US, Sweden, Australia, Switzerland, Canada, New Zealand and Belgium. Countries for which the share of co-publications with Norway stands below the world level include the **US**, **Switzerland**, **Canada** and **New Zealand.** The **US**, **Switzerland** and **New Zealand** also collaborate less than expected with Norway based on their affinity score. The top performing institutions in these strategic countries in Welfare & Working Life include: **VU University Amsterdam** and **TUDelft** (the Netherlands), **University of Oxford** (UK), **Copenhagen Business School** (Denmark), **Harvard University** and **New York University** (US), **Stockholm University** (Sweden), **Griffith University** and **Deakin University** (Australia), **University of Zurich** (Switzerland), **University of Toronto** (Canada), **Massey University** (New Zealand) and **University of Antwerp** (Belgium).

Findings in the international network of selected countries

The bibliometric information supporting the identification — as described in the above section — of foreign organisations with which Norwegian institutions could potentially establish mutually beneficial partnerships is presented in the form of collaboration networks on the organisational level. The general findings as relates to these networks' structure are detailed below.

Apart from a few exceptions, most themes share similar patterns in terms of cooperation at the international level. National aggregates are the norm with organisations presenting strong ties with other institutions at the national level. Geographical proximity also plays a major role in the international network, as does cultural proximity (e.g., linguistic affinity). American and European organisations often dictate the main structure of the network, American organisations clustering together, while European organisations form a second cluster, primarily dominated by French, UK and German organisations. Other national clusters tend to gather around these main structures.

Norwegian organisations present strong national and regional ties and are often close to other Scandinavian organisations, especially in Denmark and Sweden. However, while Swedish and Danish organisations often come close to the main clusters, Norwegian organisations frequently appear as a distinct structure in the network. **This might be a bias induced by the over-representation of Norwegian organisations in the network; they are indeed predominant since the study focused on Norway.**

Effect of multilateral co-authorship on the scientific impact of research output

Which type of scientific partnership is most beneficial to a country's scientific impact and what are the mechanisms underlying such gains in impact? These questions have attracted much attention from the scientific community in bibliometrics, as well as from decision makers within the context of collaboration policy development. It is well known that international co-publications have, on average, more impact than domestic only co-publications, and that the latter have more impact than single author publications in most scientific disciplines. However, it still remains unknown to what extent these difference in citation impact are attributable to the increased size of teams on individual papers (i.e., number of co-authors; through mechanisms such as self-citations), to the actual geographic location of the co-authors (i.e., number of countries involved), or to other factors.

Thus, analyses have been performed at the aggregate level for all countries and fields combined to investigate how the citation impact of various types of publications and co-publications, with and without self-citations, scale with the size of teams, as well as with the number of countries involved. These analyses were also performed specifically for Norway. The results shed further light on which types of collaboration (i.e., domestic vs. international and bi-lateral vs. multilateral at the researcher or country level) are the most beneficial to scientific impact and whether there is any cut-off point beyond which further increases in the number of authors and/or countries no longer increase the scientific impact of publications.

Effect of author self-citations on the citation impact of co-publications

Various explanations have been proposed to explain the increase in scientific impact of papers resulting from partnerships in the scientific literature, the most common being author self-citations. There is no doubt that as the number of co-authors on a scientific publication increases, so does the likelihood of self-citations; thus, the more authors on a paper, the higher its chances of being cited through author self-citations. If this were the sole mechanism underlying the increased impact of co-publications, serious questions could be raised about the benefit of scientific partnerships since the increased influence of a given paper would not extend beyond its actual co-authors, unless nearly all researchers in a given field contributed to the paper.

The results of this study show that factors other than author self-citations play a role in increasing the citation impact of various types of publications. It was demonstrated that when author self-citations are excluded, international co-publications continue to have a higher impact than domestic only co-publications, and both groups were still cited more than single author publications. In fact, self-citations were shown to account for only 12% of the difference in the citation impact (ARC) of international co-publications compared to single author publications. Further discussions of the impact of self-citations in measuring the scientific impact of countries/organisations are provided in Section 5.1.

Effect of the number of countries on the citation impact of co-publications

To assess the effect of the number of countries on the citation impact of co-publications, international co-publications were disaggregated into international only co-publications (i.e., papers authored by researchers located in at least two countries and only one author per country) and co-publications involving both international and domestic partnerships, hereafter "international/domestic co-publications" (i.e., papers authored by researchers located in at least two countries and with at least two authors from the same country). Since international only co-publications with the same number of authors as international/domestic and domestic only co-publications necessarily involve more countries, their comparison enabled us to gauge the effect of the number of countries on the citation impact of publications.

When controlling for the number of authors on a co-publication, it was found that international only co-publications generally achieve the highest average citation impact. These co-publications are, on average, cited 11% more often relative to the world average than international/domestic co-publications, and 40% more often than domestic only co-publications. International/domestic co-publications are also cited, on average, 38% more often relative to the world average than domestic only co-publications. Further investigations of the underlying citation distributions revealed that the observed gains in impact as the number of countries increases for a given number of authors are mainly due to a reduction in the frequency of very low impact papers (i.e., uncited papers), as well as to an increase in the frequency of very high impact papers (i.e., mostly in the top 10% most cited papers).

Similar findings were observed for Norway when self-citations were removed. The main difference for Norway is that the gap in the impact (ARC) of international only and international/domestic co-publications relative to domestic only co-publications is smaller when controlling for the number of authors. Still, an important effect is present, as shown by average gains of 34 and 26 percentage points relative to the world level of impact for international only and international/domestic co-publications respectively.

Effect of the number of authors on the citation impact of co-publications

Regardless of the co-publication type, the average citation impact increases progressively with the number of authors involved. As the number of authors increases, the ARC increases for all co-publication types, especially for international/domestic co-publications and domestic only co-publications. As shown above for a growing number of countries, the increase is, however, mainly caused by a reduction in the frequency of the least cited papers (i.e., those in the 20% less cited papers) paired with an increase in the frequency of papers in the 10% most cited papers. Thus, the more authors on a paper, the more likely it will become a very high impact paper. However, increasing the number of collaborators does not guarantee increased citation impact distributed evenly across individual papers. Similar findings were observed for Norway, with or without self-citations.

Apart from self-citations, one mechanism that may very well explain the observed increase in the citation impact of co-publications as the number of authors and/or countries increases is an increase in the visibility of the publications through the usual collaboration network of each of the co-authors. It is assumed that a paper's visibility increases with the number of authors through the connections of each author within the scientific community. This hypothesis, which will be tested by Science-Metrix in the future, is developed further in Section 5.2.

Although a positive effect of the number of authors/countries has been noted for the average citation impact of all co-publication types, it should be recalled that the citation scores of individual papers for any given number of co-authors varies substantially. As such, the number of authors is not a sound predictor of the citation impact of a specific paper (see Section 5.2). It is assumed that the same holds true for the effect of the relative number of countries on the relative number of citations of individual papers. This is because the observed increase in the ARC of the various types of co-publications does not stem from a general increase in citations distributed evenly across all papers, but mainly from increases in the frequency of occurrence of very high impact papers (in the 10% most cited) and a reduction in the frequency of very low impact papers (in the 10% to 20% less cited) as we move from the lower to the higher number of authors. In other words, although co-publications with multiple authors are not a guarantee of an increased citation impact for individual papers, they do increase the likelihood of producing very high impact papers. This also indicates that other factors must have an effect on publications' citation impact. Such factors are likely to include the novelty and quality of the research, which increases the influence/impact of publications on the broader scientific community.

Science policy recommendations

The above findings respecting the effect of the number of authors and countries on the citation impact of co-publications provide strong incentives for the development of policies promoting scientific partnerships on a national scale, and even more so on an international scale. There is no doubt that the greater the number of authors and countries involved in a scientific publication, the greater its chances of becoming a high impact paper (or potential "breakthrough").

9 Methods

The bibliometric indicators in this report were produced using the Scopus database from Elsevier, which Science-Metrix hosts as an in-house SQL-relational database. Science-Metrix has carefully conditioned this database to produce large-scale comparative bibliometric analyses. Although other databases (e.g. Web of Science) would also have allowed for the production of robust bibliometric indicators for this project, Scopus was selected for the following reasons:

1. Scopus provides a more extensive coverage of the applied sciences, particularly because it indexes a number of conference proceedings, which represent a central means of diffusion in some scientific fields (e.g., computer sciences and engineering).
2. Scopus also provides better coverage of the Social Sciences and Humanities (SSH).
3. Only Scopus links authors with their addresses, which eases the process of identifying leading co-publishing authors in selected institutions.

For this project, data was produced for the sciences in general — i.e., using the entire Scopus database. More specifically, only documents published in refereed scientific journals (mostly articles, reviews and conference proceedings) were retained, as these documents were reviewed by peers prior to being accepted for publication. The peer-review process ensures that the research is of good quality and constitutes an original contribution to scientific knowledge. In the context of bibliometrics, these documents are collectively referred to as "publications." Data was also produced by field of science using Science-Metrix's journal-based and mutually exclusive classification scheme.[31] Moreover, 15 themes of strategic interest to Norway were delineated by retrieving relevant publications using keyword-based queries, specialist journals, and entire subfields from Science-Metrix's classification where appropriate. The construction of these themes is presented in greater detail in Section 9.1.

The study covers 57 countries (i.e., those listed in the Terms of Reference for this project, as well as Greece and Croatia). Data was also produced for the following regional aggregates: the Nordic countries, EU-15 countries, EU-28 countries, and the world (i.e., all data in Scopus). Because some of the included countries (e.g., **European countries:** the UK, Germany, France and Italy; **other countries:** the US, China, Japan, India and Brazil) have large R&D systems characterised by regional differentiations and strongholds (e.g., California in the US), Science-Metrix also performed a regional analysis for these countries. Data for organisations (see Section 9.2) and researchers (see Section 9.2) was also produced. As well, for organisations, data was produced for a number of clusters or networks of highly interconnected organisations as part of optional deliverable E.

At the country level (i.e., individual, Nordic, EU-15 and EU-28 countries, and the world), the data was computed annually and globally for the period from 2003 to 2012 to allow for trend analysis. For the data produced at other aggregation levels (i.e., regions in specific countries, organisations,

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[31] Science-Metrix's journal classification is freely available at http://www.science-metrix.com/.

Archambault É., Caruso J., and Beauchesne O. (2011). Towards a Multilingual, Comprehensive and Open Scientific Journal Ontology, in Noyons, B., Ngulube, P. and Leta, *J. Proceedings of the 13th International Conference of the International Society for Scientometrics and Informetrics (ISSI)*, Durban, South Africa, pp 66-77.

clusters of organisations and researchers), the period considered is 2010–2012 with no trend analysis.

9.1 Construction of thematic datasets

In addition to the analyses at the field level using Science-Metrix's classification, the RCN requested data on Norway's 15 strategic themes. The publication datasets for these themes were created by Science-Metrix's experienced analysts on the basis of definitions provided by the RCN. Note that during this process Science-Metrix's analysts had numerous discussions with staff at the RCN to refine the final datasets. These datasets were delineated by retrieving relevant publications using keyword-based queries (hundreds of keywords by theme), specialist journals, and entire subfields from Science-Metrix's classification where appropriate. Science-Metrix's approach ensures that relevant publications published in generalist journals of often large influence (e.g., Science and Nature) are also retrieved for each theme.

All three approaches (i.e., keywords, journals and subfields) allowed for the retrieval of the core publications for each theme. To assess whether the coverage achieved with each of Science-Metrix's queries was adequately representative of the corresponding theme, the recall of the publications appearing in the identified set of specialist journals using the keyword approach (i.e., the proportion of retrieved publications) was computed. The queries provided highly satisfactory results with recalls of generally at least 70%. In many cases, the recall even surpassed 90%.

Tests for false positives were also performed since keywords can often be unspecific and refer to different and unrelated subject matters (e.g., "milk*" in the Food Sciences thematic will also retrieve publications in Astronomy and Astrophysics mentioning the "Milky Way"). Although most of the false positives can be excluded using exclusion rules, a certain level of false positives is to be expected. In this project, each theme was tested for false positives and efforts were made to reduce them to less than 5%. The following definitions highlight the salient subject matters covered under each theme:

Arctic & Antarctic Research

This theme includes documents relevant to Arctic & Antarctic Research, covering all aspects of research in both these extreme environments (e.g., polar biology, polar engineering, arctic and antarctic animal species, polar geography, polar atmospheric science and Nordic seas).

- **Examples of keywords:** Arctic, Antarctic, Glacier, Greenland, Sea-ice, Tundra.
- **Examples of journals:** *Polar Biology*, *Annals of Glaciology*, *Cold Regions Science and Technology*.

Biotechnology

This theme includes documents relevant to the use of living/biological systems in technologies, including genomics at large, bioinformatics, medical biotechnology, and bioengineering.

- **Examples of keywords:** Biotechnology, DNA, Agrobacterium, Recombinant, Stem Cell, Tissue Engineering.
- **Examples of journals:** *Nucleic Acids Research*, *Oncogene, Biomaterials*, *Biotechnology and Bioengineering*, *Biosensors & Bioelectronics*.

Education

The Education theme encompasses all aspects of research relevant to the teaching system, ranging from elementary school to university curricula. Research on teaching environments and techniques (e.g., classrooms, e-learning) as well as research on the psychological aspects of education were also included in this dataset.

- **Examples of keywords:** Student, Teacher, Classroom, Tutor, Curricula, E-Learning, Education System, Learning Outcome, Special Education, Academic Achievement.
- **Examples of journals:** *Proceedings of the Software Engineering Education Conference*, *International Journal of Artificial Intelligence in Education*.

