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Norway's scientific collaboration with China in a global context

An analysis based on articles in *Web of Science*

Gunnar Sivertsen

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Preface

This Working Paper presents the results of a small study commissioned by the Norwegian Ministry of Education and Research with the aim of mapping scientific collaboration between Norway and China within the context of global scientific collaboration. The scope is limited to collaboration that can be documented from scientific articles in journals covered by the Web of Science.

Oslo, March 1, 2022

Vibeke Opheim
Managing director

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Summary

About the report

This study provides an overview of scientific collaboration between Norway and China within the context of global scientific collaboration. The study covers Sino-Norwegian collaboration as it has developed since 2001, mainly focusing on the recent ten years. Collaboration is analysed in nine major areas of research: Biology, Biomedicine, Chemistry, Computer Science, Environmental Sciences, Health Sciences, Physics, Social Sciences and Humanities (SSH), and Technology. In a separate chapter, special attention is given to the multidisciplinary field of Arctic research.

The study is limited to collaboration that can be documented from scientific articles in journals covered by the Web of Science. This data source allows for studying Sino-Norwegian collaboration within a global network representing 27 countries and 97 percent of the world's scientific output. At the same time, it allows for identifying the active institutions on both sides of the Sino-Norwegian collaboration in each area of research.

Collaboration with China in a global context

The study shows that China has grown to become Norway's fourth largest collaboration partner in science after USA, UK, and Sweden if only scientific articles representing bilateral collaboration are considered. China is the tenth largest collaboration partner for Norway if articles with multilateral collaboration, mainly within Europe, are added.

The increasing importance of China is mainly due to the country's rapid growth within global science. China has now surpassed USA to become the largest contributor to international scientific journals. All countries have had increasing collaboration with China. Comparing with the collaboration activity in the whole global network and adjusting for size, China is collaborating most intensely with other Asian countries and with USA, Australia, and Canada. USA and China are each other's most important collaboration partners in science. However, the intensity in this bilateral relation has decreased after 2016.

China' collaboration with Norway is less intense than it is with Denmark, Finland, and Sweden. Collaboration with Norway stagnated ten years ago but a revitalization can be observed since 2017.

Sino-Norwegian collaboration in nine major areas of research

By using three criteria to assess the relative importance of an area of research in Sino-Norwegian scientific collaboration, we could rank them in this order:

1. Environmental sciences
2. Technology
3. Computer science
4. Physics and Chemistry
5. Biology
6. Biomedicine and Health Sciences
7. Social Sciences and Humanities

We find three fields of research under the umbrella Environmental sciences which stand out with high collaboration activity that seems to be organized and supported in mutual interest between the most important institutions on both sides: 1) environmental sciences based on geophysical research, particularly in climate research, 2) marine science and engineering, and 3) hydrological engineering.

Technology and computer science reflect the priorities and strengths in the research profile of China as compared to the rest of the world. There is a Norwegian 'mark' on what seems to be the common interests in these areas of research: marine engineering, materials science, and environmental engineering within technology, and telecommunications within computer science.

Chinese science is traditionally strong in the physical sciences, less strong in the life sciences. The strengths of China are mirrored in the collaboration with Norway. There is much collaboration in physics and astrophysics, but this interaction is mostly mediated by multilateral collaboration, e.g., in high energy physics. Bilateral collaboration is relatively more important in chemistry where we observe a focus on materials science and physical chemistry.

Biology includes the sciences of bioproduction in our analysis. The activity in the Sino-Norwegian relation is not high, but the profile in biology is clearly focussed on the characteristic Norwegian orientation: Marine biology and fisheries research.

In most of the areas of research mentioned so far, the universities play a major role on the Norwegian side, but the research institutes are also important in some fields of research. As we turn to biomedicine and the health sciences, the Norwegian hospitals are also active collaboration partners. However, a large part of this

collaboration with China is mediated by multilateral consortia and projects. Also, the strengths of Norwegian research in these areas are not mirrored in China.

The social sciences and humanities are areas of research without much collaboration between China and Norway. China is less active than Norway in journals covering these areas in Web of Science. The collaboration with Norway is dominated by studies in business and economics.

Collaboration in Arctic research

Arctic research is not easily defined within Web of Science. We used a combination of selected keywords and journals to delimit the field of research without excluding any country.

Norway stands out as the country most dedicated to Arctic research relative to its size. 4.5 percent of Norway's scientific output is dedicated to the field. This prioritization of Arctic research makes Norway the fifth largest country contributing to the field after USA, Canada, China, and UK. The other Nordic countries are also relatively active together with Canada and Russia.

Only 0.18 percent of China's scientific output is dedicated to Arctic research. Other large countries in science such as USA, UK, Germany, and France are clearly more active by the same measure.

Arctic research has a high degree of international collaboration. China and Norway appear to belong to different groups of collaborating countries. China collaborates most intensely with USA, Australia, Japan and Canada. The intensity is low in the relations to all European countries, also in the relation to Norway.

The low intensity in the relation to China is seen also in Norway's profile. The intensity is high for Norway in the relations to the Nordic countries and to Russia. Germany is also important in this collaborating group as well as other European countries.

Arctic research is dominated by the Environmental sciences (including climate research), which we find to be a main area for Sino-Norwegian collaboration in the general analysis – see above. However, only a small part of this collaboration is focused on the Arctic. The few articles are mainly dedicated to climate research, and most of them are based on multilateral collaboration in which other countries participate as well.

1 Introduction

1.1 Purpose and scope

This purpose of this small study is to provide the Norwegian Ministry of Education and Research with an overview of scientific collaboration between Norway and China within the context of global scientific collaboration. The study covers Sino-Norwegian collaboration as it has developed since 2001, mainly focusing on the recent ten years. Collaboration is analysed in nine major areas of research: Biology, Biomedicine, Chemistry, Computer Science, Environmental Sciences, Health Sciences, Physics, Social Sciences and Humanities (SSH), and Technology. In addition, special attention is given to the multidisciplinary field of Arctic research, which is described in a separate chapter. The scope of the study is limited to collaboration that can be documented from scientific articles in journals covered by the Web of Science.

1.2 Data and methods

1.2.1 Web of Science

Web of Science is a searchable bibliographic database with broad global coverage of the sciences and a more limited coverage of the social sciences and humanities (Aksnes & Sivertsen, 2019). It covers the published literature only. Unpublished research in the corporate sector is not covered.

This study is based on searches and downloads in Web of Science that were performed in January 2022. The searches were limited to:

- The three core indices Science Citation Index Expanded, Social Science Citation Index and Arts & Humanities Citation Index
- Original research articles and review articles with authors' addresses that can be linked to countries

As an example, a search for articles published in the year 2020 with the two limitations mentioned above results in 2.2 million articles published in 14,227 different journals among which:

- 563,666 are articles with authors' affiliations in China
- 20,093 are articles with authors' affiliations in Norway
- 1,549 are articles with the combined presence of authors' affiliations in China and Norway

For the first two types of search results, also covering 25 other countries, statistics from the searches was downloaded and transformed to a database at NIFU for further analysis. For the third type of search results, article level data was downloaded and transformed to the same database. The latter procedure allowed for identification of contributing institutions in China and Norway.

Full download of article level data was also performed for the analysis of Arctic Research in chapter 4. The delimitation of data for this chapter was not based on countries, but on selected journals and keywords, as explained in the same chapter. All countries contributing to Arctic Research, not only China and Norway, are thereby included.

1.2.2 A classification of articles in nine major areas of research

In the Web of Science, journals are classified into 152 different "Research Areas" (e.g., Agriculture, Cell Biology, Literature, Materials Science, Sociology). The articles appearing in a journal are classified in the same category. To provide a useful overview, we have merged the 152 research areas into nine major areas and added a tenth category of general journals. They are listed below along with examples the most frequent subcategories appearing among the articles. In cases of doubt, we have consulted the journal level and the frequency of articles showing Sino-Norwegian collaboration. As an example, Mathematics is included in Technology because the articles frequently appear in journals representing mathematics applied in engineering. The ten major categories are (with examples):

- Biology (Plant sciences, Zoology, Marine & Freshwater Biology, Agriculture, Fisheries, Forestry)
- Biomedicine (Biochemistry & Molecular Biology, Cell Biology, Genetics)
- Chemistry (Chemistry, Polymer Science)
- Computer Science (Computer Science, Automation & Control Science)
- Environmental Sciences (Geosciences, Environmental Science, Climate research)
- Health sciences (Clinical sciences, Health care sciences)

- Physics (Physics, Astronomy & Astrophysics)
- SSH (Social Sciences and Humanities)
- Technology (Engineering, Materials Science, Mathematics, Energy & Fuels, Telecommunications)
- General journals (e.g., PLOS One, Scientific Reports, Nature Communications, Nature, PNAS, Science)

Many journals are classified as belonging to more than one Research Area in Web of Science. As we merge them into ten main categories, some journals will still be classified in more than one group. The articles in these journals remain relevant for the analysis in each group, but double counting is unavoidable.

1.2.3 A selection of 27 countries for the global context

Scientific collaboration between countries in bilateral relations needs to be studied within the context of the global collaboration network. Collaboration between Norway and China is increasing year by year, but is collaboration increasing even more in other relations? A field of research may seem to be prioritized in the collaboration between China and Norway, but how does the frequency of articles with contributions from both countries compare to the frequencies in other bilateral relations?

We have selected 27 countries to represent the global collaboration network in science. We limit the number of countries to facilitate data collection and an easier overview as we present the results. Still, without double counting of overlapping contributions, the 27 countries are involved in 97 percent of the 2.2 million scientific articles from 2020 that we mentioned above as the result of our search strategy.

Fifteen of the countries were selected according to the size of their scientific production within Web of Science in 2020. The largest contributions came from *Australia, Brazil, Canada, France, Germany, India, Italy, Japan, the Netherlands, Peoples Republic of China, Russia, South Korea, Spain, the United Kingdom,* and *the United States of America.* The names of three of these countries are abbreviated in this study as China, UK, and USA.

Another seven countries were added to represent Northern Europe in addition to Germany and the Netherlands: *Austria, Belgium, Denmark, Finland, Norway, Sweden, and Switzerland.*

Five Asian countries were added as well to represent the largest contributors of scientific articles among those that frequently appear in the collaboration network of China: *Malaysia, Pakistan, Singapore, Taiwan, and Thailand.*

The selection thereby consists of fourteen European countries, nine Asian countries and four large countries in other continents.

1.3 Overview of the chapters

Chapter 2 presents some context for understanding collaboration with China in an analysis based on data from Web of Science. It is important to know how the global scientific production and international collaboration is increasing every year and to observe the remarkable growth of China within these trends. We present some factors determining collaboration activity and a method to measure the intensity of collaboration between two countries in a way that is independent of size and relative to all other bilateral relations in a global network.

Chapter 3 is the main part of the report with a close look at Sino-Norwegian scientific collaboration in nine major areas of research. In each of these areas, the most active contributing institutions on both sides are identified. The relative importance of each area is measured relative to the two countries' international collaboration profile in general.

In accordance with the commission, *Chapter 4* has a special focus on Arctic research by including all countries active in this field of research, not only China and Norway.

Each chapter is summarized at the end and these summaries are presented together in the Summary above.

2 The context for collaboration

2.1 Globalization and growth

China's Gross Domestic Product has doubled every eight years during the last two decades. Giving strong priority to science, the country's research intensity measured as a percentage of GDP doubled at the same time (OECD). And measured by scientific articles in *Web of Science*, China surpassed the USA as the largest contributor to international scientific journals after 2018. The rapid growth of China in the global science system is important for the understanding of trends in scientific collaboration with China. The growth of China must also be understood on the background of the general growth and globalization of science.

2.1.1 The growth within *Web of Science*

A total of 726,000 scientific articles were published in the year 2001 and indexed by *Web of Science* with authors' addresses linked to countries. As seen in Figure 2.1, there has been a considerable growth since then. Almost 2.2 million such articles have been indexed with the publication year 2020.

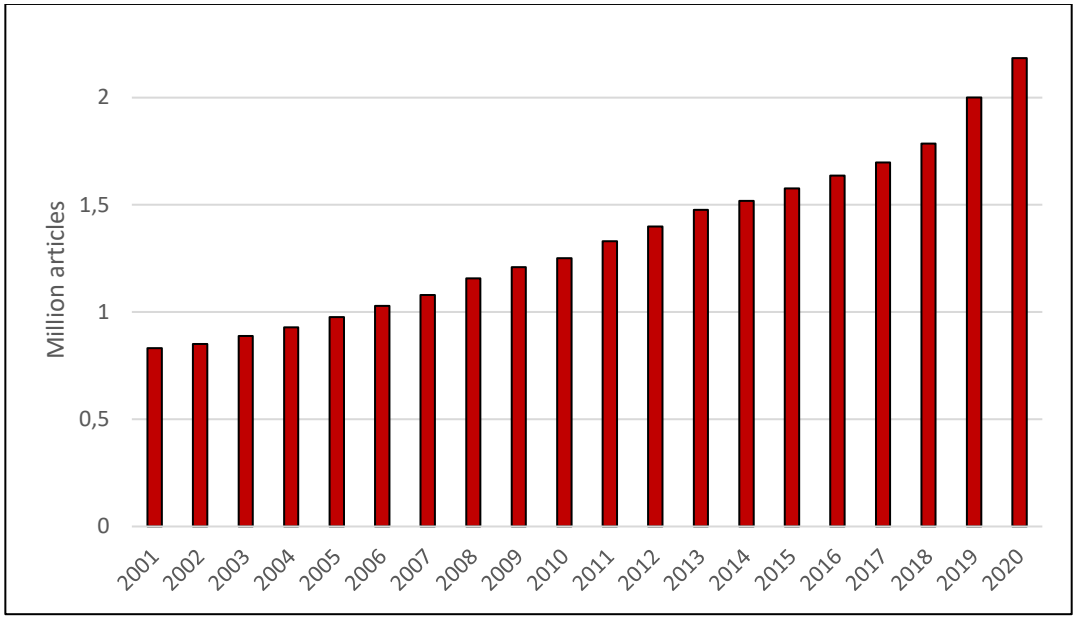

Figure 2.1. The number of scientific articles (in millions) indexed in *Web of Science* by publication year 2001-2020.

The growth within *Web of Science* is partly due to an increasing number of journals being indexed. This number increased from 9,200 in 2001 to 14,200 in 2020. The average annual volume of scientific articles in the journals also increased from 90 to 160 articles per year. Both growth factors indicate an *external* growth and change in the market of scientific journals. Article Processing Charges (APC) have been added to subscriptions as a second business model in the market. Examples of the new business model are the three largest scientific journals indexed in 2020. They did not exist in 2000 and are now published with unforeseen annual volumes: *Scientific Reports* was indexed in 2020 with 21,200 articles, *IEEE Access* with 17,800 articles, and *PLOS One* with 16,000 articles.

The growth of the market of international journals also reflects the globalization and growth of the scientific system itself. Three factors are often mentioned as explanations for this development:

- Increasing research intensity measured as a percentage of GDP, particularly in emerging economies
- Increasing international collaboration and mobility in science
- Internationalization of scientific publishing

These factors are important for understanding the global context for the development of scientific collaboration with China in each bilateral relation. Another factor to consider is that the growth rates differ among countries. We will have a look this factor now.

2.1.2 The rapid growth of China

One of the clearest changes in the global science system during the last two decades is China's rapid growth to become the world's largest contributing country to international scientific journals. As seen in Figure 2.2, China took over the role of USA after 2018. The size of China within *Web of Science* was comparable to the size of Canada back in 2001. China surpassed the UK to become the second largest country already in 2006.

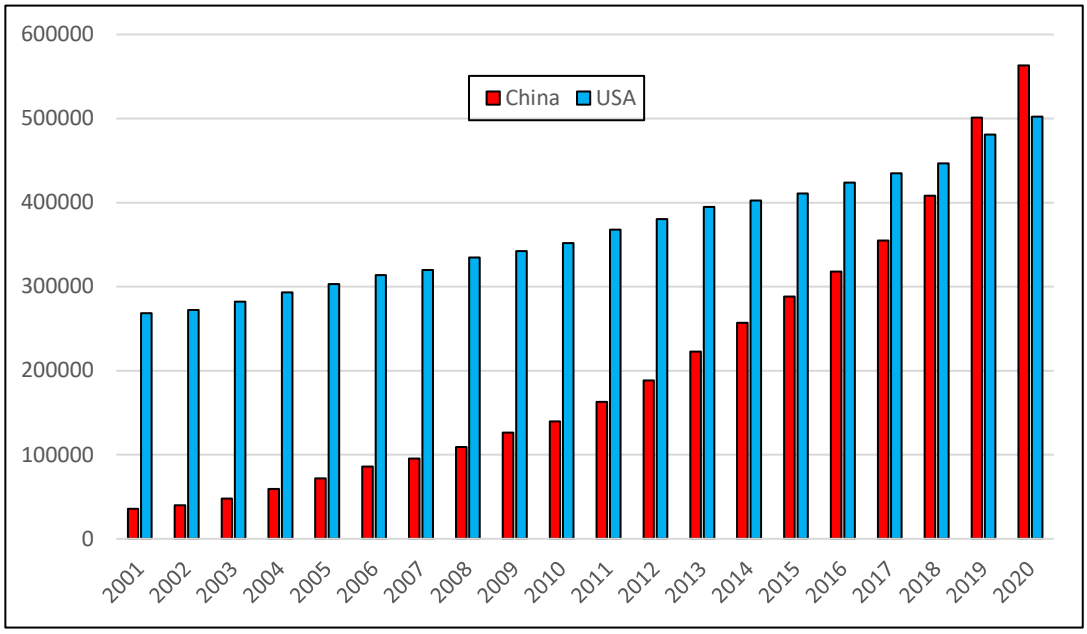

Figure 2.2. The number of scientific articles in *Web of Science* contributed to by China and USA per publication year 2001-2020.

One of the factors that may explain the China's rapid growth within Web of Science was mentioned above: The growth of the economy combined with rapidly increasing investments in science. Another factor is the strong incentives to publish in journals indexed by Web of Science. This phenomenon, named "SCI worship" in China (the original name of Web of Science was the Science Citation Index), has for many years influenced research evaluation, staff employment, career promotion, awards, university and disciplinary rankings, and funding in China (Zhang & Sivertsen, 2020). Even individual cash incentives for WoS publications have been widespread (Quan, Chen & Shu, 2017).

To further compare the growth of China with that of other countries, we will use percentage shares of scientific articles within Web of Science as the indicator. For each year, the number of scientific articles a country has contributed to is divided by the global total of articles in Web of Science. This indicator implies that countries may have overlapping shares in articles that more than one country

contributed to. We will return below to an analysis of articles based on international collaboration.

Figure 2.3 compares China to five other large countries within Web of Science. China stands out with an extraordinary growth rate. The traditional large research countries have decreasing shares, except India where the share is moderately increasing.

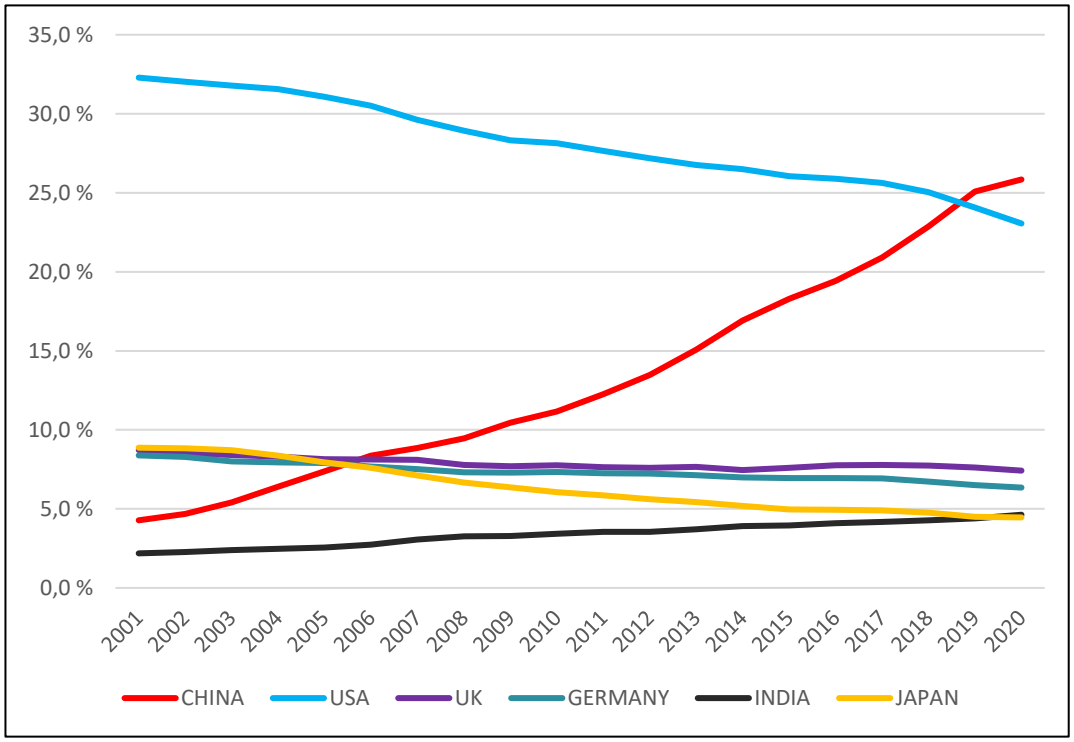

Figure 2.3. Six large contributing countries to articles in *Web of Science* and their percentage share of the global total per year 2001-2020.

The increases of China and India are typical for emerging economies and show that the globalization of science is observable in international scientific journals. Figure 2.4. shows the trends for five other Asian countries. All five have increasing shares in the first of the two decades. In the last decade, the global share of South Korea is stabilized while it is reduced for Taiwan.

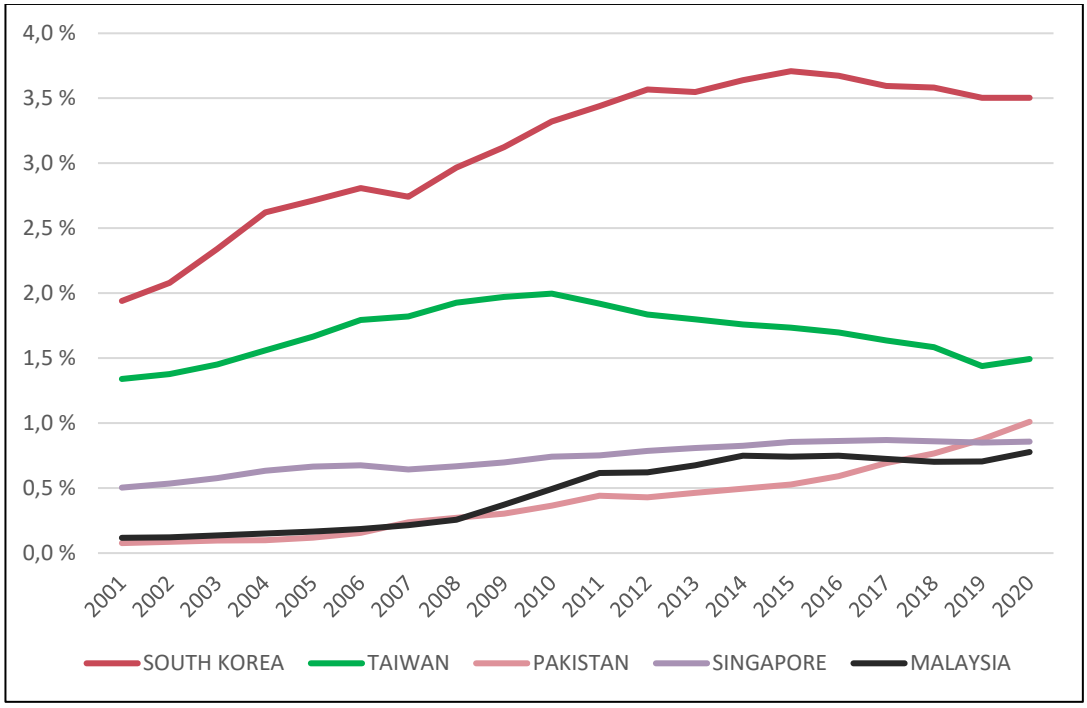

Figure 2.4. Five other Asian contributing countries to articles in *Web of Science* and their percentage share of the global total per year 2001-2020.

We already saw that Germany's share has been decreasing. Figure 2.5 shows that the share is also decreasing or stable for the Netherlands, Switzerland, Sweden, and Finland. Denmark and Norway stand out with increasing shares.

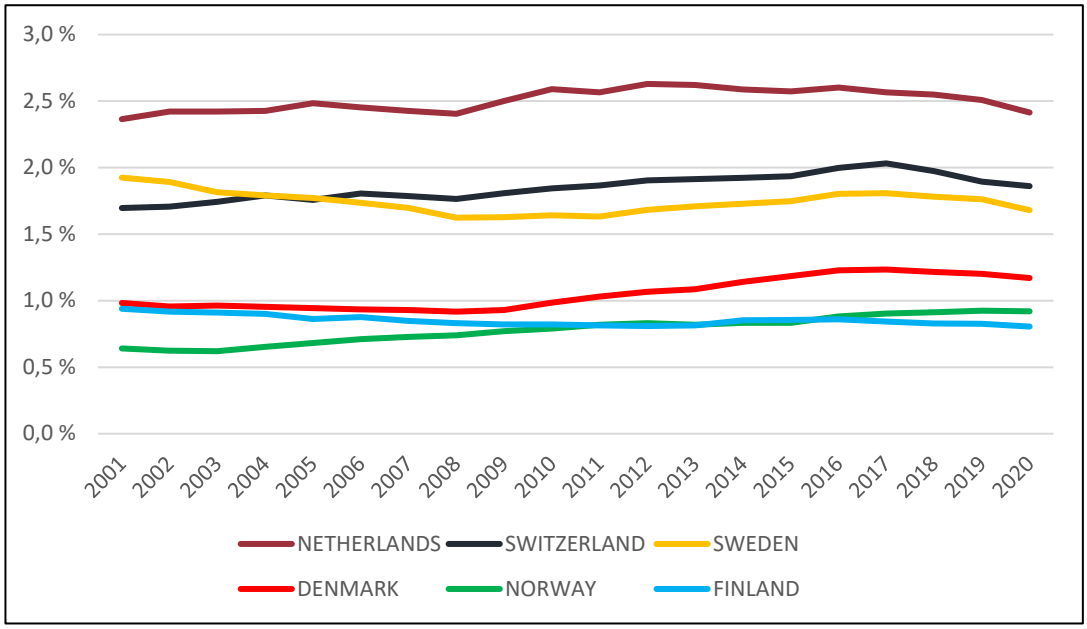

Figure 2.5. Four Scandinavian countries and two other European countries contributing to articles in *Web of Science* and their percentage share of the global total per year 2001-2020.

With China's extraordinary growth in science during the last two decades to become a major contributor to global science, all countries can expect China to have become a major collaborator in science as well. However, the degree to which this is true varies among countries, as we shall see in the next section.

2.2 Factors determining collaboration activity

International collaboration in science can be measured in bibliographic data as the co-existence of author addresses in two different countries in one and the same article. Most often, this is an indication that at least one researcher in each of the two countries have collaborated in the study reported in the article. However, a researcher may also have more than one affiliation and be affiliated with institutions in different countries. This is an indication of mobility and only indirectly an indication of collaboration, but we do not exclude these articles from our data.

The size of the two collaborating countries heavily influences the expected collaboration intensity. While China can be expected (from the results already seen above) to be a large collaboration partner for Norway, the opposite is true from the perspective of China. As we shall see, China and USA are the major collaboration partners for each other, but this is as expected given their size in the global collaboration network. In this section, we will work with *size-independent* measures to calculate the *relative intensity of collaboration* between two countries, that is, relative to the activity in all other bilateral relations in the global network. We will show that China and USA collaborate even more than expected given their sizes in the network. The opposite is true for the China-Norway relation.

We will introduce two other size-independent measures first. One is *the match of research profiles*, the degree to which countries match each other in their prioritization of areas of research. The other indicator is the *degree of international collaboration* in publications. Both may influence the expected collaboration intensity in bilateral relations.

2.2.1 The match of research profiles

Figure 2.6 compares the research profiles of Norway, China, and USA by measuring the percentage articles from 2020 in each of the nine major areas of research presented in section 1.2.2 in the introduction.

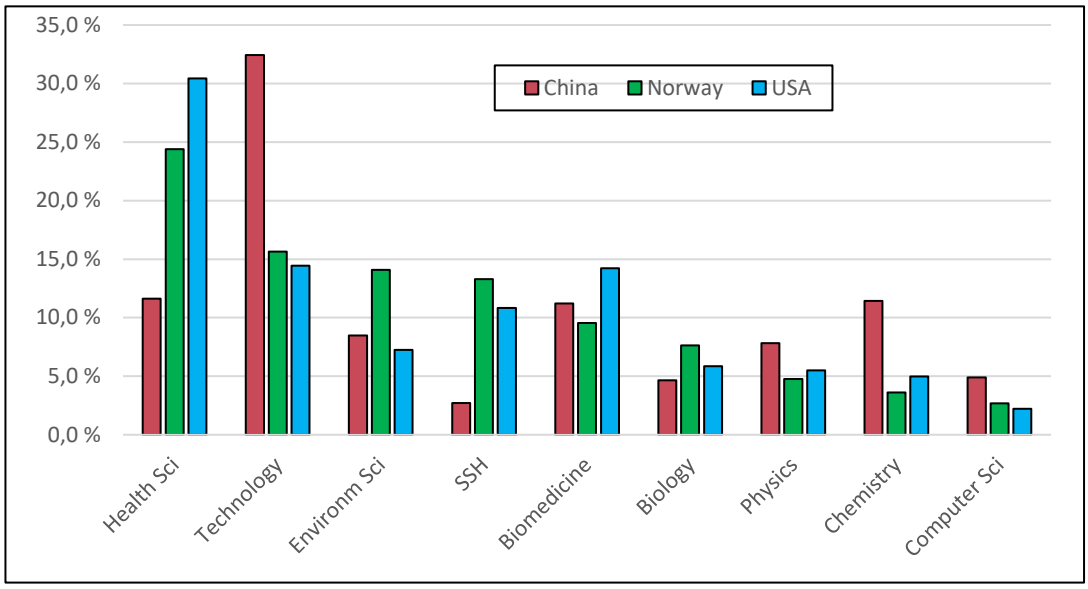

Figure 2.6. The research profiles of Norway, China, and USA in publications from 2020, measured as the percentage of the country's articles within each major area of research.

The results show that China's research profile clearly differs with a higher relative activity in the physical sciences, technology, and computer science. The profiles of Norway and USA are more similar with higher relative activity in the health and life sciences and in the social sciences and humanities.

Despite the differences in research profiles between China and USA, we will see below that the relative intensity of collaboration in their relation is high. This is an indication that other factors than the match of research profiles influence collaboration activity.

2.2.2 The degree of international collaboration in articles

Some scientific articles have authors with affiliations in only one country. Other articles have co-authors in two or more countries. The latter category has had a relative increase as a percentage within Web of Science for several decades. In most countries, the share is now over 50 percent. The share is generally higher in small countries than in large countries, indicating that small countries are more dependent on international collaboration to perform research.

We calculated the percentage share of articles with international collaboration among 27 countries during 2001-2020 and selected six countries to represent the results as shown in Figure 2.7. Norway represents the line that could be drawn for all countries in Northern Europe. Switzerland deviates from the European normal by higher shares while the UK and the USA have lower shares as expected for

larger countries. South Korea slightly deviates, and China clearly deviates, from this pattern.

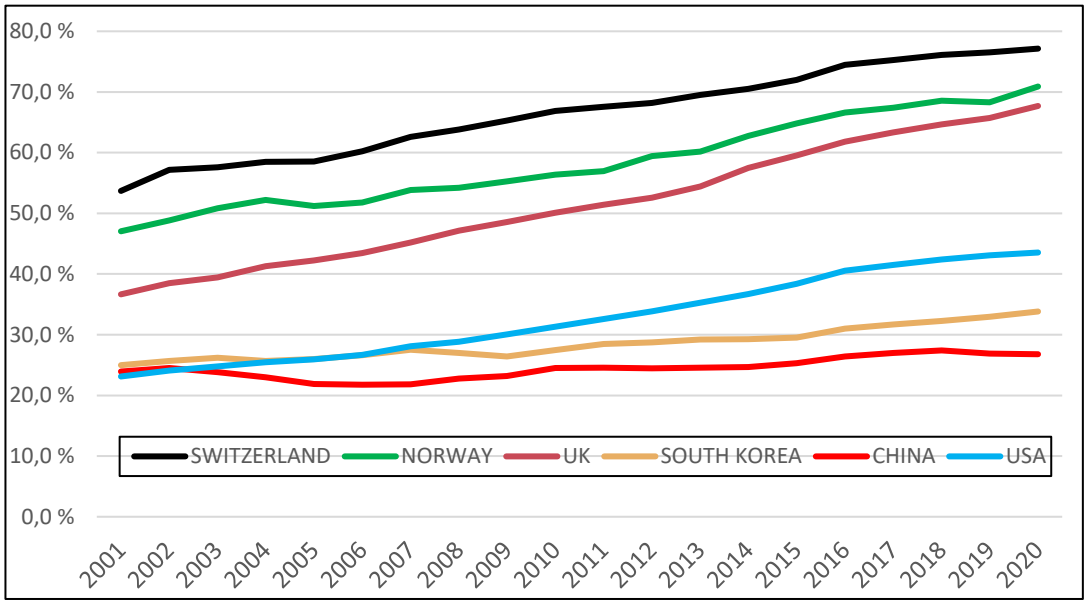

Figure 2.7. Degree of international collaboration measured as the percentage share of articles with co-authors in at least one other country among all articles from the country. Six selected countries with articles published 2001-2020.

The growth rates already shown in Figures 2.3 and 2.4 are important for the understanding of why the two Asian countries differ from the Western countries. The number of articles with international collaboration increased by five times in both South Korea and Norway between 2001 and 2020. The difference is mainly that South Korea almost doubled its size within Web of Science, thereby rising from a small to a medium-sized scientific country.

China again stands out from all other countries. While the indicator in Figure 2.7 shows an almost stable degree of international collaboration, the number of articles with collaboration between China and other countries was multiplied by 18 between 2001 and 2020. China quickly became the largest country with an expected lower degree of international collaboration, but the volume of international collaboration increased immensely.

China published more than 400,000 articles in Web of Science *without* international collaboration in 2020. The corresponding number was 27,000 in 2001. The increase is larger than could be expected from the growth and increased research-intensity of the economy. The explanation is that the Chinese research sector was large already in 2001, but the scientific output was mainly published in domestic scientific journals. China has now partly moved its scientific production to the international journals covered by Web of Science, but domestic publishing is still important and presently being stimulated (Zhang & Sivertsen, 2020).