Energy

The theme of Energy encompasses research related to energy sources, ranging from traditional sources (e.g., oil, natural gas, petroleum) and the techniques for their exploration and recovery to cleaner renewable forms (e.g., hydropower, solar energy). Energy policies are also included, as well as research on power sources, power electronics, batteries, fuel cells, the use and conversion of energy, and all aspects of energy efficiency for sustainable development (e.g., green housing).

- **Examples of keywords:** Petroleum, Fuel Cell, Solar Cell, Natural Gas, Energy Savings, Crude Oil, Renewable Energy, Wind Turbine, Biofuel, Electric Vehicle, Hydrogen Storage, Biodiesel, Petrochemical, Energy Demands, Oilfield, Gas Production, Oil Recovery, Li-Ion Battery, Smart Grid.
- **Examples of journals:** *Petroleum Science and Technology*, *Journal of Power Sources*, *International Journal of Hydrogen Energy*, *Energy Policy*, *Solar Energy Materials and Solar Cells*, *Energy Conversion and Management*, *Renewable Energy*, *Petroleum Refinery Engineering*.

Fisheries & Aquaculture

Articles related to fisheries and aquaculture practices were included in this dataset, as well as research on fish and aquatic diseases and fish biology. An exhaustive list of fish species was developed to cover most topics in fisheries research. The Fisheries subfield in Science-Metrix's classification was also added to the dataset, along with a list of specialist journals provided by the RCN.

- **Examples of keywords:** Aquaculture, Fish Culture, Sea Farming, Overfishing, Fish Species, Fisheries Management.
- **Examples of journals:** *Aquaculture*, *Journal of Fish Biology*, *Fisheries Research*, *Fish and Shellfish Immunology*, *Journal of Applied Ichthyology*, *Aquaculture Nutrition*, *Fishery Bulletin*, *Fish Pathology*, *Fish and Fisheries*.

Environment

For this study, the dataset on Environment was limited to what could be considered the core of the field, mainly including publications on environmental pollution, ecological systems, biodiversity, anthropogenic impact on the environment, etc. The dataset also encompasses all the publications retrieved for the Environmental Technology and Climate Change themes as they both constitute sub-disciplines of environmental research.

- **Examples of keywords:** Pollution, Sustainable, Emissions, Climate Change, Biodiversity, Environmental Impact, Heavy Metals, Environmental Protection, PAHs, Bioremediation, Suspended Solids, NOX, Deforestation, Carbon Cycle, Ecological Risk
- **Examples of journals:** *Atmospheric Environment*, *Science of the Total Environment*, *Environmental Pollution*, *Journal of Climate*, *Water, Air and Soil Pollution*, *Remote Sensing of Environment*, *WIT Transactions on Ecology and the Environment*.

Climate Change

This theme addresses the various aspects of research related to climate change, as well as the overall aspects of climate research and their aftermaths on society. These include the impacts of climate on the environment and research on mitigating these impacts, as well as research on past climatic conditions, the economic aspects of climate change, climate policies, etc.

- **Examples of keywords:** Climate Change, Climate Research, El Nino Southern Oscillation, Paleoclimatology, Interglacial, Hydrological Cycle, CO2 Capture.
- **Examples of journals:** *Journal of Climate*, *Global Change Biology*, *Climatic Change*, *Climate Policy*, *Climate of the Past*, *Carbon Management*.

Environmental Technology

This theme covers technological advances and techniques for improving the quality of the environment, focusing particularly on environmentally friendly technologies. These range from bioremediation techniques to clean the environment, clean transportation advances to reduce pollution, recycling at large (e.g., recycling, composting, reuse of chemicals, green chemistry) to wastewater treatment, etc.

- **Examples of keywords:** Wastewater treatment, Recycling, Bioreactor, Remediation, Electric Vehicle, Leachate, Desalination, Bioaccumulation, Eco-Environmental, Ozonation, Nanofiltration.
- **Examples of journals:** *Environmental Technology*, *Resources Conservation and Recycling*, *Ozone Science and Engineering*, *Water Science and Technology*, *Desalination, Waste Management*.

Food Sciences research

The theme Food Sciences research focuses on all aspects of food sciences and the related areas of agriculture and agronomy. An exhaustive list of food items was built to cover the theme, and the entire subfield entitled Food Sciences in Science-Metrix's classification was included in the dataset, as well as relevant subfields in Agriculture (i.e., Agronomy and Agriculture, and Agricultural Economics and Policy). The theme includes articles relevant to dairy and animal science, but does not include veterinary sciences at large since they are focused on farm animals.

- **Examples of keywords:** Farm, Breeding, Milk, Wheat, Rice, Agriculture, Cattle, Vegetables, Meat, Dairy, Soybean, Corn, Maize, Fertilizer, Potato, Bread, Tomato, Cereal, Livestock.
- **Examples of journals:** *Journal of Agricultural and Food Chemistry*, *Food Chemistry*, *Journal of Dairy Science*, *Journal of Food Science*, *Journal of Food Protection*, *Poultry Science*, *Crop Science*, *Asian-Australasian Journal of Animal Sciences*.

Health & Care

Health & Care encompasses all the articles relevant to health sciences, including patient care, research for the advancement of medical sciences and psychology and mental health. This dataset was largely built around Science-Metrix's classification, including all articles from five fields and subfields (Clinical Medicine, Public Health & Health Services, Biomedical Research, Psychology and Cognitive Sciences and Biomedical Engineering), as well as hundreds of keywords covering the different aspects of health sciences and patient care. Overall, this theme is by far the largest in this study.

- **Examples of keywords:** Clinic, Public Health, Cancer, Medical, Surgery, Medicinal, Diabetes, Health Care, Insulin, HIV, Pregnancy, Ventricular, Blood Pressure, T-Cell, Hepatic, Urinary, Interleukin, Nurse, Cholesterol, Obesity, Placebo.
- **Examples of journals:** *American Journal of Public Health*, *Environmental Health Perspectives*, *Gene Therapy*, *Clinical Therapeutics*, *Journal of Medicinal Chemistry*, *Journal of Pharmaceutical and Biomedical Analysis*.

Information & Communication Technologies

Since the theme of Information & Communication Technologies (ICT) is covered exhaustively and precisely by one of the fields in Science-Metrix's classification, this field was included in its entirety. For instance, all subfields of the ICT field, such as software, computer sciences, multimedia systems, telecommunications, etc., were included, Hundreds of keywords highly specific to ICT research were subsequently identified to complete the analysis and maximise the recall of relevant articles published in generalist journals.

- **Examples of keywords:** Information System, Image Processing, Sensor Network, Information Technology, Broadcasting, Telecommunications, MIMO, User Interface, Wireless, Web Service, Object Oriented, Cryptography, Software Development, Fuzzy Set, Peer-to-Peer, WLAN.
- **Examples of journals:** *Journal of Convergence Information Technology*, *Dianzi Yu Xinxi Xuebo/Journal of Electronics and Information Technology*, *IFIP Advances in Information & Communication Technology*, *Proceedings of the 2010 International Conference on Computed Science and Information Technology*.

Marine & Freshwater Biology

The theme of Marine & Freshwater Biology includes all biological aspects of aquatic biology in both marine and freshwater environments. This encompasses research on aquatic bacteria and microorganisms, hydrobiology, marine and freshwater ecology, aquatic toxicology, aquatic plants, etc. The subfield of Marine Biology and Hydrobiology from Science-Metrix's classification was also included in its entirety, as well as a list of specialist journals provided by the RCN.

- **Examples of keywords:** Algae, Phytoplankton, Coral, Reef, Zooplankton, Diatom, Mangrove, Aquatic Ecosystem, Macroinvertebrate, Seagrass, Crayfish, Rotifer, Aquatic Plant, Shallow Lake, Benthic Invertebrate, Eutrophic Lake, Bacterioplankton, Freshwater Ecosystem.
- **Examples of journals:** *Marine Ecology-Progress Series*, *Hydrobiologia*, *Marine Biology*, *Journal of Experimental Marine Biology and Ecology*, *Freshwater Biology*, *Aquatic Toxicology*, *Marine and Freshwater Research*, *Aquatic Botany*, *Ecology of Freshwater Fish*, *Aquatic Ecology*.

Maritime Research

Publications on the various aspects of maritime technology and their social and economic aspects populate this dataset. These include vessel design and hydrodynamics, ship construction and modelling, onboard wireless systems, maritime and sea laws, the economic aspects of this industry, etc. Some articles in offshore engineering, primarily focusing on engineering of offshore structures, were also included.

- **Examples of keywords:** Ship Design, Ship Motion, Maritime, Naval, Boat, Mooring, Tanker, Offshore Structure, Sailing, FPSO, Ship Industry, Wave Tank, Caisson, Quay, Seaport, Ocean Engineering, Berth, Hydrodynamic Coefficient, Automatic Identification System.

- **Examples of journals:** *Maritime Policy and Management*, *Journal of Ship Productions*, *Naval Engineers Journal*, *Chuan Bo Li Xue/Journal of Ship Mechanics*, *Journal of Waterway Port Coastal and Ocean Engineering*, *International Journal of Marine and Coastal Law*.

Nanotechnology & New Materials

Nanotechnology & New Materials focuses on nanotechnologies and advanced materials exhibiting peculiar behaviours (e.g. reaction to light, pressure, temperature, electricity, magnetic fields, etc.) that can be used in technologies (e.g., functional materials). These include fullerenes, nanoparticles, smart materials, shape-memory alloys and all materials with special magnetic and electric properties.

- **Examples of keywords:** Nanoparticle, Fullerene, Nanotube, Self-Assembled, TIO, Photoluminescent, Magnetic Properties, SOL-GEL, Graphite, Piezoelectric, ZNO, Quantum Dot, Ferroelectric, Nanowire, Microfluidic, MEMS, Microfabrication.
- **Examples of journals:** *Nanotechnology*, *Journal of Nanoscience and Nanotechnology*, *Ferroelectrics*, *Advanced Functional Materials*, *Journal of Sol-Gel Science and Technology*, *Small*, *Nanoscale Research Letters*, *Reviews on Advanced Materials Science*.

Welfare & Working Life

Welfare & Working Life includes the different aspects of research on societies and its many facets, including demographics, gender issues, ethnic issues, wealth, the labour market, family research, the disabled and governments. Social aspects of life in a broad definition were included to create a comprehensive dataset. Four subfields from Science-Metrix's classification were also included to complete the theme: Social Work, Family Studies, Gender Studies and Demography.

- **Examples of keywords:** Welfare, Workplace, Housing, Wealth, Immigrant, Economic Growth, Employer, Citizenship, Feminist, Human Capital, Retirement, Labour market, Public Service, Social Services, Refugee, Social Changes, Homeless, Globalisation, Family Support, Maltreatment, Foster Care.
- **Examples of journals:** *Regional Studies*, *World Development*, *Children and Youth Services Review*, *Child Abuse & Neglect*, *International Journal of Human Resource Management*, *Journal of Marriage and the Family*, *Social Work*, *Social Choice and Welfare*, *Ethnic and Racial Studies*, *Housing Studies*.

9.2 Standardisation of research organisations

A thorough data cleaning was performed on Norwegian organisations in Scopus and on their collaborators from the selection of countries for this project. Science-Metrix standardised the names of organisations by cleaning thousands of variants in Scopus. For example, the Norges teknisk-naturvitenskapelige universitet (NTNU) is written in many different forms in the database. Analyst searched for name variants (e.g., Norwegian Univ. of Sci. and Technol, NTNU, Norwegian Univ. of Sci./Technology, University of Trondheim, Norges Teknisk-naturvitenskapelige Universitet) as well as relevant sub-units (e.g., NTNU Nanolab, Department of Cancer Research and Molecular Medicine). Statistics were produced for the 10 most active organisations in each of 55 countries, as well as for the top 50 organisations from Norway. For countries with larger outputs, more organisations were cleaned to complete the analyses.

9.3 Standardisation of researchers

Cleaning the names of the most important co-authors is also a challenging task. This is largely because an author may be listed under several names, and various authors may share the same name (i.e., homographs) in the bibliographic databases. The identification of the various names used by an individual and the resolution of homographs is crucial to the production of statistics at the level of authors (i.e., researchers).

Science-Metrix has extensive expertise in author name disambiguation, having performed several contracts in which the names of thousands of researchers were disambiguated to assess the effect of various research funding programs. In fact, we have recently published a method on this topic. In brief, Science-Metrix uses a combination of human expertise aided by powerful algorithms that examine author affiliations, fields of production, co-authors, co-citation patterns, and rare words used by the authors to achieve this task. The algorithm used by Science-Metrix to support the matching exercise was developed in collaboration with a team of experts on signal and information processing from the École Polytechnique de Montréal. It uses high throughput methods developed for image processing to address the complexity of author name disambiguation based on several heterogeneous types of information contained in large bibliographic databases.

About 33,000 authors were cleaned for this project. This is based on 55 countries, each with 20 organisations for which 30 authors were standardised (10 Norwegian authors, 10 from the collaborating countries and 10 for third countries); thus, 55 X 20 X 30 = 33,000. To keep cost and time at reasonable levels, the task was performed algorithmically, with a certain amount of manual validation. This task proved to be more challenging than initially anticipated due to the very small number of co-publications of authors from the collaborating countries with Norway. Indeed, as the number of co-publications decreases, great care must be taken to ensure that the recall is very good. For instance, missing a single co-publication for a researcher can make the difference between whether or not this author appears within the top 10.

Limitation: The selection of the most active authors may favour authors in certain fields where researchers often have a larger output (e.g. Clinical Medicine). However, this was not always the case since some organisations specialise in particular niches other than health research fields. Additionally, the extent to which the world (countries other than Norway) collaborates with Norway is most pronounced in Arctic & Antarctic Research as well in as Fisheries & Aquaculture, the two areas in which Norway is most specialised. Consequently, authors outside the health sciences fields came out in the analyses.

9.4 Indicators

This section presents the bibliometric indicators computed as part of this study.

9.4.1 Number of publications

The traditional widespread publication count is one means of measuring and comparing the production of various aggregates (e.g., organisations, regions and countries). It can also be used to evaluate output in individual disciplines, such as philosophy and economics, and to track trends in research fields, collaborative research and many other aspects of research output. A number of other indicators can also be derived from these simple counts. Full and fractional counting are the two ways of counting the number of papers.

Full counting

In the full counting method, each paper is counted once for each entity listed in the address field. For example, if a paper is authored by two researchers from the University of Oslo, one from the University College London (UCL) and one from the University of Washington, the paper will be counted once for the University of Oslo, once for the University College London and once for the University of Washington. It will also be counted once for Norway, once for the UK and once for the US. When it comes to groups of institutions (e.g., research consortia) or countries (e.g., EU-28), double counting is avoided. This means that if authors from Norway and France co-publish a paper, when counting papers for the EU-28, this paper will be credited only once, even though each country will have been credited with one publication count.

Fractional Counting

Fractional counting is used to ensure that a single paper is not counted several times. This approach avoids the use of total numbers across entities (e.g., researcher, institution, region, country) that add up to more than the total numbers of papers, as is the case with full counting. Ideally, each author on a paper should be attributed a fraction of the paper that corresponds to his or her level of participation in the experiment compared to the other authors. Unfortunately, no reliable means exists for calculating the relative effort of authors on a paper, and thus each author is granted the same fraction of the paper.

For this study, fractions were calculated at the level of researchers. In the example presented for full counting (2 authors from the University of Oslo, 1 from UCL and 1 from the University of Liverpool), half of the paper can be attributed to Norway and one-quarter each to the UK and the US when the fractions are calculated at the level of researchers. Using the same approach for institutions, half of the paper would be counted for the University of Oslo and one-quarter would be attributed each to UCL and the University of Washington.

9.4.2 International co-publications and co-publications with Norway

A co-publication is defined as a publication that was co-authored by at least two authors. When a publication involves only authors from one country, it is defined as a national collaboration. When at least two different countries are identified among the addresses of authors on the publication, it is defined as an international collaboration. A publication can involve national and international partnerships simultaneously if more than at least two countries are involved with at least one of the countries being represented by more than one author on the publication.

International co-publications with Norway (i.e., papers involving at least one Norwegian author and at least one other author from another country) were also analysed to identify patterns in Norway's co-publishing behaviour.

As was the case for the number of publications, the number of co-publications can be measured using both full and fractional counting.

Full counting

In the full counting method, a co-publication is counted once for each partner, regardless of the number of authors on the publication. For instance, if Norway published 150 papers in the Education theme, and 50 of these involved authors from outside the country, Norway's international co-publications would stand at 50, and the country would have an international collaboration rate of 33.3%.

Fractional counting

In the fractional counting method, a fraction of the publication is allocated to each author (as in Section 9.4.1 above) and this fraction is equally subdivided across all their respective partners on the publication to assign a fraction to each co-author pair. For example, if a paper is co-authored by a Norwegian, a Canadian and a South African author, the following pairs would be constructed to compute the fraction of each co-author pair from the perspective of each participating author (note that the total across all pairs should always equal one):

- NO-CA: 1/3 (one-third of the paper belongs to the Norwegian author) * 1/2 (the Norwegian author has two collaborators so its fraction of the paper is divided in two to compute its fraction of co-authorship with each partner) = 1/6
- NO-ZA: 1/3 * 1/2 = 1/6
- CA-NO: 1/3 * 1/2 = 1/6
- CA-ZA: 1/3 * 1/2 = 1/6
- ZA-CA: 1/3 * 1/2 = 1/6
- ZA-NO: 1/3 * 1/2 = 1/6

Subsequently, the number of international co-publications for a given country (e.g., Norway) is obtained by adding the fractions of each pair for which the first author is Norwegian (i.e., NO-CA and NO-ZA). In this case, all pairs involve authors from two different countries. Thus, 100% of the co-authorships are international. In fact, all of Norway's partners are from other countries and the same is true for Canada and South Africa. Thus, the fraction of the paper they own (1/3) is 100% in international collaboration (1/6 for NO-CA and 1/6 for NO-ZA gives 1/3 in international collaboration for Norway).

In the case of international co-publications with Norway, the same approach is used, but this time only the fractions of co-publications (as measured above) involving the country for which the indicator is computed and Norway are considered. For Canada, one-sixth of the paper is in collaboration with Norway (i.e., CA-NO), as is the case for South Africa (i.e., ZA-NO). In total, one-third of this paper involves international co-authorship with Norway (i.e., CA-NO + ZA-NO).

Pairs of authors from the same countries are considered when computing the fraction of a paper that is in international collaboration or in international collaboration with Norway. This partly explains why international collaboration rates based on fractional counting are much lower than those based on full counting. Indeed, teams on papers authored through international partnerships often involve a majority of authors from a dominant country and a few others from other marginal countries. As a result, the fraction of the paper that is in international collaboration is much smaller than the fraction in national collaboration, and this is not accounted for when using full counting.

The number of co-publications of a country with Norway can be computed (using full or fractional counting) by sector of the given country's partnering organisations once each partnering organisation has been assigned to a sector (i.e., Higher Education, Government, Business Enterprise, other/unknown). This categorisation was performed by Science-Metrix's analysts, aided by a powerful algorithm for the automated assignment of organisations to sectors. The definitions of sectors used for this coding are aligned with those provided in the Frascatti Manual.

9.4.3 International Collaboration Rate and Collaboration Rate with Norway

To obtain the international collaboration rate or the collaboration rate with Norway of a given country, its total number of international co-publications or its number of co-publications with

Norway is divided by its total number of publications. These rates can be obtained using either full or fractional counting. Naturally, the same counting method must be used for both the numerator and the denominator of the collaboration rate being computed. As for the number of co-publications with Norway, the collaboration rate of a given country with Norway can be computed by organisational sector based on the given country's partnering organisations (see Section 9.4.2).

9.4.4 Specialisation Index

The specialisation index (SI) is the intensity of research of a given geographic or organisational entity (e.g., a country) in a given research area (e.g., domain, field) relative to the intensity of the reference entity (e.g., the world) in the same research area. The SI can be formulated as follows:

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

where

X_S Papers from entity X in a given research area (e.g., Norway in physics)

X_T Papers from entity X in a reference set of papers (e.g., Norway 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 value above 1 means that a given entity is specialised relative to the reference entity, while an index value below 1 means the opposite. For example, if 10% of an organisation's papers are in biology, and the count for biology papers at the international level represents only 5% of all papers, this organisation is considered to be specialised in biology and would have an SI score of 2. Publication counts for computing the SI are based on fractional counting.

9.4.5 Growth Ratio (GR)

The GR is the ratio between the score of a given entity (e.g., a country or an organisation) in the second half of the period over its score in the first half of the period for a given indicator. In other words, the GR is a measure of the increase/decrease in the score of a given country for a given indicator in a particular field or research area. The GR is formulated as follows:

$$GR = X_b / X_a$$

where

X_a Papers from entity X in a given research area published between 2003 and 2007 (for an organisation, the ratio is the score in 2012 over the score in 2010)

X_b Papers from entity X in a given research area published between 2008 and 2012 (for an organisation, the ratio is the score in 2012 over the score in 2010)

A GR value above 1 means that a given entity experienced an increase during the second half of the study period compared to the first half; an index value below 1 means the opposite. The GR can be expressed as a percentage change between the two periods by subtracting one from it and multiplying by 100. The GR of a given entity can be divided by the GR calculated for the world to obtain a Growth Index (GI). This enables an assessment of whether the change experienced by the entity allowed it to keep pace at the world level.

9.4.6 Average of relative citations (ARC)

The ARC is an indicator of the scientific impact of papers produced by a given entity (e.g., the world, a country, an institution) relative to the world average (i.e., the expected number of citations). Because it is based on the citations received by the actual publications of an entity, it is said to be a *direct* measure of scientific impact. The number of citations received by each publication is counted for the year in which it was published and for all the subsequent years.

To account for different citation patterns across fields and subfields of science (e.g., there are more citations in biomedical research than in mathematics), each publication's citation count is divided by the average citation count of all publications that were published the same year in the same subfield to obtain a Relative Citation count (RC). The ARC of a given entity is the average of the RCs of the papers belonging to it. An ARC value above 1 means that a given entity is cited more frequently than the world average, while a value below 1 means the opposite. The ARC was not computed for the publications in 2012 since Science-Metrix does not compute this indicator without a citation window of at least three years (i.e., publication year + two years). Note that the ARC can be computed for all publications as well as for co-publications.

9.4.7 Average of relative impact factors (ARIF)

The ARIF is a measure of the scientific impact of papers produced by a given entity (e.g., the world, a country) based on the impact factors of the journals in which they were published. As such, the ARIF is an *indirect* impact metric reflecting the scientific "quality" measured by the average citation rate of the publication venue instead of the actual publications.

Thomson Reuters calculates an annual impact factor (IF) for each journal based on the number of citations it received in the previous two years relative to the number of papers it published in the previous two years. Thus, each journal's IF will vary from year to year. The IF of a journal in 2007 is equal to the number of citations to articles published in 2006 (8) and 2005 (15) divided by the number of articles published in 2006 (15) and 2005 (23) (i.e., IF = numerator [23]/denominator [38] = 0.605). However, as Archambault pointed out (2009), this indicator carries the weight of history and of many choices that were made a long time ago, when their effect had not yet been thoroughly studied.[32] For example, Moed and colleagues have described the effect of the observed asymmetry between the numerator and denominator of the Thomson Reuters' IF:[33]

> ISI classifies documents into types. In calculating the nominator of the IF, ISI counts citations to all types of documents, while as citable documents in the denominator ISI includes as a standard only normal articles, notes and reviews. However, editorials, letters and several other types are cited rather frequently in a number of journals. When they are cited, these types do contribute to the citation counts in the IF's numerator, but are not included in the denominator. In a sense, the citations to these documents are 'for free'.

In this study, Science-Metrix therefore computes and uses a symmetric IF based on the document types that are used throughout this entire project for producing bibliometric data.

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[32] Archambault É. and Larivière V. 2009. History of the journal impact factor: contingencies and consequences. *Scientometrics*. 79(3).

[33] Moed, H.F., Van Leeuwen, T.H.N., Reedijk, J. (1999). Towards appropriate indicators of journal impact. *Scientometrics*, 46: 575-589.

The IF of publications is calculated by ascribing to them the IF of the journal in which they are published for the year in which they are published using a 5-year citation window (publication year and four previous years). Subsequently, to account for different citation patterns across fields and subfields of science (e.g., there are more citations in biomedical research than mathematics), each paper's IF is divided by the average IF of all papers that were published the same year in the same subfield to obtain a Relative Impact Factor (RIF). The ARIF of a given entity is the average of its RIFs (i.e., if an institution has 20 papers, the ARIF is the average of 20 RIFs: one per paper). When the ARIF is above 1, it means that the entity scores higher than the world average; when it is below 1, it means that, on average, the entity publishes in journals that are not cited as often as the world level. Although this indicator was not presented in this report, it is available in the report's companion database. Note that the ARIF can be computed for all publications and for co-publications.

9.4.8 Transdisciplinarity

The approach suggested here consists of measuring the diversity of disciplines (i.e., transdisciplinarity) involved in a single paper relative to a reference set of papers, while taking into account the distances (or similarities) between scientific disciplines (e.g., two disciplines that are tightly connected will contribute less to a paper's diversity than two disciplines that are somewhat disconnected). The rationale behind this approach is based on the assumption that highly transdisciplinary research is more likely to generate innovative results.

This indicator actually measures the variety of disciplines (i.e., scientific subfields based on Science-Metrix's Ontology) cited in a given paper. Subsequently, the transdisciplinarity of an entity (i.e., a researcher, a research group, an institution) is obtained by averaging the scores of its papers. This indicator is based on academic work carried out by a number of scholars (including Rafols and Meyer[34] and Stirling[35]). Taking this work as a base, Science-Metrix measured the entropy of each paper within Scopus by comparing the frequency distribution of subfields within its references to a proximity matrix between scientific subfields. This matrix provides the pairwise similarity of subfields based on their co-occurrence patterns within the references of individual scientific papers in Scopus as a whole, which is to say, the statistical likelihood of two papers from different subfields being cited together by a third paper. Using this proximity matrix in computing the transdisciplinarity indicator gives more weight to unusual co-citation patterns relative to those that are very common (e.g., a co-citation between clinical medicine and biomedical research contributes less to transdisciplinarity than a co-citation between clinical medicine and visual and performing arts).

Note that this is not a measure of interdisciplinarity in that it does not indicate whether researchers from various disciplines concerted their efforts in co-authoring their papers. This would require an analysis of co-authors' departmental affiliations. Nevertheless, it is assumed that interdisciplinary work should lead to transdisciplinary publications.

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[34] Rafols, I. and Meyer, M. 2010. Diversity and network coherence as indicators of interdisciplinarity: case studies in bionanoscience. *Scientometrics*, 82: 263-287.

[35] Stirling, Andy. 2007. A general framework for analysing diversity in science, technology and society. *Journal of the Royal Society Interface*, 4: 707-719.