2.2.3 Bilateral versus multilateral collaboration

Internationally funded research consortia with global representation of research organizations are increasingly influencing bibliometric statistics based on Web of Science. A well-known example is the publications from the CERN laboratory in Switzerland for experiments in particle physics. Their articles are published very frequently (as often as fortnightly), are often very highly cited, and represent up to 3,000 listed authors each time with affiliations in more than 40 countries on all continents, including China and Norway.

We will distinguish in this study between articles representing bilateral, trilateral, and multilateral country collaboration. Articles representing bilateral collaboration are interesting because they indicate what we often wish to know about international collaboration in research: To what extent are researchers in the two countries selecting each other for international collaboration? Articles representing trilateral or multilateral collaboration may depend more on third-party influences, but these types of collaboration can also be important for the stabilization and growth of bilateral relations in times when they are challenged (see section 2.2.5 below).

We illustrate the distinctions between the three types of international collaboration in *Figure 2.8* using Norway as an example. The 22 countries with the highest number of collaboration articles with Norway in 2020 are shown. They are ranked in Figure 2.8 according to the number of articles with bilateral collaboration.

The results are interesting from the perspective of collaboration with China: Although nine countries have higher numbers of collaboration articles with Norway, China ranks fourth by the number of articles with bilateral collaboration.

The general pattern is that member countries of the European Union tend to have high number of collaboration articles with Norway based on multilateral collaboration. This finding reflects the fact that Norway contributes financially to and takes part in EU-funded projects where multilateral collaboration is a condition for funding. Only Sweden, the UK, Germany, and Denmark differ within Europe with more engagement with Norway in bilateral and trilateral relations.

Outside of Europe, only the USA and China stand out with large shares of articles resulting from bilateral collaboration. Bilateral relations to the USA represent a long tradition in Norwegian research. Compared to the Norwegian relations with India, Russia, Brazil and Japan, the relations with China stand out as remarkably different with relatively more activity in bilateral relations. A possible explanation is the influence of country size. Double affiliations of researchers in China and Norway might also be an explanation. A third possibility is the influence of bilateral research programmes aimed at reinforced collaboration between the two countries.

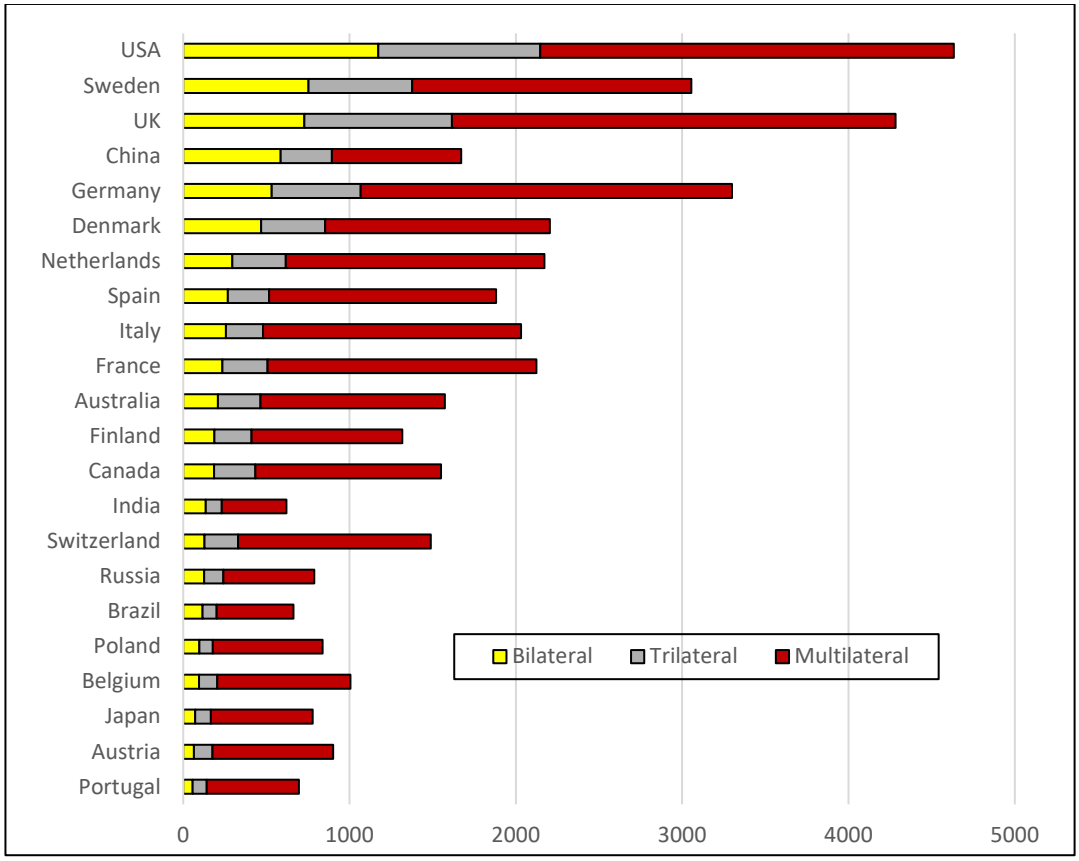

Figure 2.8. The number of collaboration articles with Norway in 2020 with a distinction between articles with evidence of bilateral, trilateral, and multilateral collaboration among countries. The countries are ranked according to the number of articles with bilateral collaboration.

2.2.4 Relative intensity of collaboration

The extent of collaboration between two countries primarily depends on the size of the two countries. China collaborated with the USA in almost 60,000 scientific articles in 2021, as shown in *Figure 2.9*. No other bilateral relation had a higher number, but the large scale mainly reflects that China and USA are the largest actors in the global network.

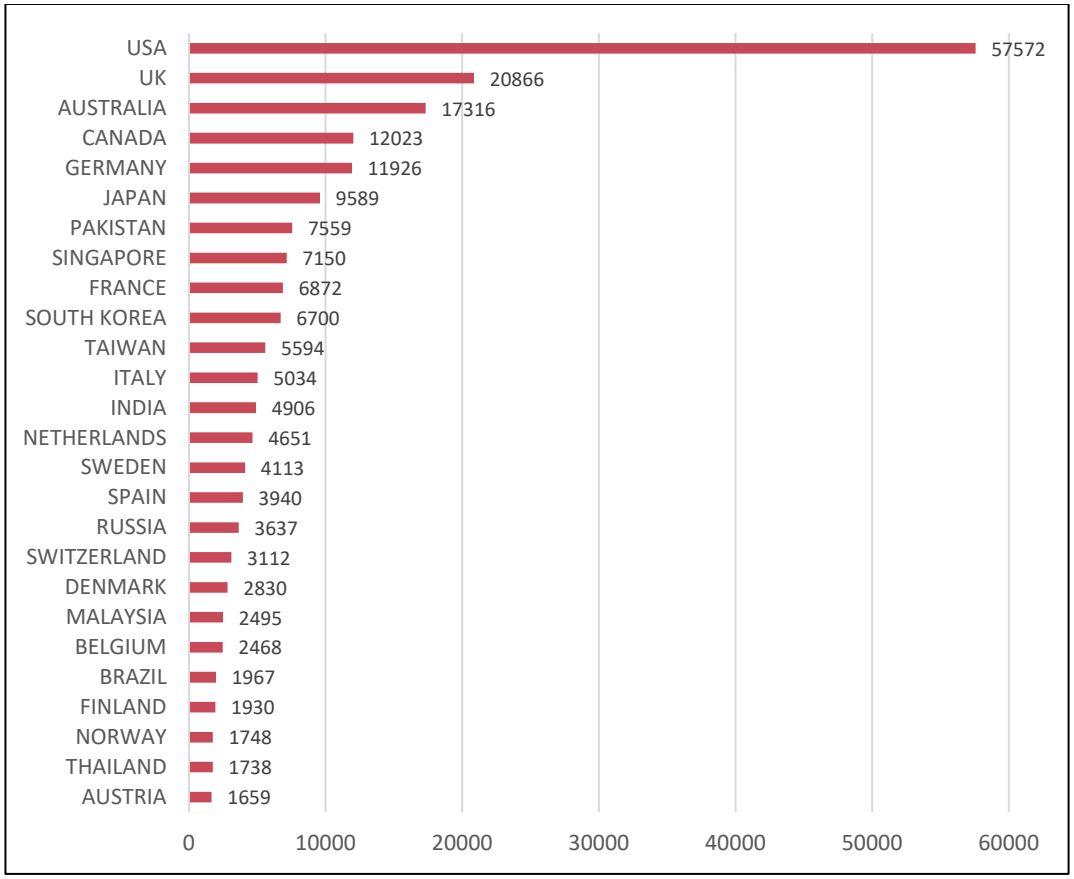

Figure 2.9. The number of collaboration articles with China in 2021.

The same influence of size is also visible in *Figure 2.10*, which shows the frequencies in Norway's relations within the same network of 27 countries in 2021. But the order of the countries is different, and so are the relative sizes of the USA and the UK in the collaboration network.

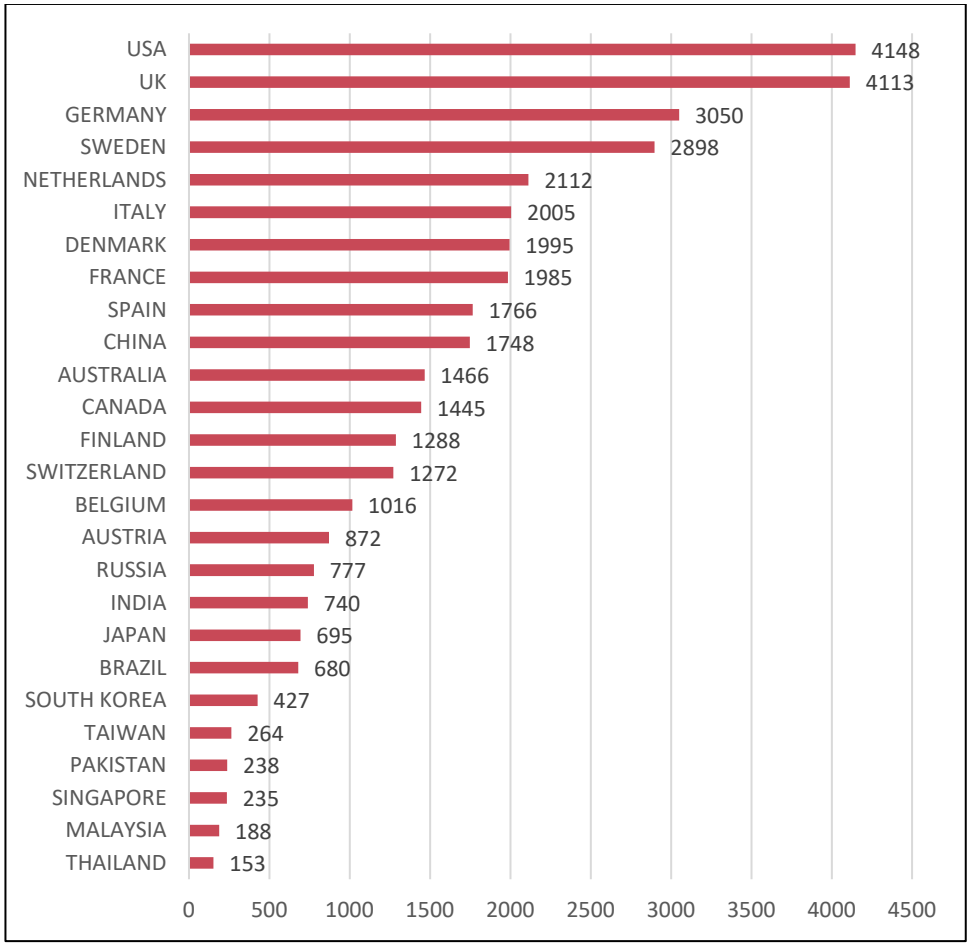

Figure 2.10. The number of collaboration articles with Norway in 2021.

To interpret such differences, we developed a size-independent indicator of relative collaboration intensity (Luukkonen, Persson & Sivertsen, 1992) which is widely used today in governmental advice, e.g., by the US National Science Board (2019) in its *Science & Engineering Indicators* report. We recently modified the indicator to become more mathematically consistent (Fuchs, Rousseau & Sivertsen, 2021). The relative intensity of collaboration (RIC) between country x and country y is calculated by using this formula:

> *RICxy = (Cxy/Cx)/(Cy-Cxy/Cw), where Cxy is the number of articles with collaboration between x and y, Cx is the total number of articles with international collaboration in which x is involved within the whole network, Cy is the total number of articles with international collaboration in which y is involved within the whole network, and Cw is the sum total of articles with international collaboration in the whole network.*

In short, the *observed* activity in a bilateral relation (e.g., 1,748 articles in the China-Norway relation in 2021, this number appears in both diagrams above) is divided by the activity that can be *expected* from the total activities of all countries in all relations in the network. The activity is below the expected if the indicator is below 0.5 and above the expected if the indicator is above 0.5. The indicator is asymmetric and always represents the relative collaboration intensity from the

perspective of country x. However, the indicator cannot be high on one side of the relation and low on the other or vice versa.

We established a matrix of collaboration activities among the selected 27 countries by collecting data from 2011, 2016, and 2021. *Figure 2.11* shows the relative intensity of collaboration from the perspective of Norway.

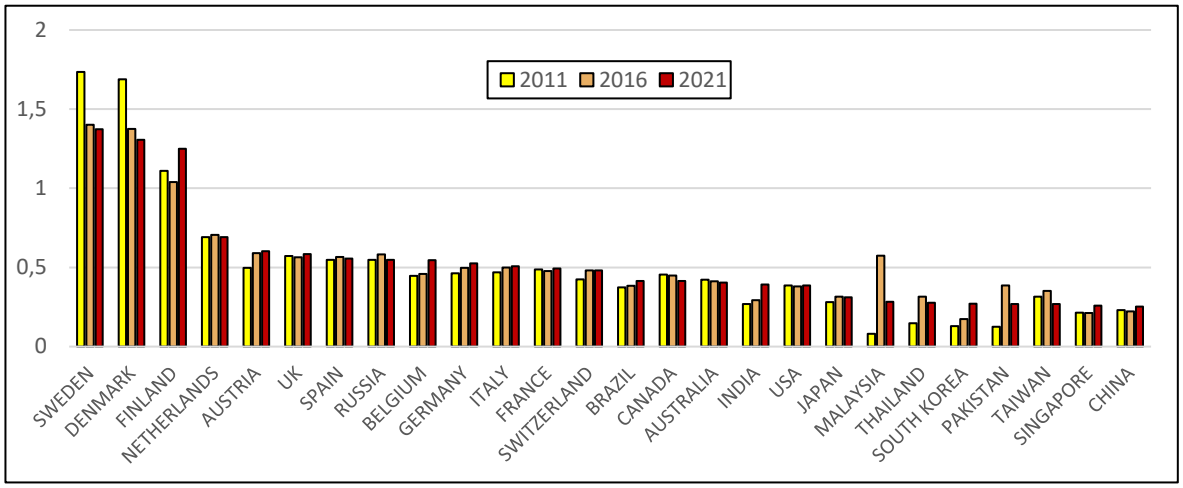

Figure 2.11. Relative intensities of collaboration in Norway's bilateral relations within a network of 27 countries in 2011, 2016, and 2021.

The scientific collaboration intensity within Scandinavia is traditionally high. A similar graph for the three other countries would confirm this. However, increasing intensities are mainly found in relations to other European countries such as Austria, Belgium, Germany, and Italy, which might reflect that collaboration within EU and with EU funding is becoming more important relative to Scandinavian collaboration.

The lowest relative intensity in Norway's bilateral relations is with China. *Figure 2.12* shows the same indicator from the perspective of China. Here, Norway stands out from the other Scandinavian countries with the lowest intensity. We will return to this observation in the next section.

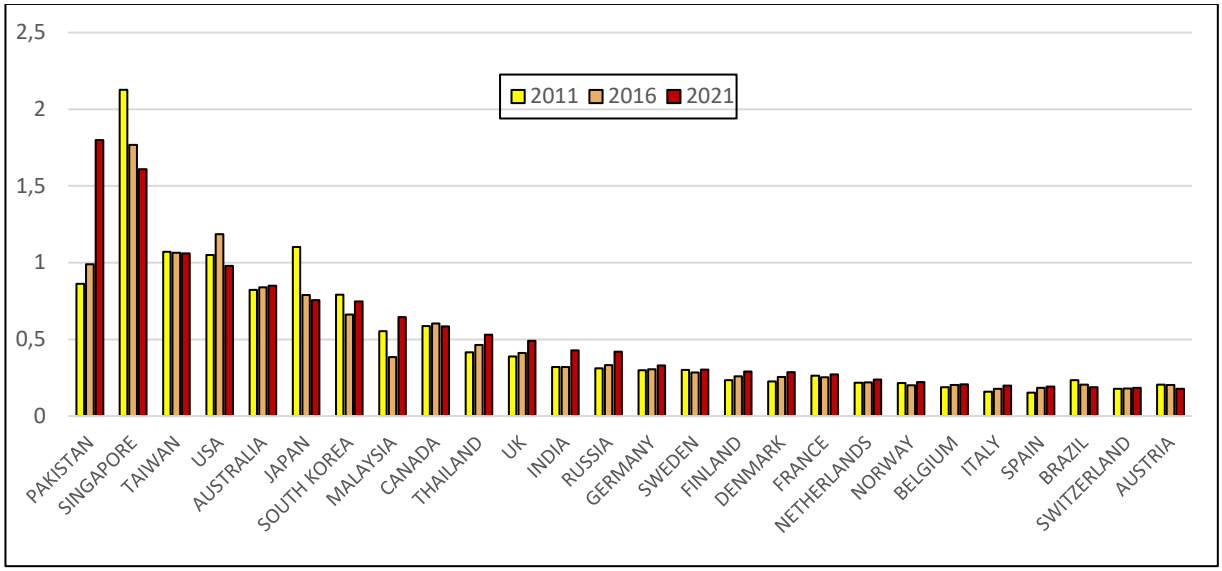

Figure 2.12. Relative intensities of collaboration in China's bilateral relations within a network of 27 countries in 2011, 2016, and 2021.