9.4.9 Collaboration index (CI) and Affinity Index (AI)

Analyses of scientific collaboration are best performed using the CI because of the presence of power law relationships in collaboration. These non-linear relationships can be observed, for example, between an entity's (e.g., a country's) number of papers and its number of co-publications (or collaborations).[36] When both indicators (collaborations and number of publications) are log transformed, power law relationships can be analysed using linear regression models. Therefore, the approach used to compute the CI consists of performing a log-log linear regression analysis between the number of co-authored publications and the number of publications at a specific aggregation level (e.g., countries) in order to estimate the constants (a and k) of the power law relationship:

$$\mathrm{Expp(M)} = \mathrm{aM^k}$$

where

Expp = the expected number of co-authored papers of an entity (e.g., a country) based on the regression model

M = the observed number of publications of the entity (e.g., country) being measured.

For this project, the number of international co-publications was used to study international collaboration patterns. The log-log linear regression analysis is performed using a reduced major axis (RMA) model to estimate the parameters (a and k) of the regression. Using these parameters, it is then possible to compute the expected number of international co-publications of a country given the size of its scientific output. In turn, the indicator is simply the ratio of observed-to-expected international co-publications. When the indicator is above 1, an entity produces more publications in international collaboration than expected based on the size of its scientific production, while an index value below 1 means the opposite. A regression with as many data points as there are countries in the database is performed for each year and each field/theme to compute this indicator on an annual basis as well as by field/theme.

This indicator was also computed asymmetrically to compute affinity indexes (AI), which identify the countries with which Norway has the strongest positive affinities and the strongest negative affinities for collaboration, as well the selected countries' affinities for Norway.

The collaboration index and the affinity index were both computed using full counts of publications and international co-publications. Only countries publishing at least 30 papers in a given area and period, and having at least one international co-publication were used in the regression analysis. Additionally, only those regressions with a coefficient of determination (R2) above 0.8 were retained in computing these indicators.

9.4.10 PageRank

The PageRank is based on an iterative algorithm that measures the importance of each node within the network. The metric assigns each node a probability of reaching another node after many steps. The PageRank values are the values in the eigenvector that has the highest corresponding eigenvalue of a normalized adjacency matrix A. The standard adjacency matrix is

[36] Katz, J. S. (2000). "Scale-independent indicators and research assessment." *Science and Public Policy*, 27: 23–36.

normalized so that the columns of the matrix sum to 1. The higher the score, the more important an entity in the network.

9.4.11 Betweenness Centrality

This indicator measures how often a node appears on shortest paths between nodes in a network.

9.4.12 Share of output available in Open Access (OA)

For this task, Science-Metrix flagged a sample of 320,000 documents in Scopus as either available or not available in open access (OA), enabling the estimation of the proportion of OA publications. Science-Metrix took care to generate a sample whose distribution across scientific fields was representative of the frequency distribution of fields in Scopus. This allowed for the production of reliable estimates of the proportion of scientific literature available in OA at the field and theme level. As with any estimate, a margin of error is associated with this measure. This data was also used to compute the fraction of a country's output that is available in OA by field and theme. Note that countries with smaller outputs in smaller fields of science tend to have a larger margin of error since their occurrence within the sample was relatively small. Scores for which the margin of error was greater than 20 percentage points are not presented as they would provide unreliable results.

It should be noted that this approach includes gold — i.e., journals published in open access — as well as hybrid — i.e., papers published in conventional journals but that are then made available (or "self-archived") in open access form on the author's website, a central repository (such as PubMed Central) or other accessible locations. To capture papers in hybrid OA, thorough web searches were conducted using a powerful algorithm developed by Science-Metrix for the European Commission project.

9.5 Regional analysis

As presented in Section 6, Science-Metrix computed various bibliometric indicators at the regional level. The following top two regions in terms of total publications per country were included in the analysis: Sao Paulo and Rio de Janeiro (Brazil), Beijing and Shanghai (China), NUTS FR10 and FR71 (France), NUTS DE21 and DE30 (Germany), Tamil Nadu and Maharashtra (India), NUTS ITC4 and ITE4 (Italy), Kanto and Kansai (Japan), NUTS UKI1 and UKH1 (UK), and California and New York (United States).

The main task associated with this section was to match author addresses on scientific papers to their corresponding regions. For the NUTS regions, Science-Metrix developed a correspondence table that built on previous work in which the administrative and statistical units of countries had already been matched. Using these preliminary relations, Science-Metrix developed a categorisation system that relied on linking the names of cities (and/or postal codes) as they appear in the address field of publications indexed in Scopus to each country's NUTS2 regions.

In a second step, an automated large-scale validation procedure for the attribution of ERA papers to individual NUTS2 regions was implemented. The approach used consisted of the automated geocoding of cities found in the author-address field of papers in Scopus to a geographical shape file delineating the NUTS2 regions (source: Eurostat). This procedure required access to a database providing the geographical coordinates of European cities. The city names, as they appeared in Scopus, were matched to city names in the database of geographical coordinates for European cities prior to being mapped to the shape file delineating the NUTS2 regions. For example, if the coordinates of Paris lie within the boundary of the FR10 region as determined by the NUTS2 shape file, than the papers associated to Paris were attributed to the FR10 region.

Although this approach would not have worked well for the core of the work related to the attribution of papers to the NUTS2 regions due to the particularities of the database providing the geographical coordinates of European cities, it did provide a sufficient amount of assignments for comparison with those made using the correspondence tables between city names (and/or postal codes) and NUTS2 regions. Differences between both assignments were investigated and false assignments corrected. The final quality assessment for the attribution of papers to NUTS2 regions is as follows:

- **Recall:** 91% of ERA addresses in Scopus for the 2000-2010 period were assigned to a NUTS2 region.
- **Precision:** there is less than 1% false assignments.

A similar approach was used for the remaining five countries (i.e., the US, China, Japan, India and Brazil). A correspondence table linking administrative units to relevant statistical units was built for each country. Author addresses were then matched to statistical units (regions) based on the city names (and/or postal codes) as they appear in Scopus. The quality of the attribution for the five countries cited above is as follows:

- **Recall:** At least 89% of addresses in Scopus were assigned to a region.
- **Precision:** There is less than 1% false assignments.

9.6 Cluster analysis

The total number of papers and the number of co-publications with Norway, as well as the bibliometric indicators ARC, ARIF, GR and SI, were computed for 20 selected clusters. As explained in Section 7, the clusters were identified by geographic location. The cities included in every cluster are shown below in Table XXVII.

Table XXVII Cities attributed to each cluster

Cluster	City	Country
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Winnipeg	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Sherbrooke	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Toronto	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	London	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Ottawa	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Essex	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Guelph	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Quebec	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Montreal	Canada
Agriculture and Agri-Food Central Canada research cluster (AAFC)	Hyacinthe	Canada
Bergen Marine Forskningsklynge	Bergen	Norway
Bergen Marine Forskningsklynge	Breivika	Norway
Bergen Marine Forskningsklynge	Troms	Norway
Bergen Marine Forskningsklynge	Tromso	Norway
Bergen Marine Forskningsklynge	As	Norway

Bergen Marine Forskningsklynge	Stavanger	Norway
Bergen Marine Forskningsklynge	Sunndalsora	Norway
Future Ocean, Kiel Marine Science	Kiel	Germany
Edmonton nanotechnology cluster	Edmonton	Canada
Edmonton nanotechnology cluster	Calgary	Canada
Edmonton nanotechnology cluster	Lethbridge	Canada
Virginia Biotechnology Research Park	Richmond	United States
Edinburgh Science triangle	Livingston	United Kingdom
Edinburgh Science triangle	Edinburgh	United Kingdom
Edinburgh Science triangle	Roslin	United Kingdom
Edinburgh Science triangle	Penicuik	United Kingdom
Edinburgh Science triangle	Midlothian	United Kingdom
Edinburgh Science triangle	Musselburgh	United Kingdom
Eindhoven-Leuven-Aachen triangle (ELAt)	Eindhoven	Netherlands
Eindhoven-Leuven-Aachen triangle (ELAt)	Leuven	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Aachen	Germany
Eindhoven-Leuven-Aachen triangle (ELAt)	Valkenswaard	Netherlands
Eindhoven-Leuven-Aachen triangle (ELAt)	Lommel	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Leopoldsburg	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Beringen	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Maaseik	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Hasselt	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Maastricht	Netherlands
Eindhoven-Leuven-Aachen triangle (ELAt)	Gent	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Liege	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Eupen	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Monchengladbach	Germany
Eindhoven-Leuven-Aachen triangle (ELAt)	Venlo	Netherlands
Eindhoven-Leuven-Aachen triangle (ELAt)	Den Bosch	Netherlands
Eindhoven-Leuven-Aachen triangle (ELAt)	Diepenbeek	Belgium
Eindhoven-Leuven-Aachen triangle (ELAt)	Tilburg	Netherlands
Eindhoven-Leuven-Aachen triangle (ELAt)	Julich	Germany
Golden Triangle	Cambridge	United Kingdom
Golden Triangle	London	United Kingdom
Golden Triangle	Oxford	United Kingdom
Medicon Valley	Hoganas	Sweden
Medicon Valley	Angelholm	Sweden
Medicon Valley	Helsingborg	Sweden
Medicon Valley	Landskrona	Sweden
Medicon Valley	Eslov	Sweden
Medicon Valley	Hassleholm	Sweden
Medicon Valley	Kristianstad	Sweden
Medicon Valley	Horby	Sweden
Medicon Valley	Ystad	Sweden
Medicon Valley	Sjobo	Sweden
Medicon Valley	Trelleborg	Sweden
Medicon Valley	Lund	Sweden
Medicon Valley	Malmo	Sweden

Medicon Valley	Lomma	Sweden
Medicon Valley	Helsingor	Denmark
Medicon Valley	Hillerod	Denmark
Medicon Valley	Roskilde	Denmark
Medicon Valley	Holbaek	Denmark
Medicon Valley	Kalundborg	Denmark
Medicon Valley	Soro	Denmark
Medicon Valley	Koge	Denmark
Medicon Valley	Næstved	Denmark
Medicon Valley	Copenhagen	Denmark
Medicon Valley	Lyngby	Denmark
Medicon Valley	Gentofte	Denmark
Medicon Valley	Horsholm	Denmark
Oulu Region	Oulu	Finland
Oulu Region	Oulunsalo	Finland
Oulu Region	Espoo	Finland
Oulu Region	Haukipudas	Finland
Oulu Region	Kempele	Finland
Oulu Region	Kiiminki	Finland
Oulu Region	Lumijoki	Finland
Oulu Region	Muhos	Finland
Oulu Region	Tyrnava	Finland
Oulu Region	Ylikiiminki	Finland
Research Triangle	Raleigh	United States
Research Triangle	Durham	United States
Research Triangle	Chapel Hill	United States
Research Triangle	Cary	United States
Research Triangle	Apex	United States
Research Triangle	Carrboro	United States
Research Triangle	Clayton	United States
Research Triangle	Fuquay-Varina	United States
Research Triangle	Garner	United States
Research Triangle	Holly Springs	United States
Research Triangle	Mebane	United States
Research Triangle	Morrisville	United States
Research Triangle	Sanford	United States
Research Triangle	Smithfield	United States
Research Triangle	Wake Forest	United States
CalValleyTech iHub	Merced	United States
CalValleyTech iHub	Fresno	United States
CalValleyTech iHub	Visalla	United States
East Bay Green Corridor iHub	Oakland	United States
East Bay Green Corridor iHub	Alameda	United States
East Bay Green Corridor iHub	San Leandro	United States
East Bay Green Corridor iHub	El Cerrito	United States
East Bay Green Corridor iHub	Albany	United States
East Bay Green Corridor iHub	Berkeley	United States
East Bay Green Corridor iHub	Hayward	United States

Massachusetts' Route 128 Corridor	Boston	United States
Massachusetts' Route 128 Corridor	Gloucester	United States
Massachusetts' Route 128 Corridor	Lynn	United States
Massachusetts' Route 128 Corridor	Cambridge	United States
Massachusetts' Route 128 Corridor	Revere	United States
Massachusetts' Route 128 Corridor	Newton	United States
Massachusetts' Route 128 Corridor	Quincy	United States
Massachusetts' Route 128 Corridor	Waltham	United States
Bothnian Arc	Kemi	Finland
Bothnian Arc	Oulu	Finland
Bothnian Arc	Raahe	Finland
Bothnian Arc	Ylivieska	Finland
Bothnian Arc	Tornio	Finland
Bothnian Arc	Kalajeki	Finland
Bothnian Arc	Haparanda	Sweden
Bothnian Arc	Kalix	Sweden
Bothnian Arc	Boden	Sweden
Bothnian Arc	Lulea	Sweden
Bothnian Arc	Alvsbyn	Sweden
Bothnian Arc	Pitea	Sweden
Bothnian Arc	Skelleftea	Sweden
Hedmark-Dalarna	Hamar	Norway
Hedmark-Dalarna	Elverum	Norway
Hedmark-Dalarna	Kongsvinger	Norway
Hedmark-Dalarna	Mora	Sweden
Hedmark-Dalarna	Fallun	Sweden
Hedmark-Dalarna	Borlange	Sweden
Hedmark-Dalarna	Avesta	Sweden
Hedmark-Dalarna	Ludvika	Sweden
Helsinki-Tallin	Tallin	Estonia
Helsinki-Tallin	keila	Estonia
Helsinki-Tallin	Helsinki	Finland
Helsinki-Tallin	Espoo	Finland
Helsinki-Tallin	Vantaa	Finland
Helsinki-Tallin	Hyvinkaa	Finland
Helsinki-Tallin	Tuusula	Finland
Oresund Region	Malmo	Sweden
Oresund Region	Lund	Sweden
Oresund Region	Helsingborg	Sweden
Oresund Region	Ronne	Sweden
Oresund Region	Copenhagen	Denmark
Oresund Region	Roskilde	Denmark
Oresund Region	Slagelse	Denmark
Oresund Region	Hillerod	Denmark
Oresund Region	Koge	Denmark
Oresund Region	Naestved	Denmark
Oresund Region	Kalundborg	Denmark
DSP Valley	Antwerp	Belgium

DSP Valley	Brussels	Belgium
DSP Valley	Genk	Belgium
DSP Valley	Liege	Belgium
DSP Valley	Leuven	Belgium
DSP Valley	Ghent	Belgium
Oslo Cancer Cluster	Oslo	Norway

9.7 Limitations

Several limitations should be noted in the context of the social sciences and humanities (SSH). First, compared to the natural sciences and engineering (NSE) and the health sciences (HS), the SSH produce a greater proportion of scientific publications in the form of books rather than journal articles. This trend is even more pronounced in the humanities, such that research in these areas would best be examined using instruments that, compared to traditional bibliometrics, also consider publications in, or as, books. When counting publications using citation databases (e.g., Scopus) as in this study, a greater portion of the scientific output is omitted in the SSH compared to the NSE and HS. In fact, journals of local interest, books and various publications that are generally referred to as "grey literature" (such as in-house research reports), as well as most conference and symposium proceedings, are not indexed in these databases. *As a result, the size of the scientific output of an entity in the SSH should not be compared to the size of its production in other areas.*

Another aspect to be considered when performing bibliometric analyses of the SSH is the more local orientation of SSH research. Whereas the research questions identified in the NSE tend to be universal, SSH research subjects are often more local in orientation/focus and, as a result, the target readership is often more limited to a country or region. Accordingly, SSH scholars publish somewhat more frequently in a language other than in English — and in journals with a national rather than an international distribution — than do NSE researchers. Because the major citation databases (e.g., Web of Science, Scopus) that are suitable to perform analyses of scientific impact are somewhat biased in favour of scientific literature authored in English, the uninformed or careless use of bibliometrics to benchmark SSH research can lead to erroneous conclusions.

The application of traditional bibliometrics to the SSH is problematic in the context of lateral comparisons (e.g., Poland vs. Spain) when the groups being compared differ in their mother tongue and/or geographical location. Thus, lateral comparisons performed with the data contained in this database in the SSH should be interpreted with caution. The authors refer readers to the following publication for a thorough and comprehensive discussion of the limitations of bibliometrics in the context of the SSH:

1. Archambault, É. and Larivière V. (2010). The limits of bibliometrics for the analysis of the social sciences and humanities literature. In *World Social Science Report: Knowledge Divides*, Chapter 7. Competing in the knowledge society (7.2 Assessment and evaluation of research), Co-publication commissioned by UNESCO from the International Social Science Council (ISSC), ISBN: 978-92-3-104131-0, pp. 251-254.
2. Archambault, É., Vignola-Gagné, É., Côté, G., Larivière, V., and Gingras, Y. (2006). Benchmarking scientific output in the social sciences and humanities: The limits of existing databases. *Scientometrics*, 68(3): 329-342.

Appendix 1 Organisation Legend

Table XXVIII Legend of the collaboration networks for the selected organisations (2010–2012)

Label	Country	University
AR-1	Argentina	CNEA - National Atomic Energy Commission
AR-2	Argentina	CONICET
AR-3	Argentina	National University of Córdoba
AR-4	Argentina	National University of La Plata
AR-5	Argentina	University of Buenos Aires
AT-1	Austria	Austrian Academy of Sciences
AT-2	Austria	Innsbruck Medical University
AT-3	Austria	Johannes Kepler University of Linz
AT-4	Austria	Medical University of Graz
AT-5	Austria	Medical University of Vienna
AT-6	Austria	TU Graz - Graz University of Technology
AT-7	Austria	TU Wien - Vienna University of Technology
AT-8	Austria	University of Graz
AT-9	Austria	University of Innsbruck
AT-10	Austria	University of Vienna
AU-1	Australia	ARC - Australian Research Council
AU-2	Australia	Australian National University
AU-3	Australia	CSIRO - Commonwealth Science and Industrial Research Organization
AU-4	Australia	Curtin University
AU-5	Australia	Deakin University
AU-6	Australia	Griffith University
AU-7	Australia	Macquarie University
AU-8	Australia	Monash University (all campuses)
AU-9	Australia	Queensland University of Technology
AU-10	Australia	RMIT University
AU-11	Australia	University of Adelaide
AU-12	Australia	University of Melbourne
AU-13	Australia	University of New South Wales
AU-14	Australia	University of Newcastle (Australia)
AU-15	Australia	University of Queensland
AU-16	Australia	University of South Australia
AU-17	Australia	University of Sydney
AU-18	Australia	University of Technology Sydney
AU-19	Australia	University of Western Australia
AU-20	Australia	University of Wollongong
BE-1	Belgium	Catholic University of Louvain
BE-2	Belgium	Free University of Brussels (Dutch-speaking VLB)
BE-3	Belgium	Free University of Brussels (French-speaking ULB)
BE-4	Belgium	Ghent University
BE-5	Belgium	Interuniversity Microelectronics Centre (IMEC)
BE-6	Belgium	KU Leuven
BE-7	Belgium	University of Antwerp
BE-8	Belgium	University of Liège
BE-9	Belgium	UZ Gent
BE-10	Belgium	UZ Leuven
BG-1	Bulgaria	Bulgarian Academy of Sciences
BG-2	Bulgaria	Medical University of Sofia
BG-3	Bulgaria	Sofia University
BG-4	Bulgaria	Technical University of Sofia
BG-5	Bulgaria	University of Chemical Technologies and Metallurgy-Sofia
BR-1	Brazil	Federal University of Minas Gerais
BR-2	Brazil	Federal University of Parana
BR-3	Brazil	Federal University of Rio de Janeiro
BR-4	Brazil	Federal University of Santa Catarina

Label	Country	University
BR-5	Brazil	FIOCRUZ - Oswaldo Cruz Foundation
BR-6	Brazil	UFRGS - Federal University of Rio Grande do Sul
BR-7	Brazil	UNESP - Universidade Estadual Paulista
BR-8	Brazil	UNIFESP - Federal University of São Paulo
BR-9	Brazil	University of Campinas
BR-10	Brazil	USP - University of São Paulo
CA-1	Canada	Dalhousie University
CA-2	Canada	Laval University
CA-3	Canada	McGill University
CA-4	Canada	McMaster University
CA-5	Canada	NRC Canada - National Research Council
CA-6	Canada	Queen's University
CA-7	Canada	Simon Fraser University
CA-8	Canada	UHN - University Health Network
CA-9	Canada	University of Alberta
CA-10	Canada	University of British Columbia
CA-11	Canada	University of Calgary
CA-12	Canada	University of Guelph
CA-13	Canada	University of Manitoba
CA-14	Canada	University of Montreal
CA-15	Canada	University of Ottawa
CA-16	Canada	University of Saskatchewan
CA-17	Canada	University of Toronto
CA-18	Canada	University of Victoria
CA-19	Canada	University of Waterloo
CA-20	Canada	University of Western Ontario
CH-1	Switzerland	ETHZ - Swiss Federal Institute of Technology in Zurich
CH-2	Switzerland	Swiss Federal Institute of Technology in Lausanne
CH-3	Switzerland	University Hospital of Geneva
CH-4	Switzerland	University Hospital of Lausanne
CH-5	Switzerland	University Hospital of Zürich
CH-6	Switzerland	University of Basel
CH-7	Switzerland	University of Bern
CH-8	Switzerland	University of Geneva
CH-9	Switzerland	University of Lausanne
CH-10	Switzerland	University of Zurich
CL-1	Chile	Federico Santa María Technical University
CL-2	Chile	Pontifical Catholic University of Chile
CL-3	Chile	University of Chile
CL-4	Chile	University of Concepción
CL-5	Chile	University of Santiago, Chile
CN-1	China	Beihang University
CN-2	China	Beijing Institute of Technology
CN-3	China	Beijing Jiaotong University
CN-4	China	Beijing Normal University
CN-5	China	Beijing University of Posts and Telecommunications
CN-6	China	Beijing University of Technology
CN-7	China	Central South University
CN-8	China	Chinese Academy of Sciences
CN-9	China	Chinese University of Hong Kong
CN-10	China	Chongqing University
CN-11	China	City University of Hong Kong
CN-12	China	CUMTB - China University of Mining and Technology
CN-13	China	Dalian University of Technology
CN-14	China	East China University of Science and Technology
CN-15	China	Fudan University
CN-16	China	Harbin Engineering University
CN-17	China	Harbin Institute of Technology
CN-18	China	Hong Kong Polytechnic University

Label	Country	University
CN-19	China	Hunan University
CN-20	China	HUST - Huazhong University of Science and Technology
CN-21	China	Jilin University
CN-22	China	Ministry of Education of the People's Republic of China
CN-23	China	Nanjing Aeronautics and Astronautics University
CN-24	China	Nanjing University
CN-25	China	Nankai University
CN-26	China	National University of Defense Technology
CN-27	China	North China Electric Power University
CN-28	China	Northeastern University (China)
CN-29	China	Northwestern Polytechnical University (China)
CN-30	China	Peking University
CN-31	China	SCUT - South China University of Technology
CN-32	China	Shandong University
CN-33	China	Shanghai Jiao Tong University
CN-34	China	Shanghai University
CN-35	China	Sichuan University
CN-36	China	Southeast University
CN-37	China	Sun Yat-sen University
CN-38	China	Tianjin University
CN-39	China	Tongji University
CN-40	China	Tsinghua University
CN-41	China	UESTC - University of Electronic Science and Technology of China
CN-42	China	University of Hong Kong
CN-43	China	USTB - University of Science and Technology Beijing
CN-44	China	USTC - University of Science and Technology of China
CN-45	China	Wuhan University
CN-46	China	Wuhan University of Technology
CN-47	China	Xi'an Jiaotong University
CN-48	China	Xiamen University
CN-49	China	Xidian University
CN-50	China	Zhejiang University
CO-1	Colombia	Los Andes University
CO-2	Colombia	National University of Colombia
CO-3	Colombia	Pontifical Xavierian University
CO-4	Colombia	University of Antioquia
CO-5	Colombia	University of Valle
CY-1	Cyprus	Cyprus University of Technology
CY-2	Cyprus	Frederick University
CY-3	Cyprus	Near East University
CY-4	Cyprus	University of Cyprus
CY-5	Cyprus	University of Nicosia
CZ-1	Czech Republic	Academy of Sciences of the Czech Republic
CZ-2	Czech Republic	Brno University of Technology
CZ-3	Czech Republic	Charles University in Prague
CZ-4	Czech Republic	Czech Technical University in Prague
CZ-5	Czech Republic	Masaryk University
DE-1	Germany	Albert Ludwig University of Freiburg
DE-2	Germany	Charité – University Medicine Berlin
DE-3	Germany	Eberhard Karls University, Tübingen
DE-4	Germany	Fraunhofer Society for the advancement of applied research
DE-5	Germany	Goethe University Frankfurt
DE-6	Germany	Heidelberg University, Ruperto Carola
DE-7	Germany	Helmholtz Association
DE-8	Germany	Leibniz Association
DE-9	Germany	Ludwig Maximilian University of Munich
DE-10	Germany	Max Planck Society
DE-11	Germany	Ruhr University Bochum
DE-12	Germany	RWTH Aachen University

Label	Country	University
DE-13	Germany	TU Berlin
DE-14	Germany	TU Dresden
DE-15	Germany	TUM - Technical University of Munich
DE-16	Germany	University of Bonn
DE-17	Germany	University of Erlangen-Nuremberg
DE-18	Germany	University of Göttingen
DE-19	Germany	University of Münster
DE-20	Germany	University of Würzburg
DK-1	Denmark	Aalborg University
DK-2	Denmark	Aarhus University Hospital
DK-3	Denmark	Copenhagen Business School (CBS)
DK-4	Denmark	Copenhagen University Hospital
DK-5	Denmark	DTU - Technical University of Denmark
DK-6	Denmark	Odense University Hospital
DK-7	Denmark	State Serum Institute
DK-8	Denmark	University of Aarhus
DK-9	Denmark	University of Copenhagen
DK-10	Denmark	University of Southern Denmark
EE-1	Estonia	Estonian University of Life Sciences
EE-2	Estonia	National Institute of Chemical Physics and BioPhysics
EE-3	Estonia	Tallinn University
EE-4	Estonia	Tallinn University of Technology
EE-5	Estonia	University of Tartu
EG-1	Egypt	Ain Shams University
EG-2	Egypt	Alexandria University
EG-3	Egypt	Cairo University
EG-4	Egypt	Mansoura University
EG-5	Egypt	National Research Centre (NRC) – Egypt
EL-1	Greece	Aristotle University of Thessaloniki
EL-2	Greece	NTUA - National Technical University of Athens
EL-3	Greece	University of Athens
EL-4	Greece	University of Ioannina
EL-5	Greece	University of Patras
ES-1	Spain	Autonomous University of Madrid
ES-2	Spain	Catalan Institution for Research and Advanced Studies (ICREA)
ES-3	Spain	Complutense University of Madrid
ES-4	Spain	CSIC - Spanish National Research Council
ES-5	Spain	Institute of Health Carlos III
ES-6	Spain	Polytechnic University of Valencia
ES-7	Spain	Technical University of Madrid
ES-8	Spain	UAB - Autonomous University of Barcelona
ES-9	Spain	University Hospital Clínic de Barcelona
ES-10	Spain	University of Barcelona
ES-11	Spain	University of Granada
ES-12	Spain	University of Murcia
ES-13	Spain	University of Oviedo
ES-14	Spain	University of Santiago de Compostela
ES-15	Spain	University of Seville
ES-16	Spain	University of the Basque Country
ES-17	Spain	University of Valencia
ES-18	Spain	University of Vigo
ES-19	Spain	University of Zaragoza
ES-20	Spain	UPC - Polytechnic University of Catalonia
FI-1	Finland	Aalto University
FI-2	Finland	University of Eastern Finland
FI-3	Finland	University of Helsinki
FI-4	Finland	University of Oulu
FI-5	Finland	University of Turku
FR-1	France	Aix-Marseille University