The most striking observation from a global perspective is the very high intensity in China's relation to the USA. This intensity is mutual, as seen in *Figure 2.13*. Calculated from the perspective of USA, the relation to China ranks highest in intensity among all American relations, even higher than the closest neighbour Canada.

The two largest countries in science, China, and the USA, are also very close collaborators and mutually dependent on each other. By the same measurement, the intensity in their relations to European countries is low. However, the UK stands out for both countries with higher intensity than in other European relations.

As shown in both diagrams, the collaboration intensity in the China-USA relation increases until 2016 and then decreases. We will return to this observation in the next section.

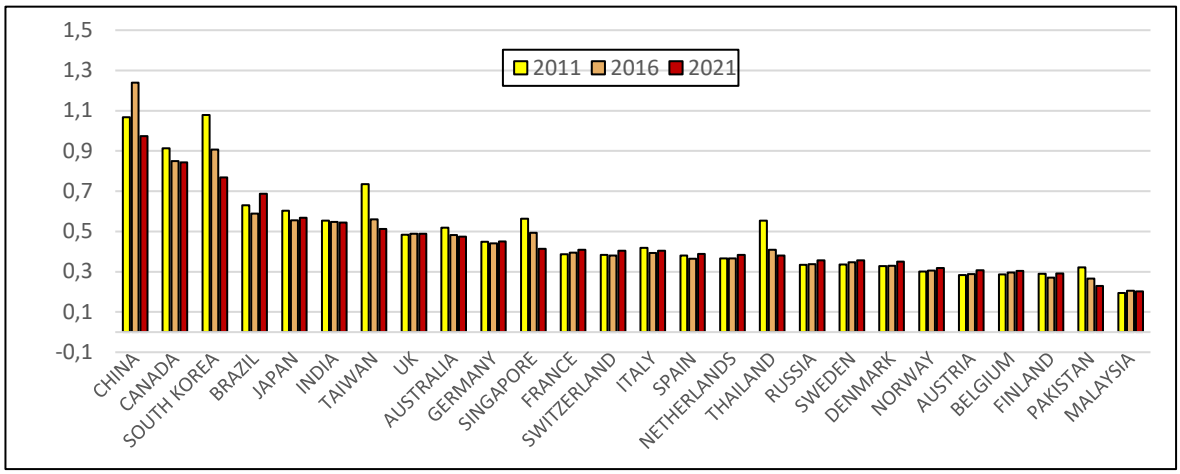

Figure 2.13. Relative intensities of collaboration in USA's bilateral relations within a network of 27 countries in 2011, 2016, and 2021.

2.2.5 Political factors

International collaboration in science is usually without abrupt changes. It normally follows the general trend of increasing globalization in research. Geographical and cultural closeness or distance, as well as multinational organizations and funding sources, also seem to play a role. However, some of the changes in collaboration intensity that were revealed in the analysis above may represent political changes. We will comment on two of them.

Figure 2.14 shows the proportions of the collaboration articles in China' relations to USA and UK within the total of China's collaboration articles each year from 2001 to 2021. The relative share of the USA drops after 2016 while the share of the UK continues to increase. This change in the relation to USA coincides with an increasing attention to national security and competition in both countries during the last five years. It has introduced hindrances to scientific collaboration and researcher and student mobility between the two countries (Zweig, 2021).

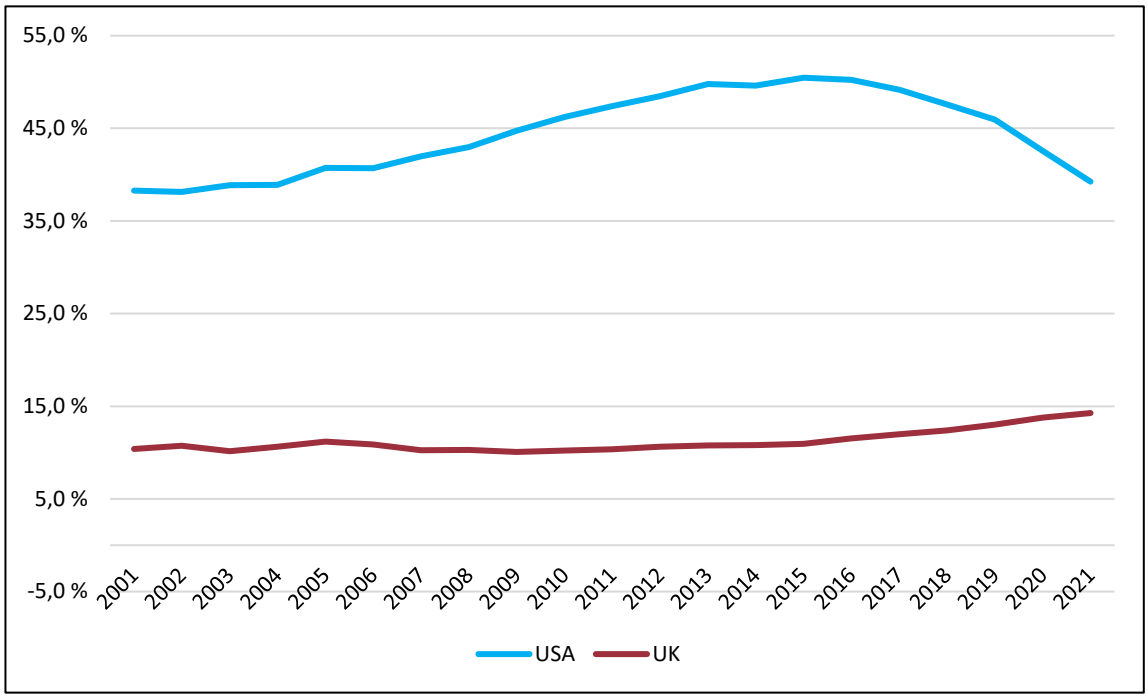

Figure 2.14. China's articles in collaboration with the UK and the USA as percentages of all of China's articles with international collaboration. Data representing Web of Science 2001-2021.

Another possible influence of policy is shown in *Figure 2.15*, which shows China's share in the total of articles with international collaboration that four Scandinavian countries were engaged in year by year between 2011 and 2021. The increasing relative importance of China in international scientific collaboration was the same for the four countries until 2014. The increase for Norway is then halted for four years until it is resumed in 2017 without reaching the same level as for the

other Scandinavian countries. This continued difference between the Scandinavian countries was also reflected in *Figure 2.12* above showing the relative intensities from the perspective of China.

The evident explanation seems to be China's unilateral decision to close official relations and collaboration with Norway after the Nobel Peace Prize was awarded to Liu Xiaobo in 2010 (Sverdrup-Thygeson, 2017). The relations were restored in 2016, among them the bilateral programme for collaboration in science. The revitalization of collaboration in higher education and science was marked by the China-Norway Science Day in Beijing on April 17, 2018. The reason why China's reaction in 2010 is not traceable in the diagram before in 2013-14, is that it may take 2-4 year from a research project is started until it is published. We also observe that collaboration did not disappear, the increase was only halted. Multilateral collaboration involving the two countries may be the stabilizing factor.

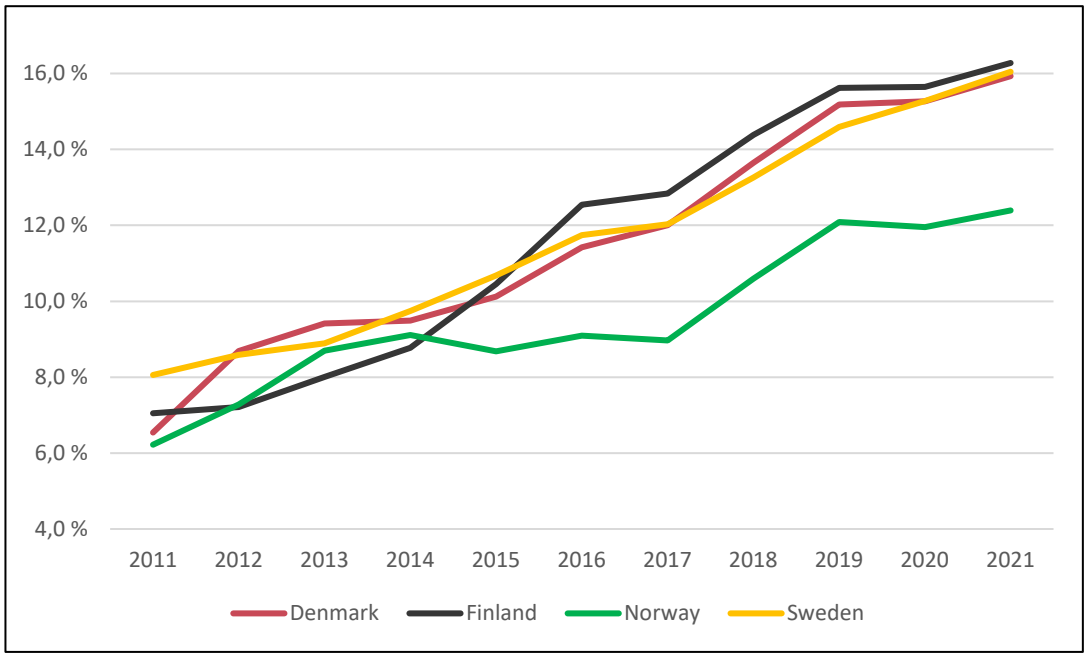

Figure 2.15. Articles in collaboration with China as a percentage of all articles with international collaboration from four Scandinavian countries in 2011-2021.

2.3 Summary

China has grown to become Norway's fourth largest collaboration partner in science after USA, UK, and Sweden if only scientific articles representing bilateral collaboration are considered. China is the tenth largest collaboration partner for Norway if articles with multilateral collaboration, mainly within Europe, are added.

The increasing importance of China is mainly due to the country's rapid growth within global science. China has now surpassed USA to become the largest

contributor to international scientific journals. All countries have had increasing collaboration with China. Comparing with the collaboration activity in the whole global network and adjusting for size, China is collaborating most intensely with other Asian countries and with USA, Australia, and Canada. USA and China are each other's most important collaboration partners in science. However, the intensity in this bilateral relation has decreased after 2016.

China' collaboration with Norway is less intense than it is with Denmark, Finland, and Sweden. Collaboration with Norway stagnated ten years ago but a revitalization can be observed since 2017.

3 Sino-Norwegian collaboration

This chapter is based on an analysis of almost 11,500 scientific articles that were published and indexed in Web of Science in 2001-2021 with authors' addresses in both China and Norway. Half of the articles were published the last five years 2017-2021. Hence, the analysis mainly reflects the more recent research collaboration activities in Sino-Norwegian relations.

Other countries than China and Norway are involved in almost two thirds of the articles. We will separate between articles with different types of collaboration – bilateral, trilateral, and multilateral – throughout the analysis.

As introduced in section 1.2.2, we separate between nine main areas of research based on a classification of journals: Biology, Biomedicine, Chemistry, Computer Science, Environmental Sciences, Health Sciences, Physics, Social Sciences and Humanities (SSH), and Technology.

Within each area of research and type of collaboration, we will identify the institutions that most frequently practice Sino-Norwegian collaboration in each of the countries. The most frequently used journals in each area of research will be listed to indicate the active fields of research more specifically.

3.1 Areas of research and type of collaboration

After allowing for double counting when classifying the articles by main area of research, the sum of analysed articles increases by 30 percent to 15,000. Within this number, the groups have different sizes, as shown in *Figure 3.1* where we also distinguish between three types of collaboration.

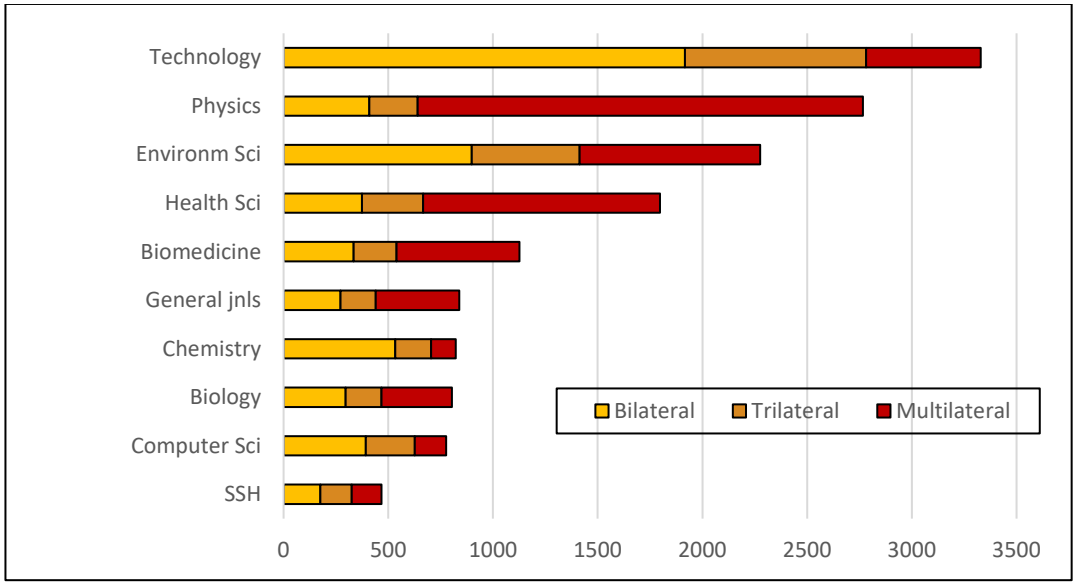

Figure 3.1. The number in articles with Sino-Norwegian collaboration 2001-2021 in each of ten categories and with a distinction between three types of collaboration at country level.

China and Norway often engage in collaboration in Physics and the Health Sciences, but this engagement is mostly driven by multinational collaboration. On the other hand, Technology, Environmental Sciences, Chemistry, and Computer Science represent main areas with more bilateral and trilateral collaboration. Collaboration in these areas is to a higher degree based on a specific mutual interest between Chinese and Norwegian researchers and their institutions.

Sino-Norwegian collaboration in science has a distinct profile when compared to the two countries general research profiles. We already saw in *Figure 2.6* above that the general profiles differ. In *Figure 3.2* below, all the years 2001-2021 are included to make visible the distinct profile of Sino-Norwegian collaboration, as shown in yellow.

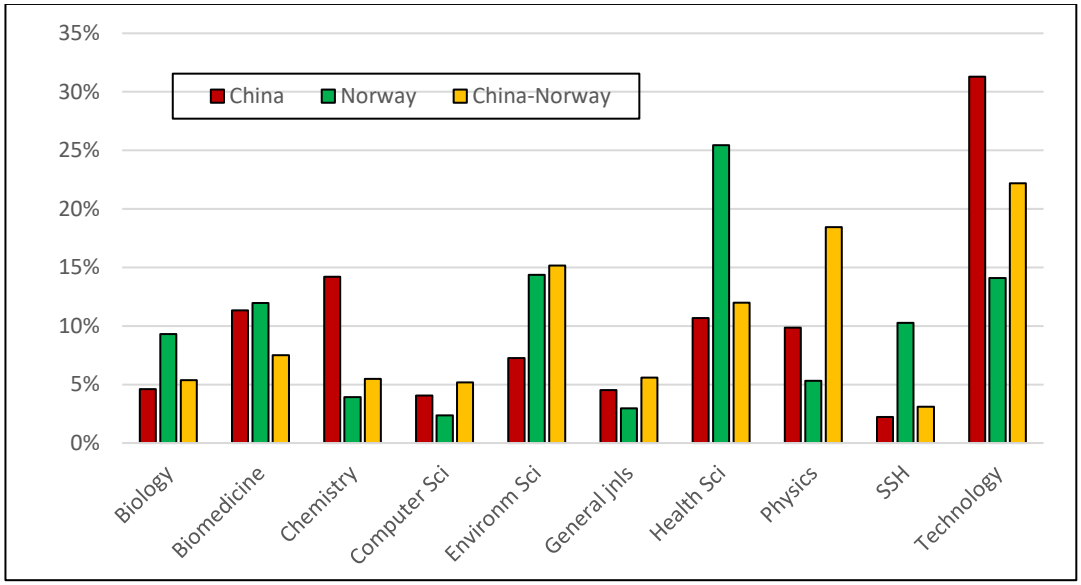

Figure 3.2. The shares of articles with Sino-Norwegian collaboration 2001-2021 in each of ten categories (in yellow) compared to the similar distribution when all articles from each of the countries in the same period are considered.