Label	Country	University
FR-2	France	Assistance publique - Hôpitaux de Paris (AP-HP)
FR-3	France	CEA - Atomic Energy and Alternative Energies Commission
FR-4	France	Claude Bernard University Lyon 1
FR-5	France	CNRS - French National Center for Scientific Research
FR-6	France	INRA - French National Institute for Agricultural Research
FR-7	France	INRIA
FR-8	France	INSERM
FR-9	France	Institute of research for development – IRD
FR-10	France	Joseph Fourier University
FR-11	France	Montpellier 2 University
FR-12	France	Paris Descartes University
FR-13	France	Paris Diderot University - Paris 7
FR-14	France	Paul Sabatier University
FR-15	France	University of Bordeaux 1
FR-16	France	University of Lorraine
FR-17	France	University of Paris-Sud - Paris 11
FR-18	France	University of Rennes 1
FR-19	France	University of Strasbourg
FR-20	France	UPMC - Pierre-and-Marie-Curie University
HU-1	Hungary	BME - Budapest University of Technology and Economics
HU-2	Hungary	Eötvös Loránd University
HU-3	Hungary	Hungarian Academy of Sciences
HU-4	Hungary	Semmelweis University
HU-5	Hungary	University of Szeged - Szegedi Tudományegyetem
ID-1	Indonesia	Bandung Institute of Technology
ID-2	Indonesia	Bogor Agricultural University
ID-3	Indonesia	Centre for International Forestry Research – CIFOR
ID-4	Indonesia	Gadjah Mada University
ID-5	Indonesia	University of Indonesia
IE-1	Ireland	Dublin City University
IE-2	Ireland	National University of Ireland, Galway
IE-3	Ireland	Trinity College Dublin
IE-4	Ireland	University College Cork
IE-5	Ireland	University College Dublin
IL-1	Israel	Ben-Gurion University of the Negev
IL-2	Israel	Hebrew University of Jerusalem
IL-3	Israel	Technion – Israel Institute of Technology
IL-4	Israel	Tel Aviv University
IL-5	Israel	Weizmann Institute of Science
IN-1	India	Aligarh Muslim University
IN-2	India	All India Institute of Medical Sciences (AIIMS)
IN-3	India	Anna University
IN-4	India	Annamalai University
IN-5	India	Banaras Hindu University
IN-6	India	Bhabha Atomic Research Centre
IN-7	India	Council of Scientific and Industrial Research (CSIR)
IN-8	India	Indian Institute of Science - IISC Bangalore
IN-9	India	Indian Institute of Technology - IIT Bombay
IN-10	India	Indian Institute of Technology - IIT Delhi
IN-11	India	Indian Institute of Technology - IIT Guwahati
IN-12	India	Indian Institute of Technology - IIT Kanpur
IN-13	India	Indian Institute of Technology - IIT Kharagpur
IN-14	India	Indian Institute of Technology - IIT Madras
IN-15	India	Indian Institute of Technology - IIT Roorkee
IN-16	India	Jadavpur University
IN-17	India	Panjab University
IN-18	India	Tata Institute of Fundamental Research
IN-19	India	University of Calcutta
IN-20	India	University of Delhi

Label	Country	University
IR-1	Iran	Amirkabir University of Technology
IR-2	Iran	Ferdowsi University of Mashhad
IR-3	Iran	Iran University of Science and Technology
IR-4	Iran	Isfahan University of Technology
IR-5	Iran	Islamic Azad University
IR-6	Iran	Sharif University of Technology
IR-7	Iran	Shiraz University
IR-8	Iran	Tarbiat Modares University
IR-9	Iran	Tehran University of Medical Sciences
IR-10	Iran	University of Tehran
IS-1	Iceland	DeCODE Genetics
IS-2	Iceland	Landspitali- National University Hospital of Iceland
IS-3	Iceland	Matís ltd. - Icelandic Food and Biotech R&D
IS-4	Iceland	Reykjavik University
IS-5	Iceland	University of Iceland
IT-1	Italy	Catholic University of the Sacred Heart
IT-2	Italy	CNR - National Research Council
IT-3	Italy	INAF - National Institute for Astrophysics
IT-4	Italy	INFN - Italian Institute for Nuclear Physics
IT-5	Italy	IRCCS - Scientific Institute for Research, Hospitalization and Health Care
IT-6	Italy	Polytechnic University of Milan
IT-7	Italy	Polytechnic University of Turin
IT-8	Italy	UNIBA - University of Bari Aldo Moro
IT-9	Italy	UNIBO - University of Bologna
IT-10	Italy	UNICT - University of Catania
IT-11	Italy	UNIFI - University of Florence
IT-12	Italy	UNIGE - University of Genoa
IT-13	Italy	UNIMI - University of Milan
IT-14	Italy	UNINA - University of Naples Federico II
IT-15	Italy	UNIPD - University of Padova
IT-16	Italy	UNIPI - University of Pisa
IT-17	Italy	UNIPV - University of Pavia
IT-18	Italy	UNIROMA1 - University of Rome La Sapienza
IT-19	Italy	UNIROMA2 - University of Rome Tor Vergata
IT-20	Italy	University of Turin
JP-1	Japan	AIST - Advanced Industrial Science and Technology
JP-2	Japan	Chiba University
JP-3	Japan	Hiroshima University
JP-4	Japan	Hokkaido University
JP-5	Japan	JST - Japan Science and Technology Agency
JP-6	Japan	Keio University
JP-7	Japan	Kobe University
JP-8	Japan	Kyoto University
JP-9	Japan	Kyushu University
JP-10	Japan	Nagoya University
JP-11	Japan	National Institute for Materials Science
JP-12	Japan	Okayama University
JP-13	Japan	Osaka University
JP-14	Japan	RIKEN
JP-15	Japan	Tohoku University
JP-16	Japan	Tokyo Institute of Technology
JP-17	Japan	Tokyo Medical and Dental University
JP-18	Japan	University of Tokyo
JP-19	Japan	University of Tsukuba
JP-20	Japan	Waseda University
KR-1	Rep. of Korea	KAIST - Korea Advanced Institute of Science and Technology
KR-2	Rep. of Korea	Korea University
KR-3	Rep. of Korea	Seoul National University
KR-4	Rep. of Korea	Sungkyunkwan University

Label	Country	University
KR-5	Rep. of Korea	Yonsei University
LT-1	Lithuania	Center for physical sciences and technology
LT-2	Lithuania	Kaunas University of Technology
LT-3	Lithuania	Lithuanian University of Health Sciences
LT-4	Lithuania	Vilnius Gediminas Technical University
LT-5	Lithuania	Vilnius University
LU-1	Luxembourg	Centre Hospitalier de Luxembourg
LU-2	Luxembourg	Public Research Center for Health (CRP-Santé)
LU-3	Luxembourg	Public Research Centre - Gabriel Lippmann
LU-4	Luxembourg	Public Research Centre Henri Tudor
LU-5	Luxembourg	University of Luxembourg
LV-1	Latvia	Daugavpils University
LV-2	Latvia	Latvia University of Agriculture
LV-3	Latvia	Riga Stradinš University
LV-4	Latvia	Riga Technical University
LV-5	Latvia	University of Latvia
MT-1	Malta	Mater Dei Hospital
MT-2	Malta	University of Malta
MX-1	Mexico	CONACYT - National Council of Science and Technology
MX-2	Mexico	Meritorious Autonomous University of Puebla
MX-3	Mexico	Metropolitan Autonomous University
MX-4	Mexico	National Autonomous University of Mexico
MX-5	Mexico	National Polytechnic Institute
MY-1	Malaysia	International Islamic University Malaysia
MY-2	Malaysia	MARA University of Technology
MY-3	Malaysia	Monash University (all campuses)
MY-4	Malaysia	Multimedia University
MY-5	Malaysia	National University of Malaysia
MY-6	Malaysia	PETRONAS University of Technology
MY-7	Malaysia	Putra University, Malaysia
MY-8	Malaysia	University of Malaya
MY-9	Malaysia	University of Science, Malaysia
MY-10	Malaysia	University of Technology, Malaysia
NG-1	Nigeria	Ahmadu Bello University
NG-2	Nigeria	Obafemi Awolowo University
NG-3	Nigeria	University of Ibadan
NG-4	Nigeria	University of Lagos
NG-5	Nigeria	University of Nigeria (UNN)
NL-1	Netherlands	Academic Medical Centre (AMC)
NL-2	Netherlands	Erasmuc MC - University Medical Center Rotterdam
NL-3	Netherlands	Radboud University Nijmegen
NL-4	Netherlands	TUDelft - Delft University of Technology
NL-5	Netherlands	University Medical Center Utrecht
NL-6	Netherlands	University of Groningen
NL-7	Netherlands	Utrecht University
NL-8	Netherlands	UvA - University of Amsterdam
NL-9	Netherlands	VU University Amsterdam
NL-10	Netherlands	WUR - Wageningen University and Research Centre
NO-1	Norway	Akvaplan-niva
NO-2	Norway	Bergen University College – HBI
NO-3	Norway	BI Norwegian Business School
NO-4	Norway	Bioforsk - Norwegian Institute for Agricultural and Environmental Research
NO-5	Norway	Buskerud University College
NO-6	Norway	Cancer Registry of Norway
NO-7	Norway	Center for International Climate and Environmental Research - Oslo (CICERO)
NO-8	Norway	Det Norske Veritas AS
NO-9	Norway	Diakonhjemmet Hospital
NO-10	Norway	EMBL - European Molecular Biology Laboratory
NO-11	Norway	Fram Centre

Label	Country	University
NO-12	Norway	Fridtjof Nansen Institute
NO-13	Norway	General Electric Co.
NO-14	Norway	Geological Survey of Norway
NO-15	Norway	Gjøvik University College
NO-16	Norway	Harstad University College
NO-17	Norway	Haukeland University Hospital
NO-18	Norway	Hedmark University College
NO-19	Norway	Innlandet Hospital Trust
NO-20	Norway	Institute for Energy Technology
NO-21	Norway	Institute of Marine Research
NO-22	Norway	Institute of Transport Economics
NO-23	Norway	International Research Institute of Stavanger IRIS
NO-24	Norway	Lillehammer University College
NO-25	Norway	Lovisenberg Deaconess Hospital
NO-26	Norway	Lovisenberg Diaconal University College
NO-27	Norway	Molde University College
NO-28	Norway	Nansen Environmental and Remote Sensing Center
NO-29	Norway	Narvik University College
NO-30	Norway	National Institute of Nutrition and Seafood Research (NIFES)
NO-31	Norway	National Institute of Occupational Health
NO-32	Norway	National Veterinary Institute (Norway)
NO-33	Norway	NHH - Norwegian School of Economics
NO-34	Norway	Nofima - Norwegian Institute of Food
NO-35	Norway	Nord-Trøndelag Hospital Trust
NO-36	Norway	Nord-Trøndelag University College
NO-37	Norway	Nordland Hospital
NO-38	Norway	Northern Research Institute Tromsø AS
NO-39	Norway	Norwegian Academy of Science and Letters
NO-40	Norway	Norwegian Centre for Violence and Traumatic Stress Studies
NO-41	Norway	Norwegian Computing Center
NO-42	Norway	Norwegian Defence Research Establishment (FFI)
NO-43	Norway	Norwegian Forest and Landscape Institute
NO-44	Norway	Norwegian Geotechnical Institute
NO-45	Norway	Norwegian Institute for Air Research
NO-46	Norway	Norwegian Institute for Alcohol and Drug Research (SIRUS)
NO-47	Norway	Norwegian Institute for Nature Research (NINA)
NO-48	Norway	Norwegian Institute for Water Research
NO-49	Norway	Norwegian Institute of Public Health
NO-50	Norway	Norwegian Knowledge Centre for the Health Services
NO-51	Norway	Norwegian Meteorological Institute
NO-52	Norway	Norwegian Polar Institute
NO-53	Norway	Norwegian Radiation Protection Authority
NO-54	Norway	Norwegian School of Sport Sciences
NO-55	Norway	Norwegian School of Veterinary Science
NO-56	Norway	Norwegian Seismic Array (NORSAR)
NO-57	Norway	Norwegian University of Life Sciences (UMB)
NO-58	Norway	Oslo and Akershus University College of Applied Sciences
NO-59	Norway	Oslo School of Management
NO-60	Norway	Oslo University Hospital
NO-61	Norway	Østfold Hospital Trust
NO-62	Norway	Østfold University College
NO-63	Norway	Peace Research Institute Oslo (PRIO)
NO-64	Norway	Polar Environmental Centre
NO-65	Norway	Simula Research Laboratory
NO-66	Norway	SINTEF
NO-67	Norway	Sogn og Fjordane University College
NO-68	Norway	Sør-Trøndelag University College
NO-69	Norway	Sorlandet Hospital
NO-70	Norway	St. Olavs University Hospital

Label	Country	University
NO-71	Norway	Statistics Norway
NO-72	Norway	STATOIL
NO-73	Norway	Stavanger University Hospital
NO-74	Norway	Stord/Haugesund University College
NO-75	Norway	Sunnaas Hospital
NO-76	Norway	Telemark Hospital
NO-77	Norway	Telemark University College
NO-78	Norway	Telenor Group
NO-79	Norway	The Norwegian University of Science and Technology (NTNU)
NO-80	Norway	The University of Bergen
NO-81	Norway	The University of Nordland
NO-82	Norway	Uni Research
NO-83	Norway	University Centre in Svalbard (UNIS)
NO-84	Norway	University Hospital of North Norway
NO-85	Norway	University of Agder
NO-86	Norway	University of Oslo
NO-87	Norway	University of Stavanger
NO-88	Norway	University of Tromsø
NO-89	Norway	Vestfold Hospital Trust
NO-90	Norway	Vestfold University College
NO-91	Norway	Vestre Viken Hospital Trust
NZ-1	New Zealand	Massey University
NZ-2	New Zealand	University of Auckland
NZ-3	New Zealand	University of Canterbury
NZ-4	New Zealand	University of Otago
NZ-5	New Zealand	Victoria University of Wellington
PK-1	Pakistan	COMSATS Institute of Information Technology
PK-2	Pakistan	Quaid-i-Azam University
PK-3	Pakistan	University of Agriculture, Faisalabad
PK-4	Pakistan	University of Karachi
PK-5	Pakistan	University of the Punjab
PL-1	Poland	Adam Mickiewicz University
PL-2	Poland	AGH University of Science and Technology
PL-3	Poland	Jagiellonian University
PL-4	Poland	Medical University of Lodz
PL-5	Poland	Nicolaus Copernicus University
PL-6	Poland	Polish Academy of Sciences
PL-7	Poland	Politechnika Warszawska
PL-8	Poland	Politechnika Wroclawska
PL-9	Poland	Silesian University of Technology
PL-10	Poland	University of Warsaw
PT-1	Portugal	New University of Lisbon
PT-2	Portugal	University of Aveiro
PT-3	Portugal	University of Coimbra
PT-4	Portugal	University of Lisbon
PT-5	Portugal	University of Porto
RO-1	Romania	Alexandru Ioan Cuza University
RO-2	Romania	Babes-Bolyai University
RO-3	Romania	Carol Davila University of Medicine and Pharmacy
RO-4	Romania	Gh. Asachi Technical University
RO-5	Romania	Horia Hulubei Institute of Physics and Nuclear Engineering (IFIN-HH)
RO-6	Romania	Iuliu Hatieganu University of Medicine and Pharmacy Cluj-Napoca
RO-7	Romania	National Institute for Laser, Plasma and Radiation Physics - INFLPR
RO-8	Romania	National Institute of Materials Physics (NIMP)
RO-9	Romania	Polytechnic University of Timisoara
RO-10	Romania	Romanian Academy
RO-11	Romania	Technical University of Cluj-Napoca
RO-12	Romania	The Academy of Economic Studies (ASE) of Bucharest
RO-13	Romania	Transilvania University of Brasov

Label	Country	University
RO-14	Romania	University of Bucharest
RO-15	Romania	University of Craiova
RO-16	Romania	University of Medicine and Pharmacy V.Babes Timisoara
RO-17	Romania	University of Medicine and Pharmacy, Gr. T. Popa (UMF)
RO-18	Romania	University of Oradea
RO-19	Romania	UPB - Polytechnic University of Bucarest
RO-20	Romania	West University of Timi?oara
RU-1	Russia	Joint Institute for Nuclear Research
RU-2	Russia	Moscow State University
RU-3	Russia	Russian Academy of Medical Sciences
RU-4	Russia	Russian Academy of Sciences
RU-5	Russia	St. Petersburg State University
SE-1	Sweden	Chalmers University of Technology
SE-2	Sweden	Karolinska Institute
SE-3	Sweden	Karolinska University Hospital
SE-4	Sweden	KTH - Royal Institute of Technology
SE-5	Sweden	Linköping University
SE-6	Sweden	Lund University
SE-7	Sweden	Stockholm University
SE-8	Sweden	Umeå University
SE-9	Sweden	University of Gothenburg
SE-10	Sweden	Uppsala University
SG-1	Singapore	A-STAR Agency for Science, Technology and Research
SG-2	Singapore	Duke University
SG-3	Singapore	MIT - Massachusetts Institute of Technology
SG-4	Singapore	Nanyang Technological University (NTU)
SG-5	Singapore	National University Health System
SG-6	Singapore	National University Hospital (NUH)
SG-7	Singapore	National University of Singapore (NUS)
SG-8	Singapore	Singapore General Hospital (SGH)
SG-9	Singapore	Singapore Management University
SG-10	Singapore	Singapore National Eye Center (SNEC)
SI-1	Slovenia	Jožef Stefan Institute
SI-2	Slovenia	Ljubljana University Medical Center
SI-3	Slovenia	National Institute of Chemistry
SI-4	Slovenia	University of Ljubljana
SI-5	Slovenia	University of Maribor
SK-1	Slovakia	Comenius University
SK-2	Slovakia	Pavol Jozef Šafárik University
SK-3	Slovakia	Slovak Academy of Sciences
SK-4	Slovakia	Slovak University of Technology
SK-5	Slovakia	Technical University of Košice
TH-1	Thailand	Chiang Mai University
TH-2	Thailand	Chulalongkorn University
TH-3	Thailand	Kasetsart University
TH-4	Thailand	Mahidol University
TH-5	Thailand	Prince of Songkla University
TR-1	Turkey	Ankara University
TR-2	Turkey	Ataturk University
TR-3	Turkey	Ege University
TR-4	Turkey	Erciyes University
TR-5	Turkey	Gazi University
TR-6	Turkey	Hacettepe University
TR-7	Turkey	Istanbul Technical University
TR-8	Turkey	Istanbul University
TR-9	Turkey	Middle East Technical University
TR-10	Turkey	Selcuk University
TW-1	Taiwan	Academia Sinica
TW-2	Taiwan	Chang Gung University

Label	Country	University
TW-3	Taiwan	China Medical University
TW-4	Taiwan	National Central University
TW-5	Taiwan	National Cheng Kung University
TW-6	Taiwan	National Chiao Tung University
TW-7	Taiwan	National Chung Hsing University
TW-8	Taiwan	National Taiwan University
TW-9	Taiwan	National Tsing Hua University
TW-10	Taiwan	National Yang-Ming University
UK-1	United Kingdom	Cardiff University
UK-2	United Kingdom	Imperial College London
UK-3	United Kingdom	Medical Research Council – MRC
UK-4	United Kingdom	Newcastle University
UK-5	United Kingdom	University of Birmingham
UK-6	United Kingdom	University of Bristol
UK-7	United Kingdom	University of Cambridge
UK-8	United Kingdom	University of Edinburgh
UK-9	United Kingdom	University of Glasgow
UK-10	United Kingdom	University of Leeds
UK-11	United Kingdom	University of Liverpool
UK-12	United Kingdom	University of London, King's College London
UK-13	United Kingdom	University of London, Queen Mary
UK-14	United Kingdom	University of London, University College London
UK-15	United Kingdom	University of Manchester
UK-16	United Kingdom	University of Nottingham
UK-17	United Kingdom	University of Oxford
UK-18	United Kingdom	University of Sheffield
UK-19	United Kingdom	University of Southampton
UK-20	United Kingdom	University of Warwick
US-1	United States	Battelle Memorial Institute
US-2	United States	Boston University
US-3	United States	Brigham and Women's Hospital
US-4	United States	Caltech - California Institute of Technology
US-5	United States	Columbia University
US-6	United States	Cornell University
US-7	United States	DOE - US Department of Energy
US-8	United States	Duke University
US-9	United States	Emory University
US-10	United States	Georgia Tech - Georgia Institute of Technology
US-11	United States	Harvard University
US-12	United States	Johns Hopkins University
US-13	United States	Massachusetts General Hospital
US-14	United States	Mayo Clinic
US-15	United States	Michigan State University
US-16	United States	MIT - Massachusetts Institute of Technology
US-17	United States	NASA
US-18	United States	New York University
US-19	United States	NIH - National Institutes of Health
US-20	United States	Northwestern University
US-21	United States	Ohio State University
US-22	United States	Penn State - Pennsylvania State University
US-23	United States	Purdue University – Lafayette
US-24	United States	Rutgers University
US-25	United States	Stanford University
US-26	United States	Texas A and M University - College Station
US-27	United States	University of Arizona
US-28	United States	University of California, Berkeley
US-29	United States	University of California, Davis
US-30	United States	University of California, Irvine
US-31	United States	University of California, Los Angeles

Label	Country	University
US-32	United States	University of California, San Diego
US-33	United States	University of California, San Francisco
US-34	United States	University of Chicago
US-35	United States	University of Florida
US-36	United States	University of Illinois at Urbana-Champaign
US-37	United States	University of Maryland College Park
US-38	United States	University of Michigan
US-39	United States	University of Minnesota-Twin Cities
US-40	United States	University of North Carolina at Chapel Hill
US-41	United States	University of Pennsylvania
US-42	United States	University of Pittsburgh
US-43	United States	University of Southern California
US-44	United States	University of Tennessee at Knoxville
US-45	United States	University of Texas at Austin
US-46	United States	University of Washington
US-47	United States	University of Wisconsin-Madison
US-48	United States	USDA - US Department of Agriculture
US-49	United States	Washington University - St. Louis
US-50	United States	Yale University
VN-1	Vietnam	Can Tho University
VN-2	Vietnam	Hanoi University of Science and Technology
VN-3	Vietnam	Vietnam Academy of Science and Technology
VN-4	Vietnam	Vietnam National University – Hanoi
VN-5	Vietnam	Vietnam National University, Ho Chi Minh City
ZA-1	South Africa	Stellenbosch University
ZA-2	South Africa	University of Cape Town
ZA-3	South Africa	University of KwaZulu-Natal
ZA-4	South Africa	University of Pretoria
ZA-5	South Africa	University of the Witwatersrand

Source: Produced by Science-Metrix

Appendix 2 Supplementary Tables

Table XXIX Average of the relative number of authors per paper for each combination of co-publication type, author decile, citation decile and method for counting citations (1996–2010)

	Author/ Cit. decile	With Self-Citations									Without Self-Citations								
		1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th	1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Intl./Domestic Co-Pubs*	1st	0.437	0.434	0.441	0.435	0.435	0.433	0.433	0.428	0.423	0.434	0.437	0.434	0.439	0.434	0.435	0.434	0.431	0.422
	2nd	0.611	0.606	0.606	0.604	0.606	0.606	0.607	0.608	0.610	0.612	0.604	0.605	0.605	0.605	0.606	0.606	0.607	0.609
	3rd	0.716	0.720	0.721	0.720	0.720	0.721	0.721	0.721	0.718	0.716	0.722	0.721	0.720	0.721	0.721	0.721	0.720	0.719
	4th	0.831	0.827	0.827	0.827	0.826	0.828	0.827	0.828	0.829	0.831	0.827	0.827	0.827	0.827	0.827	0.827	0.827	0.829
	5th	0.946	0.944	0.944	0.942	0.945	0.943	0.945	0.945	0.947	0.946	0.944	0.944	0.944	0.943	0.946	0.944	0.945	0.947
	6th	1.053	1.057	1.055	1.056	1.057	1.056	1.056	1.056	1.054	1.053	1.059	1.055	1.055	1.057	1.056	1.056	1.056	1.055
	7th	1.199	1.195	1.196	1.196	1.195	1.195	1.197	1.197	1.198	1.199	1.195	1.195	1.198	1.194	1.197	1.196	1.197	1.198
	8th	1.353	1.361	1.360	1.360	1.359	1.362	1.361	1.360	1.358	1.353	1.362	1.361	1.360	1.361	1.360	1.361	1.360	1.358
	9th	1.609	1.601	1.604	1.603	1.604	1.606	1.608	1.607	1.610	1.610	1.600	1.603	1.605	1.604	1.607	1.608	1.607	1.609
	10th	2.679	2.716	2.649	2.745	2.804	2.872	2.830	3.006	3.497	3.016	2.875	2.884	2.818	2.843	2.784	2.804	2.863	3.274
Intl. Only Co-Pubs	1st	0.433	0.428	0.435	0.431	0.431	0.427	0.425	0.420	0.410	0.431	0.429	0.434	0.433	0.430	0.430	0.426	0.422	0.410
	2nd	0.603	0.592	0.595	0.593	0.596	0.596	0.597	0.598	0.604	0.602	0.591	0.593	0.596	0.593	0.598	0.596	0.598	0.603
	3rd	0.697	0.709	0.706	0.708	0.705	0.706	0.705	0.706	0.702	0.698	0.711	0.708	0.705	0.710	0.704	0.707	0.705	0.703
	4th	0.830	0.830	0.833	0.831	0.830	0.831	0.829	0.828	0.827	0.831	0.828	0.831	0.833	0.829	0.832	0.831	0.828	0.827
	5th	0.944	0.943	0.943	0.943	0.944	0.942	0.941	0.943	0.944	0.943	0.943	0.946	0.941	0.944	0.944	0.940	0.943	0.943
	6th	1.069	1.062	1.057	1.069	1.069	1.067	1.071	1.068	1.066	1.073	1.054	1.065	1.057	1.070	1.067	1.066	1.069	1.067
	7th	1.179	1.196	1.179	1.193	1.182	1.185	1.182	1.184	1.186	1.179	1.208	1.189	1.177	1.185	1.184	1.186	1.182	1.187
	8th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	9th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	10th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Domestic Only Co-Pubs	1st	0.453	0.450	0.453	0.452	0.454	0.453	0.454	0.453	0.451	0.452	0.451	0.453	0.454	0.453	0.455	0.454	0.454	0.450
	2nd	0.606	0.598	0.600	0.598	0.601	0.600	0.601	0.602	0.604	0.606	0.596	0.598	0.600	0.598	0.602	0.600	0.601	0.604
	3rd	0.709	0.717	0.715	0.715	0.715	0.715	0.715	0.715	0.712	0.709	0.718	0.716	0.714	0.717	0.714	0.716	0.714	0.712
	4th	0.826	0.823	0.825	0.825	0.825	0.825	0.826	0.826	0.827	0.826	0.823	0.825	0.825	0.825	0.825	0.825	0.826	0.827
	5th	0.945	0.943	0.944	0.942	0.945	0.943	0.944	0.943	0.945	0.945	0.943	0.944	0.944	0.942	0.945	0.942	0.944	0.945
	6th	1.050	1.055	1.053	1.053	1.055	1.054	1.054	1.055	1.053	1.051	1.056	1.053	1.052	1.055	1.054	1.054	1.055	1.054
	7th	1.196	1.193	1.192	1.194	1.194	1.193	1.194	1.195	1.195	1.196	1.192	1.192	1.195	1.192	1.195	1.193	1.194	1.195
	8th	1.351	1.358	1.356	1.358	1.356	1.358	1.358	1.357	1.356	1.351	1.359	1.358	1.356	1.358	1.356	1.358	1.357	1.356
	9th	1.601	1.596	1.599	1.599	1.599	1.600	1.601	1.601	1.603	1.601	1.595	1.600	1.599	1.599	1.600	1.600	1.601	1.602
	10th	2.255	2.240	2.244	2.250	2.250	2.266	2.285	2.307	2.402	2.266	2.244	2.258	2.243	2.260	2.263	2.288	2.297	2.383