Biomedicine stands out as a major area of research where there is less collaboration than could be expected from the relative activity in each of the countries. The opposite is the case for Physics and Computer Science, where there is more collaboration than expected from the perspective of both countries. There is high collaboration activity in the Environmental Sciences, which is strong in Norway's profile, and in Technology, which is strong in China's profile. Collaboration in Biology, Chemistry, Health Sciences, and Social Sciences and Humanities is not influenced by high activity in one of the countries.

When combining Figures 3.1 and 3.2, we observe that Environmental Sciences, Technology and Computer Science are the areas of research with high relative collaboration intensity within mainly the bilateral and trilateral types of collaboration. Below, we will present the areas of research in an order of importance according to these criteria.

Figure 3.3 shows that in the same three main areas, Environmental Sciences, Technology and Computer Science, we find the strongest revitalization of collaboration after 2017. Biology is another area with strong increase, although the number of articles is lower.

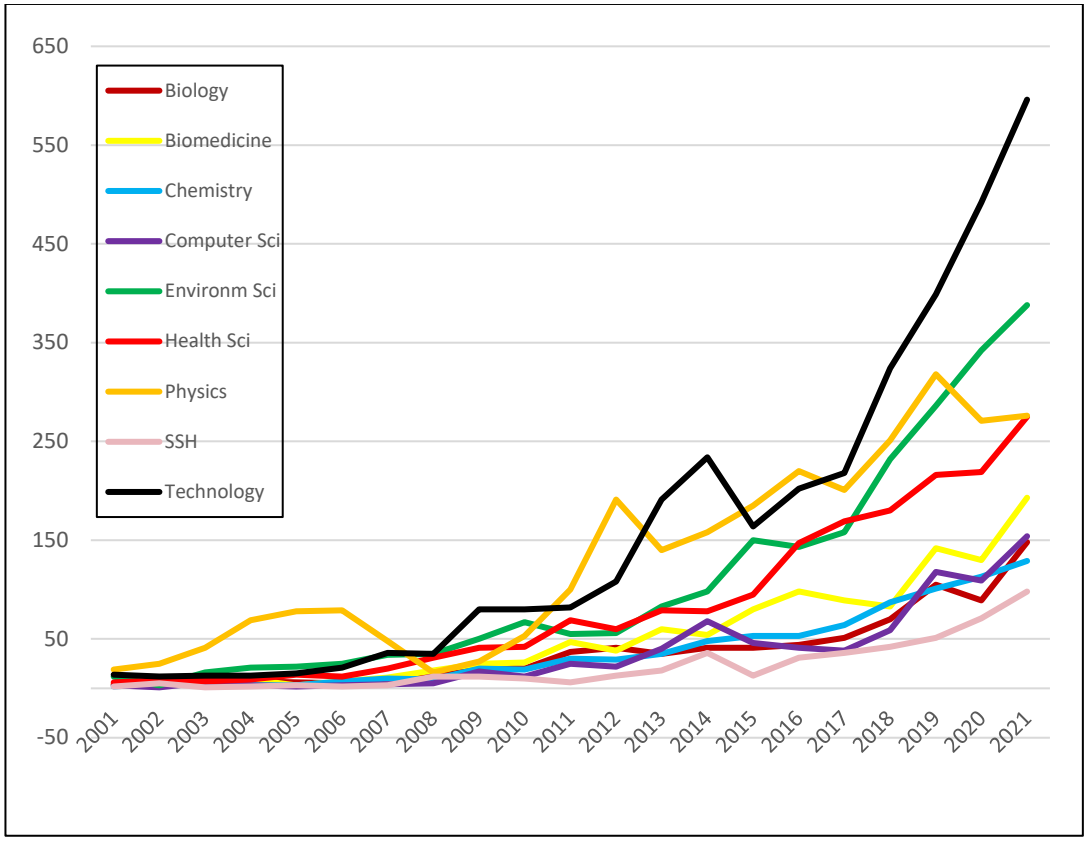

Figure 3.3. Number of articles with Sino-Norwegian collaboration 2001-2021 in nine major areas of research.

3.1.1 Contributing research sectors on the Norwegian side

The universities and other higher education institutions in Norway are the most frequent Norwegian partners in published research from Sino-Norwegian collaboration. This is shown in *Figure 3.4*. The independent research institutes are also active in the collaboration, particularly in biology, environmental sciences, and computer science. (We chose to classify the Bjerknes Centre for Climate Research and its affiliated organizations in Bergen as belonging to the higher education sector, which might underestimate the contribution of the institute sector to the collaboration in environmental sciences.) The contribution of research in the health sector is as expected significant in Biomedicine and the Health Sciences. There are small contributions from the corporate sector in all areas of research. But the contribution of this sector to research collaboration might be underestimated in our data since this sector's research is often not published.

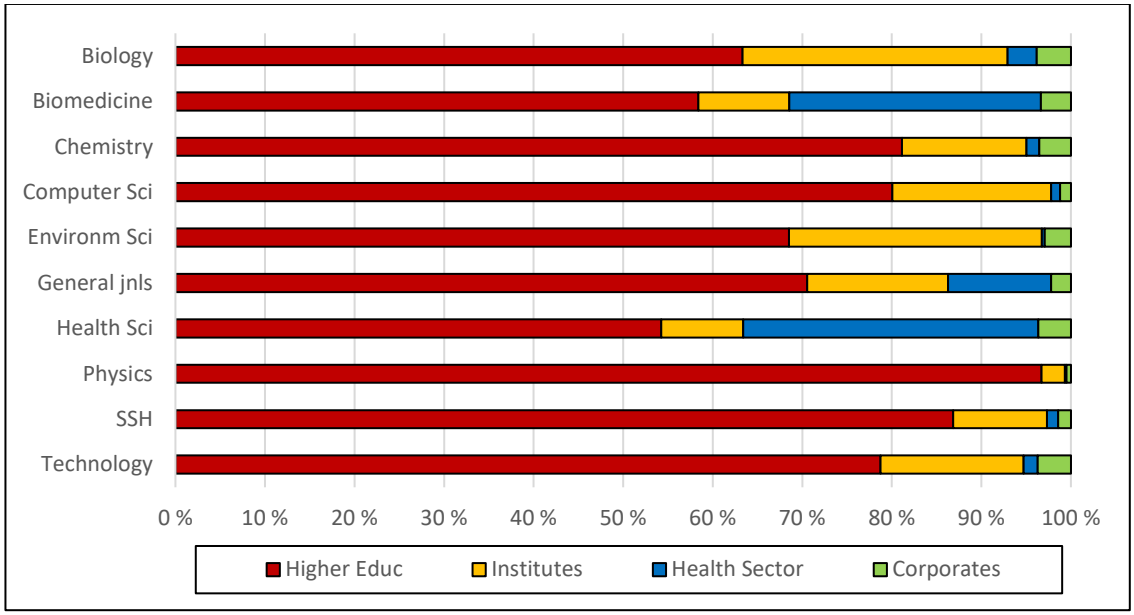

Figure 3.4 Articles with Sino-Norwegian collaboration 2001-2021 in nine major areas of research. Shares between four sectors of research on the Norwegian side.

In the following, we will have a closer look at the most frequent journals and collaborating institutions in Sino-Norwegian research collaboration in each of nine major areas of research (excluding the category General Journals). We present the areas of research in the order or relative importance for the bilateral relation as found in the analysis above. The underlying data represent scientific articles with author addresses in both China and Norway published 2001-2021 and indexed in Web of Science.

3.2 Collaboration in nine major areas of research

3.2.1 Environmental sciences

The analysis of Sino-Norwegian collaboration in this area of research is based on 2,276 articles published 2001-2021. Of these, 898 are based on bilateral collaboration. In 515 articles with trilateral collaboration, USA, UK, Germany, Sweden, Australia, and Canada are the six most frequent third partners. France replaces Sweden among the six most frequent partners in 863 articles with multilateral collaboration.

The most frequent journals that have published articles from Sino-Norwegian collaboration in the Environmental Sciences are listed in *Figure 3.5*. Specialized journals in climate research and marine research and engineering are present are present among more general journals representing geophysics and environmental

science. Hydrological engineering also seems to be a focused area of frequent collaboration.

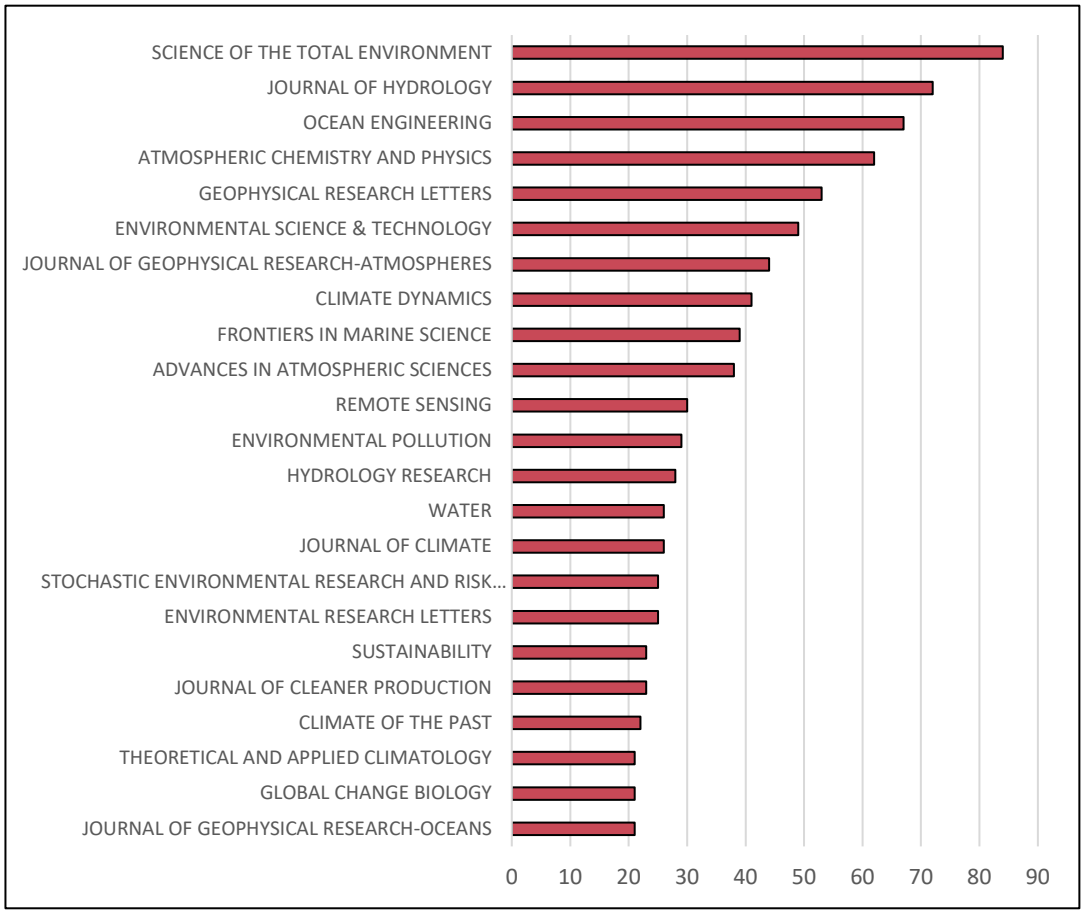

Figure 3.5. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in the Environmental sciences.

The most active partners on the Norwegian side in the Environmental sciences are University of Bergen (Geophysical institute, Bjerknes Centre for Climate Research, Nansen Environmental and Remote Sensing Centre) and University of Oslo (particularly Department of Geosciences). The three other major universities in the sciences are active: Norwegian University of Science and Technology, UiT - the Arctic University of Norway, and Norwegian University of Life Sciences. Several independent institutes are important for collaboration in this area of research: Norwegian Institute for Water Research (NIVA), CICERO - Center for International Climate Research, Norwegian Institute for Air Research (NILU), Norwegian Meteorological Institute, Institute for Marine Research, Norwegian Institute of Bioeconomy Research (NIBIO), Norwegian Polar Research Institute, Norwegian Geotechnical Institute (NGI), Geological Survey of Norway (NGU), and Norwegian Institute for Natural Research (NINA).

On the Chinese side, a major partner is the Institute of Atmospheric Physics (IAP) of the Chinese Academy of Sciences. Some of this collaboration is with two centres hosted by IAP, the Climate Change Research Center (CCRC) and the Nansen-Zhu International Research Center (NZC). The latter was founded in collaboration with the above-mentioned partners in Bergen. Several other CAS institutes are active partners as well: Institute of Geology and Geophysics, Guangzhou Institute of Geochemistry, Institute of Geographical Sciences and Natural Resources Research, Nanjing Institute of Geography and Limnology, Institute of Tibetan Plateau Research, and the Research Center for Eco-Environmental Sciences.

Another major Chinese partner is the State Key Laboratory of Water Resources and Hydropower Engineering Science at Wuhan University. Two other state laboratories are also active: The State Key Laboratory of Hydrology-Water Resources and Hydraulic Engineering at Hohai University, and the State Key Laboratory of Estuarine and Coastal Research at East China Normal University.

The most active other universities are the University of the Chinese Academy of Sciences, Peking University, the China University of Geosciences in Wuhan, Tsinghua University, Beijing Normal University, and Nanjing University.

After going through the material, we see that there are in fact three fields of research that we have analysed under the umbrella 'Environmental sciences', each of them with a high collaboration activity supported by mutual interest and the most important institutions on both sides: 1) environmental sciences based on geophysical research, particularly in climate research, 2) marine science and engineering, and 3) hydrological engineering.

3.2.2 Technology

The analysis of Sino-Norwegian collaboration in this area of research is based on 3,329 articles published in 2001-2021. Of these, 1,917 are based on bilateral collaboration. In 865 articles with trilateral collaboration, USA, UK, Sweden, Australia, Singapore, and Germany are the six most frequent third partners. Italy and France replace Sweden and Singapore among the six most frequent partners in 547 articles with multilateral collaboration.

The most frequent journals that have published articles from Sino-Norwegian collaboration in Technology are listed in *Figure 3.6*. The profile represents industrial and marine engineering, materials science, and environmental engineering, the latter with overlap towards environmental sciences, see above. There is also overlap with information technology, see Computer science below.

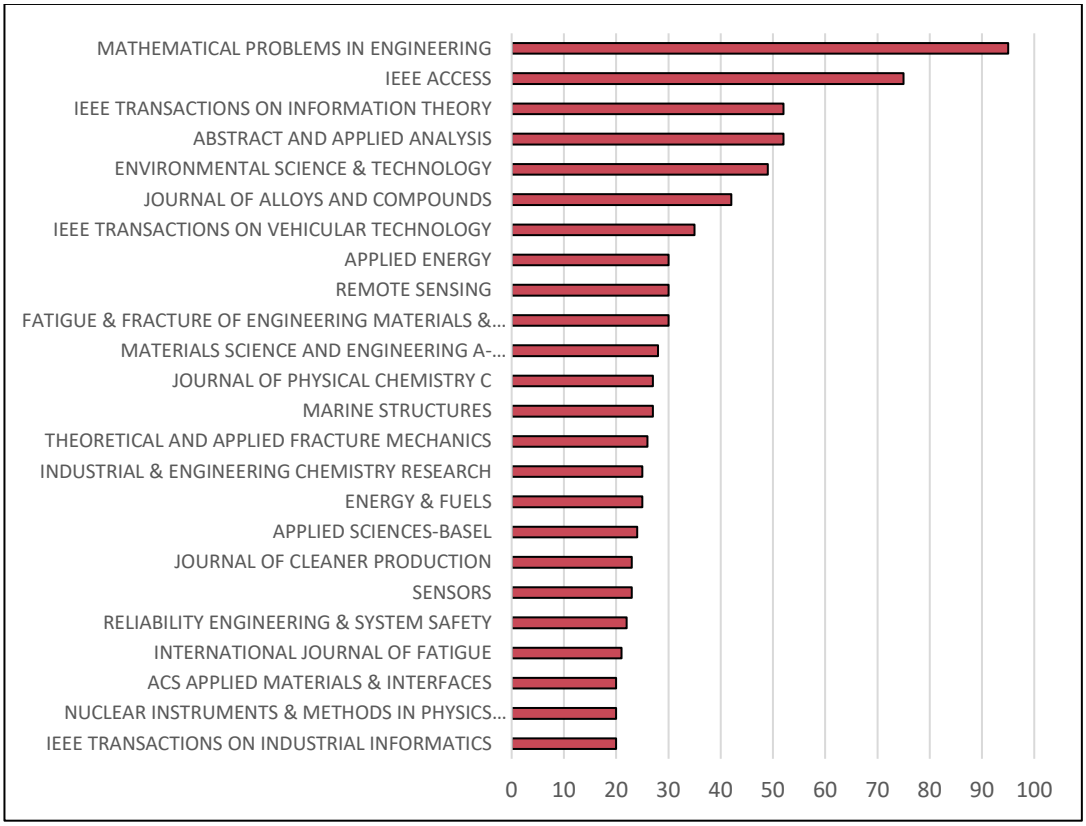

Figure 3.6. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in Technology.

The two major partners on the Norwegian side are the Norwegian University of Science and Technology (NTNU) and several divisions of SINTEF. Other institutes are active as well: Simula Research Laboratory, Simula Metropolitan Center for Digital Engineering, Norwegian Geotechnical Institute (NGI), and Institute for Energy Technology (IFE).

The other most active universities are University of Oslo, University of Agder, University of Bergen, University of Stavanger, and University of South-Eastern Norway.

Corporate research in Norway is also involved: Equinor, Super Radio AS, DNV GL, and Marintek.