Note: *International/domestic co-publications account for about 87% of all international co-publications. Results for this latter category are therefore highly similar to those for international/domestic co-publications and the conclusions remain unchanged. The latter type is therefore not presented here to save space. n.a. = not applicable.

Source: Computed by Science-Metrix using Scopus (Elsevier)

Table XXX Lower limit of the 95% confidence interval of the average of the relative number of authors per paper for each combination of co-publication type, author decile, citation decile and method for counting citations (1996–2010)

		With Self-Citations									Without Self-Citations								
	Author/ Cit. decile	**1st & 2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**1st & 2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**
Intl./Domestic Co-Pubs*	**1st**	0.433	0.429	0.435	0.430	0.431	0.428	0.429	0.422	0.418	0.431	0.433	0.430	0.435	0.431	0.431	0.429	0.426	0.416
	2nd	0.610	0.604	0.604	0.602	0.604	0.604	0.605	0.606	0.608	0.610	0.602	0.603	0.603	0.603	0.604	0.604	0.605	0.607
	3rd	0.714	0.718	0.719	0.719	0.718	0.719	0.720	0.718	0.716	0.715	0.720	0.719	0.719	0.719	0.719	0.719	0.718	0.716
	4th	0.830	0.826	0.825	0.825	0.825	0.826	0.825	0.826	0.827	0.830	0.826	0.825	0.824	0.825	0.825	0.825	0.825	0.827
	5th	0.945	0.942	0.942	0.940	0.944	0.941	0.943	0.943	0.946	0.945	0.942	0.941	0.943	0.941	0.944	0.942	0.942	0.945
	6th	1.051	1.055	1.054	1.054	1.055	1.055	1.054	1.054	1.052	1.052	1.057	1.053	1.053	1.055	1.053	1.054	1.055	1.052
	7th	1.197	1.192	1.193	1.194	1.193	1.192	1.195	1.194	1.196	1.197	1.193	1.192	1.196	1.191	1.194	1.194	1.194	1.195
	8th	1.350	1.357	1.358	1.358	1.356	1.359	1.358	1.358	1.356	1.351	1.358	1.358	1.356	1.358	1.357	1.358	1.357	1.355
	9th	1.604	1.596	1.598	1.597	1.599	1.602	1.603	1.603	1.606	1.605	1.595	1.599	1.599	1.599	1.602	1.602	1.603	1.604
	10th	2.527	2.460	2.431	2.488	2.555	2.648	2.633	2.783	3.224	2.805	2.560	2.573	2.553	2.618	2.589	2.612	2.670	2.966
Intl. Only Co-Pubs	**1st**	0.431	0.424	0.431	0.426	0.427	0.423	0.420	0.415	0.406	0.428	0.425	0.429	0.427	0.425	0.427	0.418	0.416	0.405
	2nd	0.601	0.590	0.593	0.591	0.594	0.593	0.595	0.596	0.601	0.601	0.589	0.591	0.594	0.591	0.596	0.593	0.596	0.600
	3rd	0.696	0.708	0.704	0.706	0.703	0.704	0.704	0.705	0.701	0.697	0.710	0.706	0.703	0.708	0.702	0.705	0.703	0.702
	4th	0.829	0.828	0.831	0.830	0.829	0.829	0.828	0.827	0.826	0.830	0.826	0.829	0.831	0.828	0.830	0.829	0.826	0.825
	5th	0.943	0.942	0.942	0.941	0.942	0.941	0.940	0.942	0.942	0.942	0.942	0.945	0.939	0.942	0.942	0.939	0.942	0.942
	6th	1.068	1.060	1.056	1.068	1.067	1.066	1.070	1.067	1.064	1.072	1.052	1.063	1.054	1.068	1.065	1.064	1.068	1.065
	7th	1.178	1.194	1.177	1.191	1.180	1.183	1.180	1.182	1.184	1.177	1.206	1.187	1.175	1.184	1.182	1.184	1.180	1.186
	8th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	9th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	10th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Domestic Only Co-Pubs	**1st**	0.451	0.446	0.450	0.448	0.451	0.446	0.450	0.447	0.444	0.450	0.447	0.449	0.450	0.448	0.450	0.449	0.450	0.442
	2nd	0.605	0.595	0.598	0.596	0.599	0.598	0.599	0.599	0.602	0.605	0.594	0.596	0.597	0.596	0.600	0.597	0.599	0.601
	3rd	0.708	0.715	0.713	0.713	0.713	0.713	0.713	0.712	0.710	0.708	0.715	0.714	0.712	0.715	0.712	0.714	0.712	0.710
	4th	0.825	0.822	0.824	0.824	0.823	0.824	0.823	0.824	0.825	0.826	0.822	0.823	0.823	0.823	0.823	0.823	0.824	0.825
	5th	0.944	0.941	0.942	0.940	0.943	0.941	0.941	0.941	0.943	0.944	0.941	0.941	0.942	0.940	0.944	0.940	0.942	0.942
	6th	1.049	1.053	1.051	1.051	1.053	1.051	1.051	1.052	1.051	1.049	1.054	1.051	1.049	1.053	1.052	1.052	1.052	1.051
	7th	1.194	1.191	1.191	1.190	1.192	1.191	1.192	1.192	1.192	1.194	1.190	1.190	1.192	1.189	1.192	1.191	1.191	1.191
	8th	1.350	1.354	1.353	1.355	1.352	1.355	1.354	1.353	1.353	1.350	1.356	1.355	1.354	1.354	1.353	1.353	1.354	1.353
	9th	1.598	1.591	1.593	1.593	1.593	1.594	1.596	1.596	1.596	1.599	1.590	1.595	1.593	1.591	1.595	1.595	1.596	1.596
	10th	2.226	2.198	2.205	2.215	2.217	2.229	2.250	2.268	2.355	2.244	2.202	2.218	2.212	2.222	2.209	2.251	2.260	2.334

Note: *International/domestic co-publications account for about 87% of all international co-publications. Results for this latter category are therefore highly similar to those for international/domestic co-publications and the conclusions remain unchanged. The latter type is therefore not presented here to save space. n.a. = not applicable.

Source: Computed by Science-Metrix using Scopus (Elsevier

Table XXXI Upper limit of the 95% confidence interval of the average of the relative number of authors per paper for each combination of co-publication type, author decile, citation decile and method for counting citations (1996−2010)

		With Self-Citations									Without Self-Citations								
	Author/ Cit. decile	1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th	1st & 2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Intl./Domestic Co-Pubs*	1st	0.439	0.438	0.444	0.439	0.439	0.438	0.438	0.432	0.428	0.437	0.440	0.438	0.444	0.438	0.440	0.438	0.437	0.427
	2nd	0.613	0.608	0.608	0.605	0.609	0.608	0.609	0.610	0.612	0.613	0.606	0.607	0.606	0.607	0.608	0.608	0.609	0.611
	3rd	0.717	0.722	0.723	0.722	0.722	0.722	0.722	0.722	0.720	0.717	0.723	0.722	0.722	0.722	0.723	0.722	0.722	0.721
	4th	0.833	0.829	0.829	0.829	0.828	0.830	0.829	0.829	0.831	0.832	0.829	0.829	0.829	0.828	0.829	0.829	0.829	0.831
	5th	0.947	0.946	0.946	0.945	0.948	0.945	0.947	0.947	0.949	0.947	0.946	0.946	0.946	0.944	0.947	0.945	0.947	0.948
	6th	1.054	1.060	1.057	1.058	1.058	1.059	1.058	1.058	1.056	1.054	1.061	1.057	1.057	1.059	1.058	1.058	1.058	1.056
	7th	1.201	1.198	1.199	1.198	1.198	1.197	1.199	1.200	1.201	1.200	1.197	1.197	1.200	1.197	1.201	1.199	1.200	1.201
	8th	1.356	1.364	1.364	1.363	1.363	1.364	1.363	1.362	1.361	1.356	1.365	1.364	1.363	1.364	1.363	1.364	1.363	1.361
	9th	1.614	1.607	1.608	1.610	1.609	1.611	1.612	1.612	1.615	1.613	1.605	1.608	1.609	1.609	1.612	1.613	1.612	1.613
	10th	2.900	2.991	2.908	3.046	3.116	3.179	3.076	3.359	3.969	3.269	3.107	3.204	3.037	3.117	3.067	3.063	3.105	3.769
Intl. Only Co-Pubs	1st	0.436	0.433	0.439	0.436	0.438	0.432	0.431	0.426	0.415	0.434	0.434	0.438	0.438	0.435	0.435	0.432	0.427	0.416
	2nd	0.604	0.593	0.597	0.595	0.598	0.598	0.599	0.600	0.606	0.603	0.593	0.596	0.599	0.595	0.601	0.598	0.600	0.605
	3rd	0.698	0.711	0.707	0.709	0.707	0.709	0.707	0.707	0.704	0.698	0.713	0.709	0.707	0.713	0.706	0.709	0.706	0.705
	4th	0.831	0.832	0.834	0.833	0.832	0.833	0.831	0.830	0.828	0.832	0.829	0.832	0.835	0.831	0.834	0.832	0.829	0.828
	5th	0.945	0.944	0.944	0.944	0.945	0.944	0.943	0.944	0.945	0.944	0.944	0.948	0.942	0.945	0.945	0.942	0.945	0.945
	6th	1.071	1.064	1.060	1.070	1.070	1.069	1.073	1.070	1.068	1.074	1.056	1.067	1.058	1.071	1.068	1.068	1.071	1.068
	7th	1.181	1.197	1.181	1.195	1.184	1.187	1.183	1.186	1.188	1.180	1.210	1.191	1.179	1.188	1.186	1.187	1.184	1.189
	8th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	9th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	10th	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Domestic Only Co-Pubs	1st	0.455	0.454	0.457	0.456	0.458	0.458	0.458	0.458	0.458	0.454	0.455	0.456	0.457	0.457	0.460	0.458	0.459	0.457
	2nd	0.607	0.600	0.601	0.600	0.603	0.602	0.603	0.604	0.606	0.607	0.599	0.601	0.602	0.601	0.605	0.603	0.604	0.606
	3rd	0.710	0.719	0.717	0.716	0.716	0.717	0.717	0.716	0.714	0.710	0.719	0.717	0.716	0.718	0.716	0.718	0.717	0.714
	4th	0.827	0.825	0.827	0.827	0.827	0.828	0.828	0.828	0.830	0.827	0.825	0.826	0.827	0.828	0.828	0.829	0.828	0.830
	5th	0.947	0.945	0.946	0.945	0.946	0.945	0.946	0.946	0.947	0.947	0.945	0.945	0.946	0.944	0.948	0.945	0.946	0.947
	6th	1.051	1.057	1.055	1.055	1.056	1.057	1.056	1.057	1.056	1.052	1.059	1.055	1.054	1.057	1.057	1.056	1.057	1.057
	7th	1.197	1.195	1.195	1.196	1.197	1.196	1.197	1.197	1.197	1.197	1.195	1.194	1.198	1.195	1.198	1.196	1.197	1.197
	8th	1.353	1.361	1.360	1.361	1.359	1.361	1.362	1.360	1.362	1.353	1.364	1.361	1.359	1.360	1.359	1.362	1.360	1.361
	9th	1.604	1.602	1.604	1.604	1.604	1.603	1.605	1.607	1.608	1.604	1.601	1.605	1.605	1.606	1.605	1.606	1.607	1.609
	10th	2.279	2.298	2.289	2.292	2.294	2.324	2.341	2.372	2.447	2.291	2.289	2.311	2.286	2.333	2.304	2.341	2.351	2.435

Note: *International/domestic co-publications account for about 87% of all international co-publications. Results for this latter category are therefore highly similar to those for international/domestic co-publications and the conclusions remain unchanged. The latter type is therefore not presented here to save space. n.a. = not applicable.

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