Major actors on the Chinese side are the State Key Laboratory of Chemical Engineering at East China University of Science and Technology, and the State Key Laboratory of Ocean Engineering at Shanghai Jiao Tong University. Active are also the College of Engineering at Bohai Univ, the School of Automation of Guangdong University of Technology, Harbin Institute of Technology, and Nanjing University of Science and Technology, Chongqing University, Wuhan University of Technology, University of Science and Technology Beijing, and Jiangsu University of Science & Technology.

3.2.3 Computer science

The analysis of Sino-Norwegian collaboration in this area of research is based on 776 articles published 2001-2021. Of these, 392 are based on bilateral collaboration. In 234 articles with trilateral collaboration, UK, USA, Singapore, Canada, Australia, and France are the six most frequent third partners. Taiwan and Germany replace Singapore and France among the six most frequent partners in 150 articles with multi-lateral collaboration.

The most frequent journals that have published articles from Sino-Norwegian collaboration in Computer science are listed in *Figure 3.7*. The profile represents both industrial applications and applications in telecommunication.

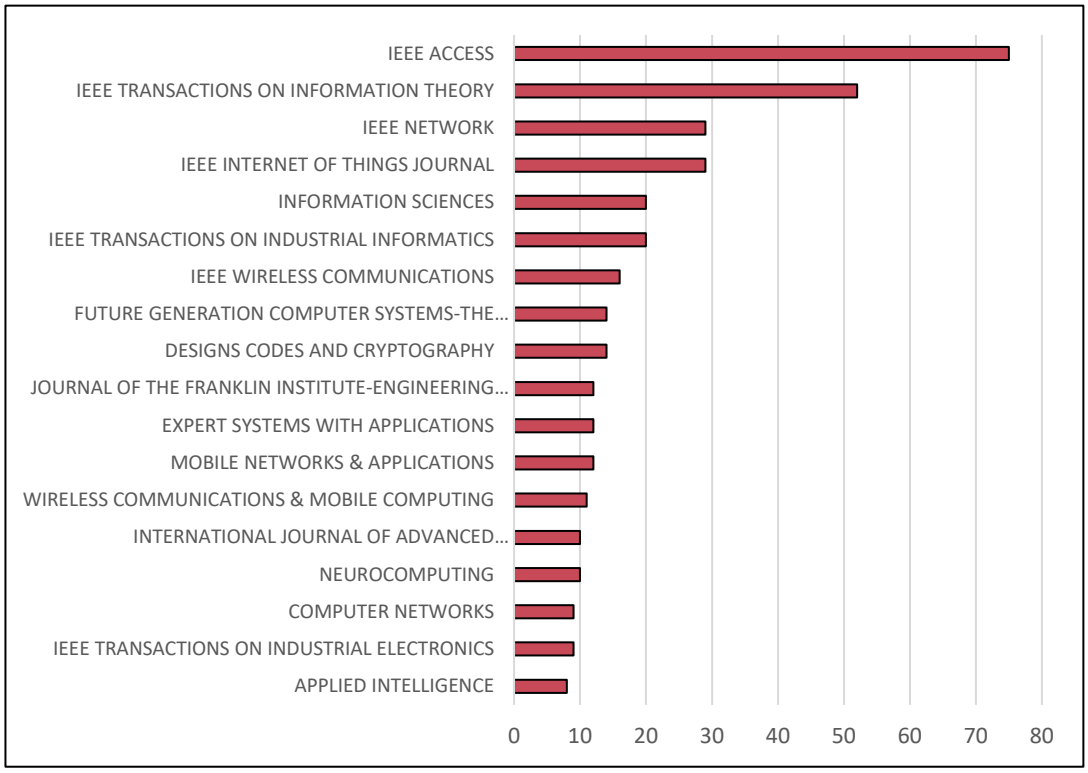

Figure 3.7. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in Computer science.

The two major partners on the Norwegian side are the Norwegian University of Science and Technology (NTNU) and University of Oslo. The other most active universities are University of Agder, University of Bergen, Western Norway University of Applied Sciences and University of Stavanger. Simula Research Laboratory and Simula Metropolitan Center for Digital Engineering are also active.

The major actor on the Chinese side is Harbin Institute of Technology. Otherwise, as in Norway, universities dominate in the collaboration: Macau University of Science & Technology, Guangdong University of Technology, University of

Electronic Science and Technology of China, Hubei University, Nanjing University of Science and Technology, and Shandong University of Science & Technology.

3.2.4 Physics

The analysis of Sino-Norwegian collaboration in this area of research is based on 2,766 articles published 2001-2021. Of these, only 410 are based on bilateral collaboration. In 230 articles with trilateral collaboration, USA, Sweden, UK, Germany, Italy, and Australia are the six most frequent third partners. France and Russia replace Sweden and Australia among the six most frequent partners in 2,126 articles with multilateral collaboration, which Sino-Norwegian collaboration in this area of research is dominated by.

The most frequent journals that have published articles from Sino-Norwegian collaboration in Physics are listed in *Figure 3.8*. The profile is dominated by high-energy physics, but astrophysics and applied physics are represented as well.

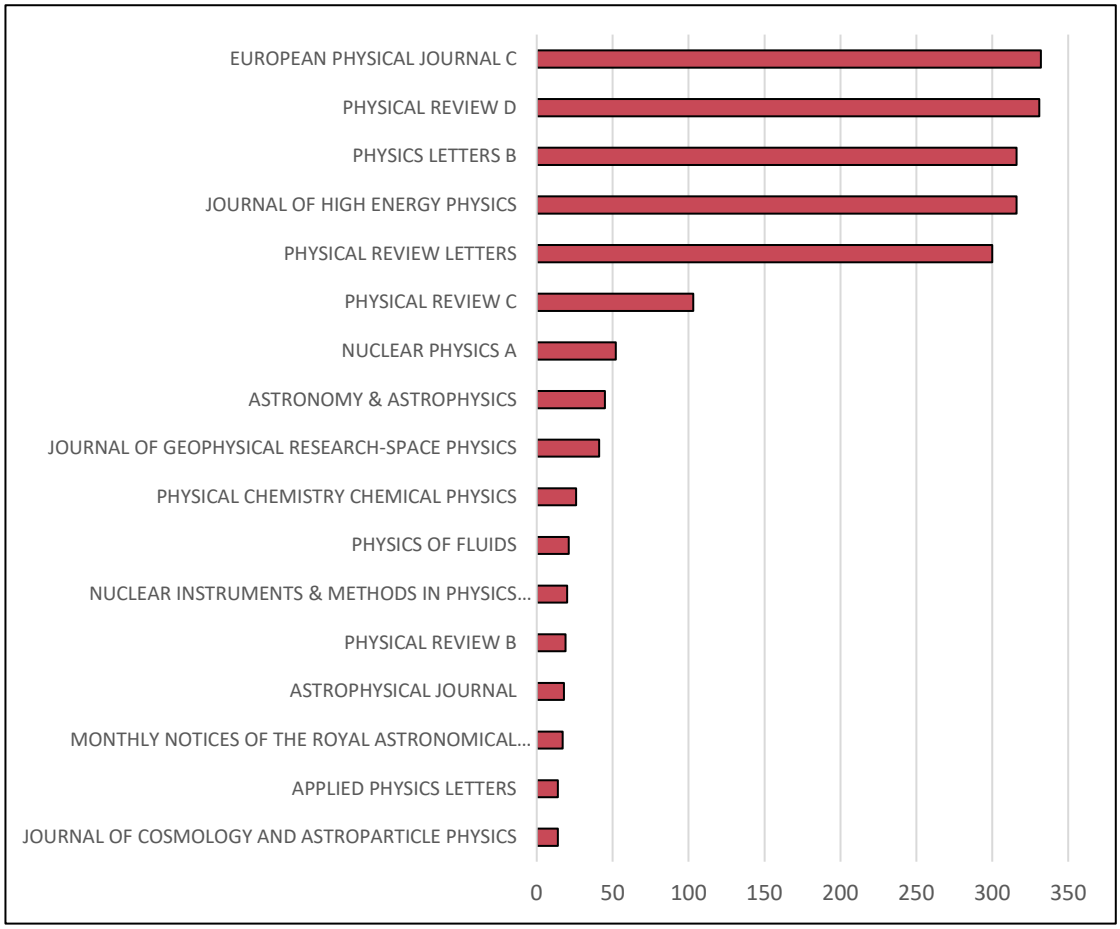

Figure 3.8. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in Physics.

Five universities are the major partners on the Norwegian side: University of Bergen, University of Oslo, University of South-Eastern Norway, Western Norway University of Applied Sciences, and Norwegian University of Science and Technology.

The major actors on the Chinese side are the Institute for High Energy Physics and the China Institute of Atomic Energy of the Chinese Academy of Sciences, as well as the Department of Physics at Nanjing University. Departments of Physics at other universities are active as well: University of Science and Technology of China, University of Hong Kong, Chinese University of Hong Kong, Shandong University, Hong Kong University of Science & Technology, Tsinghua University, University of the Chinese Academy of Sciences, and Central China Normal University in Wuhan.

3.2.5 Chemistry

The analysis of Sino-Norwegian collaboration in this area of research is based on 822 articles published 2001-2021. Of these, as many as 533 are based on bilateral collaboration. In 171 articles with trilateral collaboration, Sweden, USA, Denmark, UK, Germany, and Italy are the six most frequent third partners. France replaces Italy among the six most frequent partners in 118 articles with multilateral collaboration.

The most frequent journals that have published articles from Sino-Norwegian collaboration in Chemistry are listed in *Figure 3.9*. The profile is focused on materials science and physical chemistry.

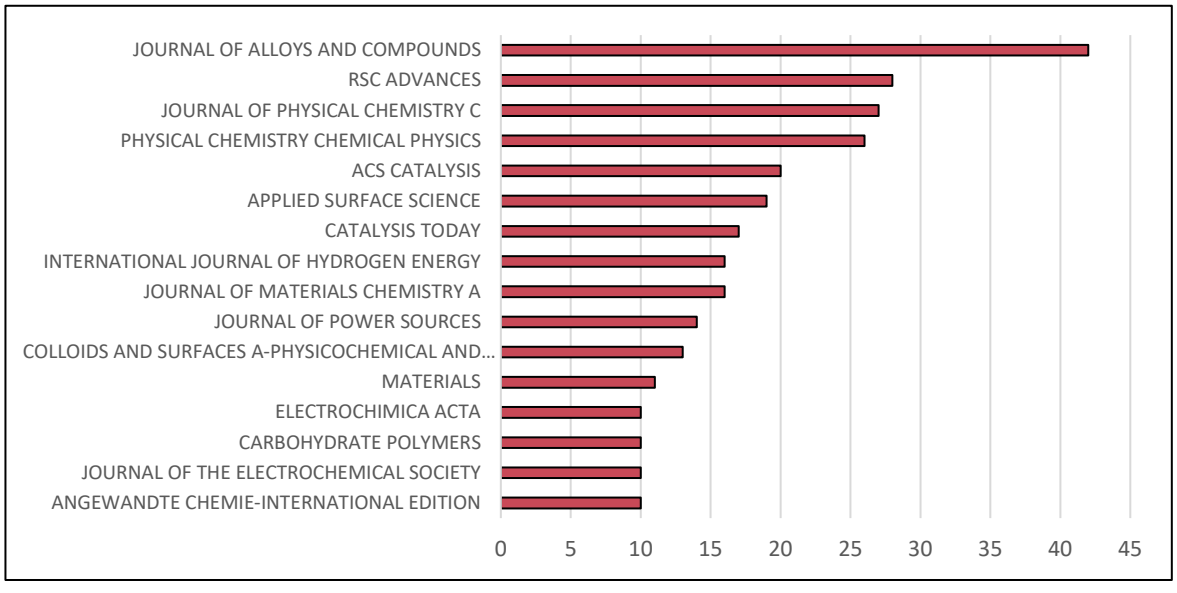

Figure 3.9. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in Chemistry.

SINTEF and four universities are the major partners on the Norwegian side: Norwegian University of Science and Technology, University of Oslo, University of Bergen, and University of South-Eastern Norway.

The major actor on the Chinese side is the State Key Laboratory of Chemical Engineering, East China University of Science and Technology. Other frequent collaborators are Sichuan Agricultural University, Jiaxing University, China University of Petroleum, Central South University, and Jiangsu University.

3.2.6 Biology

The analysis of Sino-Norwegian collaboration in this area of research is based on 804 articles published 2001-2021. Of these, 296 are based on bilateral collaboration. In 172 articles with trilateral collaboration, USA, Germany, UK, Finland, Denmark, and Sweden are the six most frequent third partners. France, Australia, and Canada replace the other Nordic countries among the six most frequent partners in 118 articles with multilateral collaboration.

The most frequent journals that have published articles from Sino-Norwegian collaboration in Biology are listed in *Figure 3.10*. The profile is clearly focused on the characteristic Norwegian orientation in biology: Marine biology and fisheries research.

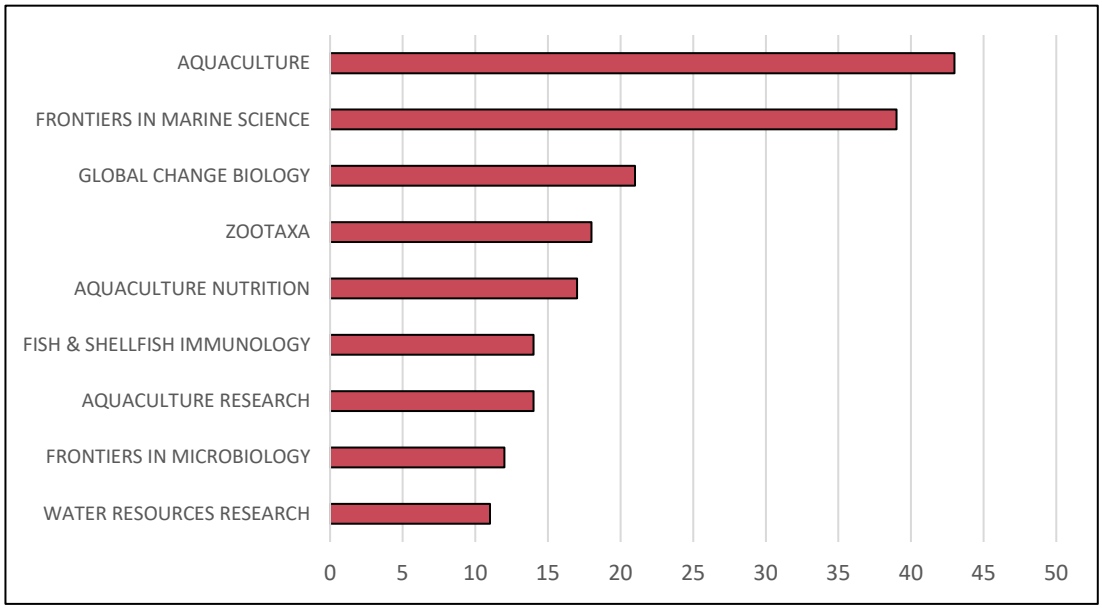

Figure 3.10. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in Biology.

The five largest universities in Norway are major actors on the Norwegian side: University of Oslo, University of Bergen, Norwegian University of Life Sciences, Norwegian University of Science and Technology, and UiT - The Arctic University

of Norway. However, research institutes are also major contributors: Institute for Marine Research, NIBIO, Norwegian Institute for Natural Research, Norwegian Institute for Water Research, and Nofima.

The Feed Research Institute of the Chinese Academy of Agricultural Sciences is an active partner on the Chinese side. Several institutes of the Chinese Academy of Sciences also contribute: Institute of Zoology, Kunming Institute of Botany, Institute of Oceanology, Institute of Microbiology, Institute of Applied Ecology, and Chengdu Institute of Biology. Among the universities, the main partners are the College of Life Sciences at Nankai University, The School of Life Sciences at Sun Yat-sen University, and the College of Life Sciences at Hainan Normal University.

3.2.7 Biomedicine

The analysis of Sino-Norwegian collaboration in this area of research is based on 1,126 articles published 2001-2021. Of these, 335 are based on bilateral collaboration. In 204 articles with trilateral collaboration, USA, UK, Denmark, Sweden, Netherlands, and Australia are the six most frequent third partners. Germany and Canada replace Denmark and the Netherlands among the six most frequent partners in 587 articles with multilateral collaboration.

The most frequent journals that have published articles from Sino-Norwegian collaboration in Biomedicine are listed in *Figure 3.11*. The profile is mostly focused on human biology and genetics, and on oncology, but marine biology is also represented here.

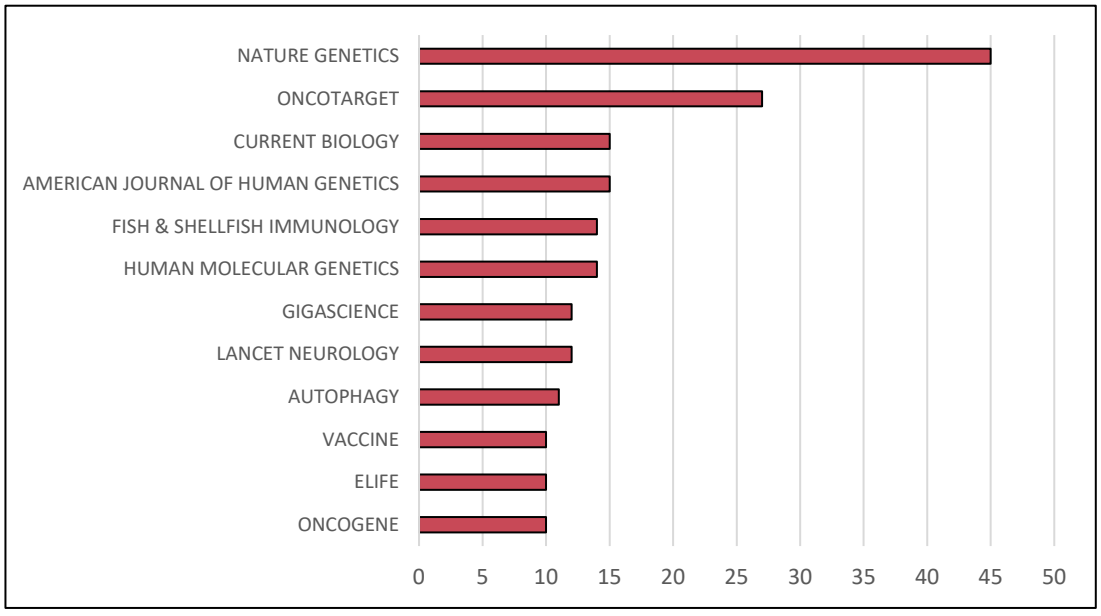

Figure 3.11. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in Biomedicine.

The major actors on the Norwegian side are the university hospitals and universities in Oslo, Bergen, Trondheim, and Tromsø. In addition, Institute for Marine Research in Bergen and the National Public Health Institute contribute.

Major partners on the Chinese side are the Medical Schools and the affiliated hospitals of Zhengzhou University, Shandong University, Shanghai Jiao Tong University, and Peking University. In addition, there are several contributions from the Shanghai Cancer Institute and from BGI Shenzhen life sciences company (formerly Beijing Genomics Institute).

3.2.8 Health sciences

The analysis of Sino-Norwegian collaboration in this area of research is based on 1,797 articles published 2001-2021. Of these, 375 are based on bilateral collaboration. In 291 articles with trilateral collaboration, USA, UK, Sweden, Denmark, Australia, and Canada are the six most frequent third partners. Germany replaces Denmark among the six most frequent partners in 1,131 articles with multilateral collaboration, which is the dominating type of Sino-Norwegian collaboration in this area of research.

The most frequent journals that have published articles from Sino-Norwegian collaboration in the health sciences are listed in *Figure 3.12*. Prestigious general journals dominate, which is as expected in studies based on multilateral collaboration in the health sciences. Oncology is the dominating subdiscipline.

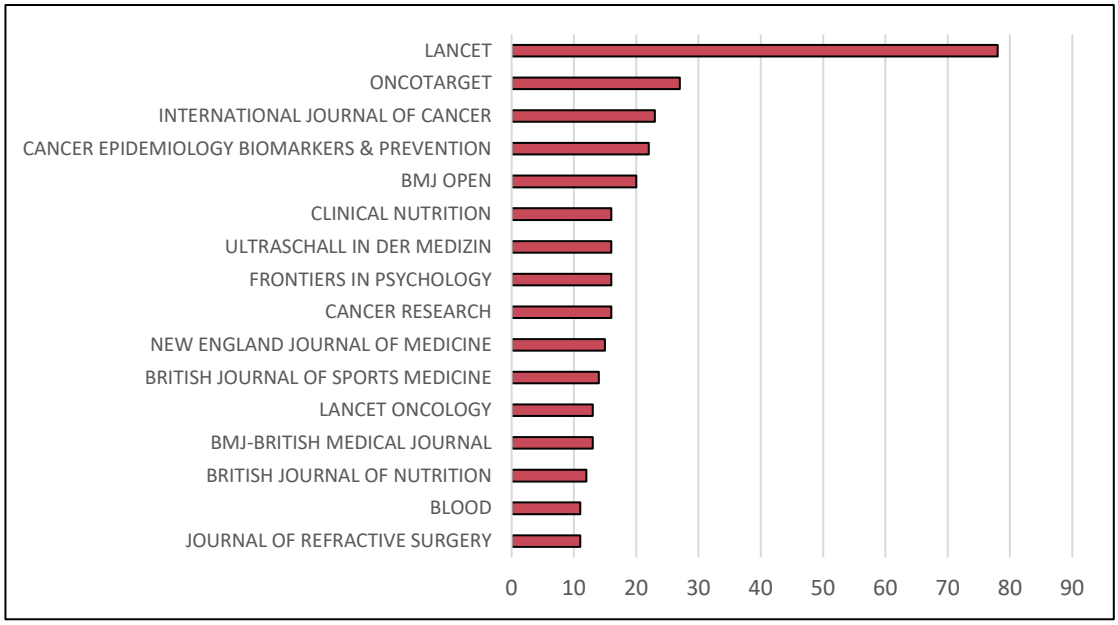

Figure 3.12. The journals that most frequently published articles with Sino-Norwegian collaboration 2001-2021 in Health sciences.

Again, as in biomedicine, the major actors on the Norwegian side are the university hospitals and universities in Oslo, Bergen, Trondheim, and Tromsø. The hospitals in Stavanger and Lillehammer also contribute. In addition, the Cancer Registry of Norway and the Norwegian School of Sports Sciences are active.

Major partners on the Chinese side are the Medical Schools and the affiliated hospitals of Zhengzhou University, Nanjing Medical University, Shandong University, Shanghai Jiao Tong University, Sichuan University, Fudan University, and University of Hong Kong. In addition, there are several contributions from the Chinese Center for Disease Control and Prevention.

3.2.9 Social sciences and humanities

The analysis of Sino-Norwegian collaboration in these areas of research is based on 467 articles published 2001-2021. Of these, 175 are based on bilateral collaboration. In 151 articles with trilateral collaboration, USA, UK, Israel, Australia, Canada, and the Netherlands are the six most frequent third partners. Germany replaces Israel among the six most frequent partners in 141 articles with multilateral collaboration.

The social sciences and humanities (SSH) are wide areas of research represented with only a limited number of articles in this report. One reason is that Web of Science has limited coverage of scholarly publishing in these areas (Aksnes & Sivertsen, 2019). We also saw in Figure 3.2 above that the relative activity of China is low in the SSH, at least as measured within Web of Science. The relative activity for Norway is much higher but seems not to be prioritized in the Sino-Norwegian relation.

To solve the problem with few articles representing two wide areas of research, we will, instead of presenting just one list of journals, name a few journals per discipline within the SSH. We present the disciplines in descending order of articles in our data and concentrate on those with at least fifteen articles.

Business and Economics dominate in our data with 280 articles. The most frequent journals are INTERNATIONAL JOURNAL OF PROJECT MANAGEMENT, PROJECT MANAGEMENT JOURNAL, and ENERGY POLICY.

Education & Educational Research is also frequent with 46 articles. Most frequent are SCANDINAVIAN JOURNAL OF EDUCATIONAL RESEARCH, INTERNATIONAL JOURNAL OF SCIENCE AND MATHEMATICS EDUCATION, and HIGHER EDUCATION POLICY.

Public Administration is represented with 41 articles. The most frequent journals are TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE, INTERNATIONAL REVIEW OF ADMINISTRATIVE SCIENCES, INTERNATIONAL PUBLIC MANAGEMENT JOURNAL, and HABITAT INTERNATIONAL.

Psychology is represented with 26 articles. The most frequent journals are JOURNAL OF HAPPINESS STUDIES, JOURNAL OF ORGANIZATIONAL BEHAVIOR, PERSONNEL PSYCHOLOGY, APPLIED PSYCHOLOGICAL MEASUREMENT, and ARCHIVES OF SEXUAL BEHAVIOR.

Geography is represented with 21 articles. The most frequent journals are GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS, INTERNATIONAL JOURNAL OF GEOGRAPHICAL INFORMATION SCIENCE, TRANSACTIONS IN GIS, and EUROPEAN PLANNING STUDIES.

Information Science & Library Science is represented with 15 articles. The most frequent journals are JOURNAL OF KNOWLEDGE MANAGEMENT, SCIENTOMETRICS, and JOURNAL OF GEOGRAPHICAL INFORMATION SCIENCE.

The main actors on the Norwegian side of Sino-Norwegian collaboration in the SSH are University of Oslo, Norwegian University of Science & Technology, BI Norwegian Business School (BI), University of Stavanger, University of Bergen, University of Agder, Norwegian School of Economics (NHH), CICERO - Center for International Climate Research, Oslo Metropolitan University, and Nordic Institute for Studies in Innovation, Research and Education (NIFU).

The main actors on the Chinese side are City University of Hong Kong, Tsinghua University, Zhejiang University, Renmin University, University of Hong Kong, Chinese University of Hong Kong, Beijing Normal University, and Wuhan University.

3.3 Summary

By using three criteria to assess the relative importance of an area of research in Sino-Norwegian scientific collaboration, we could rank them in this order:

1. Environmental sciences
2. Technology
3. Computer science
4. Physics and Chemistry
5. Biology
6. Biomedicine and Health Sciences
7. Social Sciences and Humanities

We find three fields of research under the umbrella Environmental sciences which stand out with high collaboration activity that seems to be organized and supported in mutual interest between the most important institutions on both sides: 1) environmental sciences based on geophysical research, particularly in climate research, 2) marine science and engineering, and 3) hydrological engineering.

Technology and computer science reflect the priorities and strengths in the research profile of China as compared to the rest of the world. There is a Norwegian 'mark' on what seems to be the common interests in these areas of research:

marine engineering, materials science, and environmental engineering within technology, and telecommunications within computer science.

Chinese science is traditionally strong in the physical sciences, less strong in the life sciences. The strengths of China are mirrored in the collaboration with Norway. There is much collaboration in physics and astrophysics, but this interaction is mostly mediated by multilateral collaboration, e.g., in high energy physics. Bilateral collaboration is relatively more important in chemistry where we observe a focus on materials science and physical chemistry.

Biology includes the sciences of bioproduction in our analysis. The activity in the Sino-Norwegian relation is not high, but the profile in biology is clearly focussed on the characteristic Norwegian orientation: Marine biology and fisheries research.

In most of the areas of research mentioned so far, the universities play a major role on the Norwegian side, but the research institutes are also important in some fields of research. As we turn to biomedicine and the health sciences, the Norwegian hospitals are also active collaboration partners. However, a large part of this collaboration with China is mediated by multilateral consortia and projects. Also, the strengths of Norwegian research in these areas are not mirrored in China.

The social sciences and humanities are areas of research without much collaboration between China and Norway. China is less active than Norway in journals covering these areas in Web of Science. The collaboration with Norway is dominated by studies in business and economics.

4 Collaboration in Arctic Research

4.1 Defining Arctic research

This chapter seeks to describe Sino-Norwegian research collaboration in a specific field of research, Arctic research, within the global context of all research performed in the same field. Including the global context requires other methods for delimitation of data than the country affiliations of authors. The usual method is instead to use the field classifications available in Web of Science which are based sets of journals. However, Arctic research is not a field classification in Web of Science. Only a few journals are specialized in Arctic research and most relevant publications are found in more general journals.

We have applied the same solution to this problem as in a previous NIFU-publication with publication analysis of Polar research (Aksnes, 2017). Artic research is thereby defined by a small set of journals[1] and an additional topical search by certain keywords.[2] We regard this solution as sufficiently precise and comprehensive for our purpose, which is describing main actors and trends in international collaboration. The method provided a dataset of almost 32,600 scientific articles from the five years 2017-2021.

[1] Antarctic Science; Arctic, Antarctic & Alpine Research; Arctic Anthropology; Permafrost and Periglacial Processes; Polar Biology; Polar Record; Polar Research; Polish Polar research.

[2] Arctic; Svalbard; Spitsbergen; Longyearbyen; Ny-Alesund; Hornsund; Barentsburg; Kongsfjord; Hopen; Bjornoya (Bear Island); Greenland; Baffin Island; Queen Elizabeth Islands ; Ellesmere Island; Devon Island; Somerset Island; Prince of Wales Island; Banks Island; Ellef Ringnes Island; Amund Ringnes Island; Bathurst Island; Axel Heiberg Island; Prince Patrick Island; King William Island; Prince Charles Island; Bylot Island; Bathurst Island; Southampton Island; Brooks Range; St Lawrence Island; St Matthew Island; Seward Peninsula; Nunivak Island; Novaya Zemlya; Severnaja Zemlya; Novosibirskije Ostrova; Jan Mayen; Victoria islands; Nunavut; Greenland sea; Fram strait; Beaufort sea; North-pole; Davis Strait; Barents sea; Kara sea; Storfjorden; Baffin; Hudson Bay; Siberian Sea; Laptev Sea; Chukchi Sea; Bering Strait; Bering Sea; Karskoje Sea; Yamal Peninsula; Hudson Strait; Lomonosov Ridge; north polar; north magnetic pole; Amundsen Basin; Amundsen Gulf; Beaufort Gyre; Cambridge Bay; Canada Basin; Cumberland Sound; Denmark Strait; Eurasian Basin; Lancaster Sound; Mendeleev Ridge; Nares Strait; Northwest Passage; Repulse Bay; polynya; Resolute Bay; Taymyr Peninsula; qaanaaq; Tiksi; Chukchi; Wrangel Island; Nunavik; Barents; Ungava; Yupik; Inupiat; Inuit; Eskimo; Greenlander.

4.2 Characteristics of Arctic research

4.2.1 Frequently contributing countries

The sixteen countries that contribute the most to Arctic research are shown in *Figure 4.1*. The number of scientific articles in the field published 2017-2021 (left scale) is calculated as a percentage of the total of scientific articles from the country in all fields of science in the same period. Norway stands out as the country most dedicated to Arctic research relative to its size (4.5 percent of Norway's scientific output is dedicated to the field). This is a prioritization of Arctic research that makes Norway the fifth largest country contributing to the field. The other Nordic countries are also relatively active together with Canada and Russia. The least active country is China with 0.18 percent of its publications dedicated to Arctic research. Other large countries in science such as USA, UK, Germany, and France are clearly more active by the same measure. However, the number of scientific articles with contributions from China are as many as those from UK and Norway.

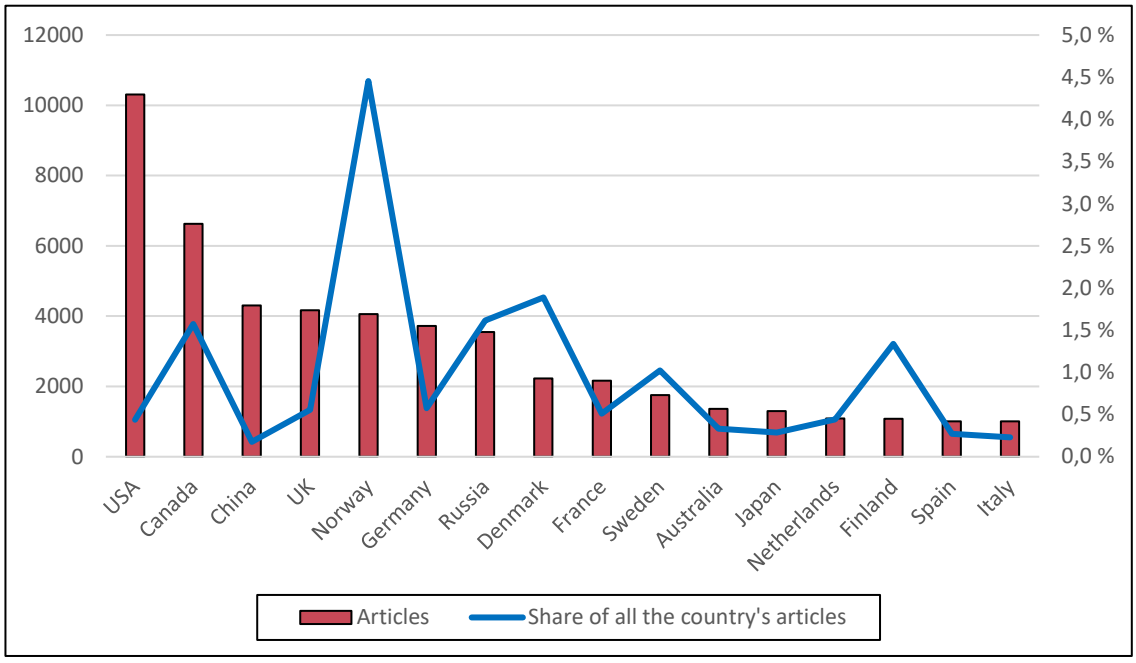

Figure 4.1. The 16 countries contributing most to Arctic research 2017-2021. The number articles is shown in red. In blue: The share these articles represent among all scientific articles from the same country in the same period.

To study the relative activity over time, we selected eight countries for further analysis, those that are most active relative to size (Norway, Denmark, Russia, Canada, Finland), and the three largest other contributors (USA, China, UK). As seen in *Figure 4.2*, only Russia has an increase during 2017-2021 in the country's engagement in Arctic research relative to other research activities. Although the number

of articles with contributions from China to Arctic research almost doubles from 609 to 1,185 between 2017 and 2021, this increase only reflects the general increase in Chinese contributions to journals in Web of Science (see section 2.1.2 above).

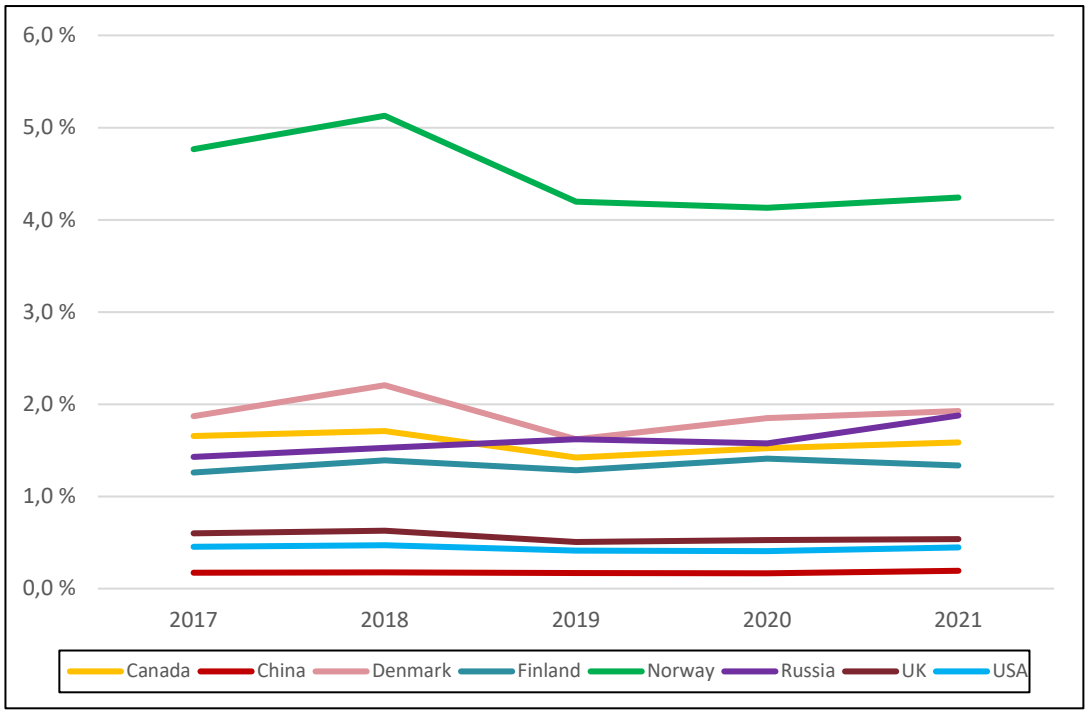

Figure 4.2. The share of articles contributing to Arctic research per year 2017-2021 as a percentage of all scientific articles from the same country in the same period.

4.2.2 Research profile

The most active research areas contributing to Arctic research are the Environmental sciences (including geosciences) and Biology (including Marine biology and Fisheries). *Figure 4.3* compares the shares of the main areas of research contributing to Arctic research to their general shares in Web of Science during the same period. Almost 60 percent of the research contributing to Arctic research is performed by the Environmental sciences. The general share of this area of research in global science is less than 8 percent.

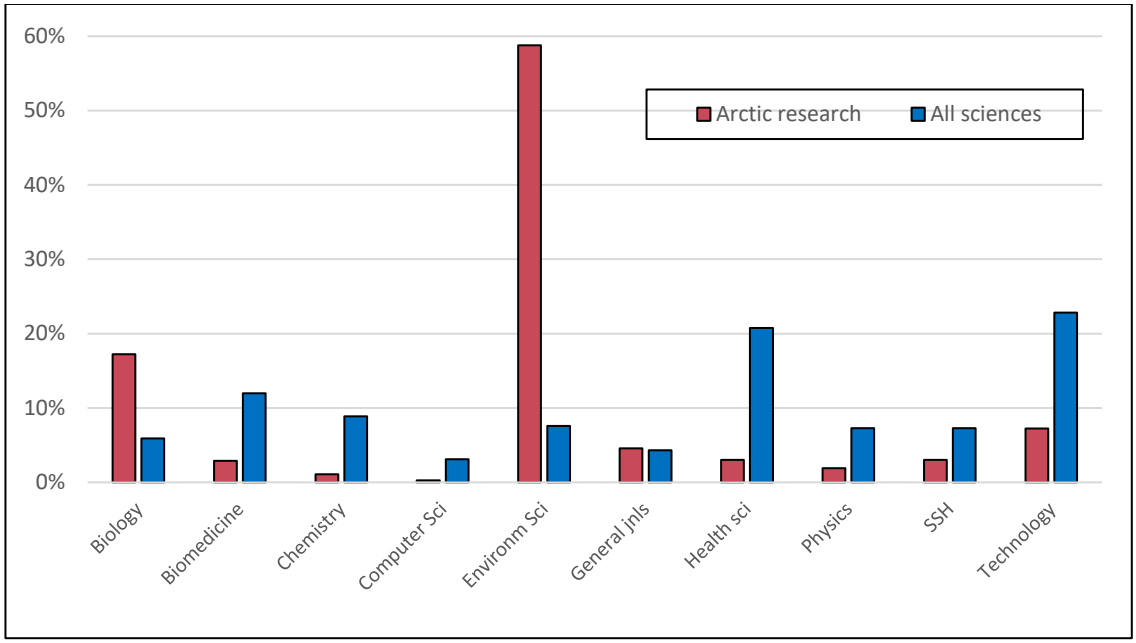

Figure 4.3. The share of main areas of research contributing to Arctic research in 2017-2021 compared to the share in all scientific articles indexed by Web of Science in the same period.

A clearer picture of the orientation towards *geoscience, environmental research, climate research, and biological resources* is given in *Figure 4.4.* It presents the number of articles in each of the 30 most frequent journals in our data representing Arctic research. (The journals *Scientific Reports, PLOS One* and *Nature Communications* publish all areas of research and are among those classified as general journals in *Figure 4.3*.)

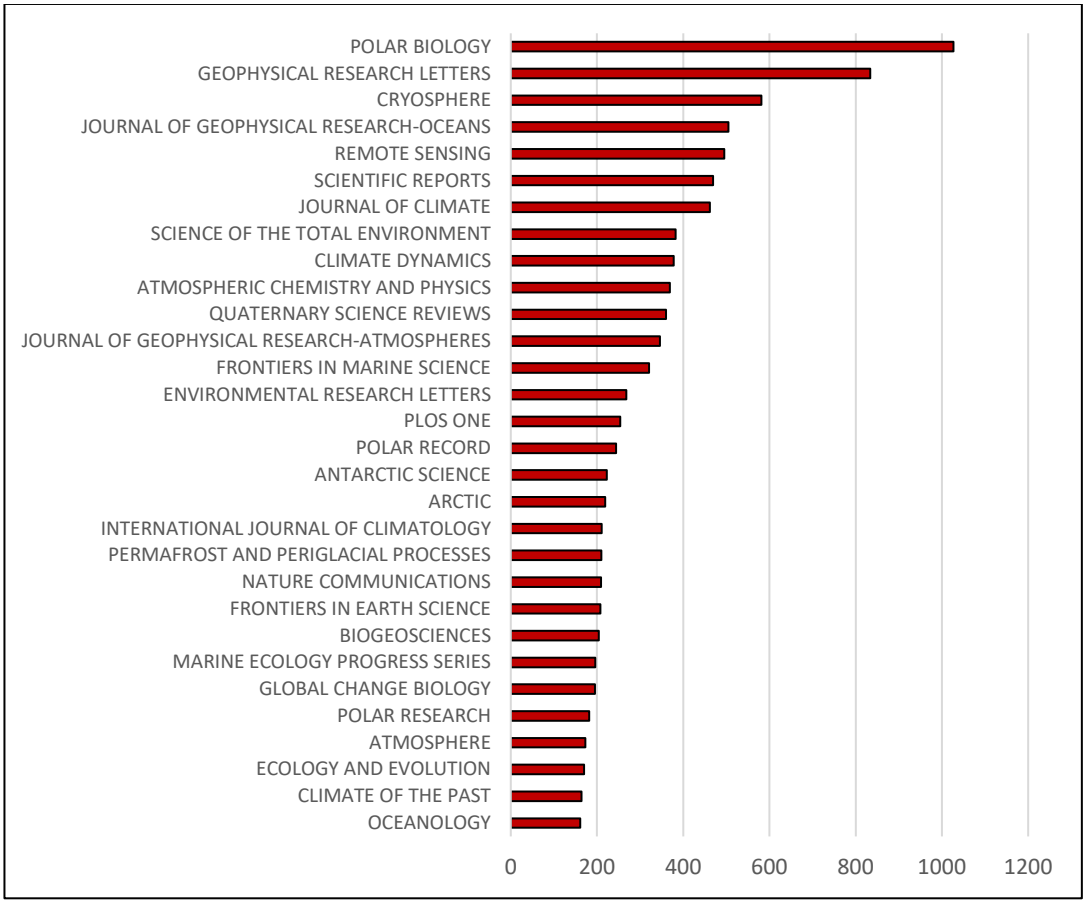

Figure 4.4. Number of articles published by the 30 most frequent journals in our data representing Arctic research 2017-2021 in Web of Science.

4.3 International collaboration

Among all scientific articles Web of Science in 2017-2021, 75 percent have one contributing country only. The share is much lower at 54 percent in our data covering Arctic research only. This field of research has a high degree on international collaboration. Bilateral collaboration is found in 27 percent of the articles, trilateral collaboration in 11 percent, and multilateral collaboration in 8 percent.

We used the method introduced in section 2.2.4 above to measure the relative intensity of collaboration between the 16 countries that contribute the most to Arctic research (as seen in Figure 4.1 above). Figure 4.5 compares the collaboration profiles of China, Norway, Russia, and USA. The measurement is based on the perspective of these four countries. It shows that:

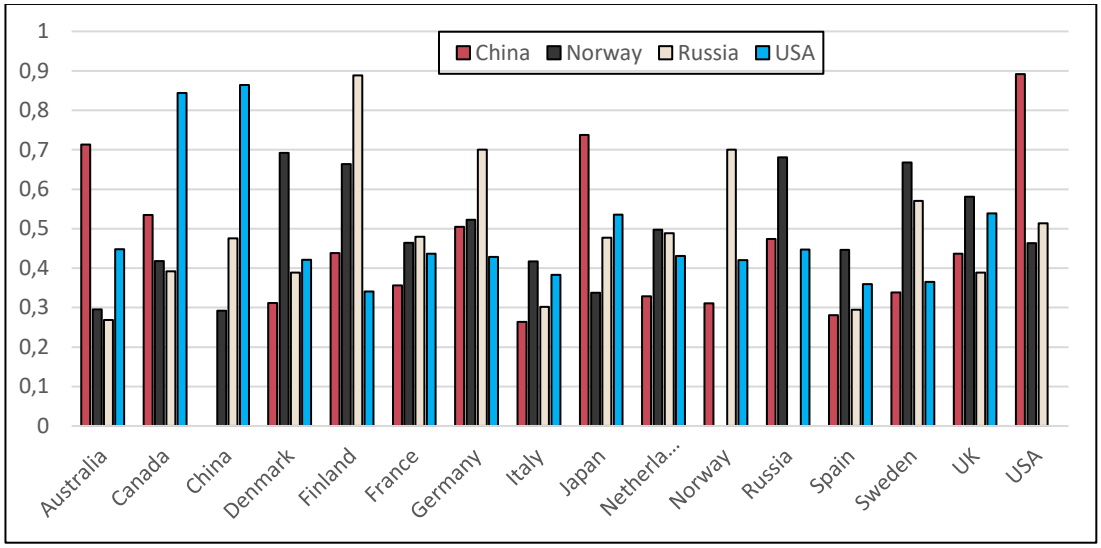

Figure 4.5. Relative intensities of international collaboration within Arctic research in the profiles of China, Norway, Russia, and USA within the network of the sixteen most contributing countries to the field. The method as explained in section 2.2.4.

- China collaborates most intensely with USA, Australia, and Japan. The intensity is low in the relations to all European countries, also in the relation to Norway.
- The low intensity in the relation to China is seen also in Norway's profile. The intensity is high for Norway in the relations to the Nordic countries and to Russia.
- The high intensity in the relation to Norway is seen also in Russia's profile. Collaboration with the other Nordic countries and with Germany also has high intensities.
- USA has high intensities of collaboration in the relations to China and Canada.

4.4 Sino-Norwegian collaboration

China and Norway are among the five countries contributing the most to Arctic research. They contributed to almost the same number of articles in 2017-2021, as seen in *Figure 4.1*. Yet, the collaboration intensity between the two countries is low, as seen in *Figure 4.5*. The two countries have different orientations within the network, China mainly towards USA, Australia and Japan, and Norway mainly towards the Nordic countries, Russia, and Europe in general. The two countries also operate differently when they engage in Arctic research. Only half of the contributions from China are based on international collaboration while 75 percent of Norway's contributions have authors in at least one other country.

There are only 208 articles showing collaboration between China and Norway in Arctic research 2017-2021. In section 3.2.1 above, we analysed Sino-Norwegian collaboration in general in the Environmental sciences. Our analysis was based on

more than 1,400 articles from 2017-2021 of which only 162 articles overlap with our study of Arctic research. It seems that Arctic research is not a main meeting place for Sino-Norwegian collaboration in the Environmental sciences.

Of the 208 articles with Sino-Norwegian collaboration in Arctic research, 64 are based on bilateral collaboration and 45 on trilateral collaboration. The most frequent third party is Germany. The remaining 99 articles are based on multilateral collaboration. This number is higher than expected from the two countries' general engagement in multilateral collaboration in Arctic research, indicating that Sino-Norwegian collaboration in Arctic research is mainly mediated by other countries. The most frequent other countries in the 99 articles are USA (66), Canada (53), UK (53), and Germany (50).

The 208 articles with Sino-Norwegian collaboration in Arctic research seem to be mainly focused on Climate research. The most frequently used journals are *Climate Dynamics* (14 articles), *Geophysical Research Letters* (10), *Journal of Climate* (9), *Advances in Atmospheric Sciences* (8), *Atmospheric Chemistry and Physics* (7), *International Journal of Climatology*, *Climate of the Past*, and *Cryosphere* (6 each).

The by far most active research partner on the Norwegian side is the Bjerknes Centre for Climate Research and its participating organizations, Geophysical Institute of University of Bergen, Institute for Marine Research and Nansen Environmental and Remote Sensing Centre.

Other active Norwegian research partners are the Norwegian Institute for Air Research (NILU), the Norwegian Polar Research Institute, the University Centre in Svalbard (UNIS), the Norwegian Meteorological Institute, and the Department of Geosciences of University of Oslo.

On the Chinese side, the major partner is the Climate Change Research Center (CCRC) at the Institute of Atmospheric Physics (IAP) of the Chinese Academy of Sciences. IAP also hosts the Nansen-Zhu International Research Center (NZC) which was founded in collaboration with the above-mentioned partners in Bergen.

Another active partner is the Polar Research Institute of China in Shanghai, which was founded for Sino-Nordic collaboration in social science Arctic research. Other active Chinese partners are mainly the University of the Chinese Academy of Sciences, Beijing Normal University, Nanjing University of Information Science & Technology, the Ocean University of China, and the Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou).

4.5 Summary

Norway stands out as the country most dedicated to Arctic research relative to its size. 4.5 percent of Norway's scientific output is dedicated to the field. This is a prioritization of Arctic research that makes Norway the fifth largest country

contributing to the field after USA, Canada, China, and UK. The other Nordic countries are also relatively active together with Canada and Russia.

Only 0.18 percent of China's scientific output is dedicated to Arctic research. Other large countries in science such as USA, UK, Germany, and France are clearly more active by the same measure.

Arctic research has a high degree on international collaboration. China and Norway appear to belong to different groups of collaborating countries. China collaborates most intensely with USA, Australia, Japan, and Canada. The intensity is low in the relations to all European countries, also in the relation to Norway.

The low intensity in the relation to China is seen also in Norway's profile. The intensity is high for Norway in the relations to the Nordic countries and to Russia. Germany is also important in this group as well as other European countries.

Arctic research is dominated by the Environmental sciences (including climate research), which we find to be a main area for Sino-Norwegian collaboration in the general analysis. However, only a small part of this collaboration is focused on the Arctic. The few articles are mainly dedicated to climate research, and most of them are based on multilateral collaboration in which other countries participate as well.

References

Aksnes, D.W. (2017). Norwegian Polar Research & Svalbard Research: Publication Analysis, NIFU-rapport 2017:6.

Aksnes, D.W., Sivertsen, G. (2019). A Criteria-based Assessment of the Coverage of Scopus and Web of Science. *Journal of Data and Information Science*, 4(1): 1-21.

Fuchs, J.E., Sivertsen, G., Rousseau, R. (2021). Measuring the relative intensity of collaboration within a network. *Scientometrics*, 126(10), 8673-8682.

Luukkonen, T., Persson, O., & Sivertsen, G. (1992). Understanding Patterns of International Scientific Collaboration. *Science, Technology & Human Values*, 17(1), 101-126.

Quan, W., Chen, B., Shu, F. (2017). Publish or impoverish: An investigation of the monetary reward system of science in China (1999-2016). *Aslib Journal of Information Management*, 69(5), 1-18.

Sverdrup-Thygeson, B. (2017). Norge – Kina: Fra isfront til tøvær. *NUPI Skole*, nr. 1, 2017. https://www.nupi.no/nupi_school/HHD-Artikler/2017/Norge-Kina-Fra-isfront-til-toevaer

Zhang, L., & Sivertsen, G., (2020). The New Research Assessment Reform in China and Its Implementation. *Scholarly Assessment Reports*, 2(1), 3. DOI: http://doi.org/10.29024/sar.15

Zweig, D.A. (2021). Is Sino–American Scientific Collaboration a Thing of the Past? *International Higher Education*, 108, 5-7.

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