Norwegian Polar Research & Svalbard Research

Publication Analysis

Dag W. Aksnes

Report 2017:6

NIFU

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Preface

This report presents a bibliometric analysis of Norwegian polar research and research in Svalbard and is a background report for the ongoing evaluation of the field. The analysis is carried out on the commission of the Research Council of Norway by Research Professor Dag W. Aksnes at the Nordic Institute for Studies in Innovation, Research and Education (NIFU). For the analysis of PhD students, Bo Sarpebakken has collected data from NIFU's Research Personnel Register and Doctoral Register.

Oslo, 29/05 2017

Sveinung Skule
Director

Susanne L. Sundnes
Head of Research

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Summary

This report provides a bibliometric analysis of Norwegian polar research and research in Svalbard. The report contains indicators on various dimensions of this research, with a particular focus on the citation impact of the publications.

Polar research: Norway among the world's largest contributors

Measured by scientific publishing Norway is the world's fifth largest polar research nation. Thus, polar research is one of few disciplines where Norway is a major contributor on the global research arena. While Norway contributes to 0.62 per cent of the world's total scientific publication output, the proportion is 5.6 per cent for polar research (2012-2014). Norway is the third largest nation in terms of publications relating to the Arctic, only the USA and Canada have higher numbers. In the period 2012-2014, Norway contributed to 8.3 per cent of the global article production relating to the Arctic.

The Arctic university of Norway (UiT) is the largest institutional contributor to Norwegian polar research measured by publication numbers, followed by the University of Bergen (UiB), the University of Oslo (UiO), the Norwegian Polar Institute (NPI) and the University Centre in Svalbard (UNIS).

Extensive international collaboration

Polar research is characterised by extensive international collaboration and Norway is strongly embedded in the international networks of polar research. Of the Norwegian polar research articles (2012-2014), 73 per cent also had co-authors from other countries. Still, this proportion is even higher in several other countries.

Citation impact of Norwegian polar research

The impact of Norwegian polar research in terms of citation rates is lower than for several other major polar research nations. The analysis shows that Norway ranks behind the leading countries on several indicators used measuring this impact: full and fractionalised publication and citation counts, and first-author/corresponding author publications. Findings that may explain this pattern are:

- Norwegian polar research is less often published in the leading and prestigious scientific journals.
- Svalbard has a key role in the Norwegian polar research and many Norwegian polar research articles relate to Svalbard. These articles are on average less cited than other polar research articles.

- Compared with the leading countries, Norway has a higher percentage of articles that are uncited or little cited and a lower percentage of highly cited articles.

- Naturally, the citation rates differ at the level of fields and disciplines, institutions and institutes. Some units perform below or on par with the world average. Within almost all fields, Norwegian researchers have contributed to publications with high impact, but in some areas there are relatively fewer such articles.

Norwegian Antarctic research: smaller contributor

When it comes to Antarctic research, Norway is a significantly smaller contributor than for Arctic research and ranks as the 21st largest research nation in terms of publication volume with a proportion of 1.2 per cent of the world production. In 2014, 12 per cent of the Norwegian polar research articles were related to the Antarctic. The Norwegian Antarctic articles cover a variety of fields. The majority of the publications are within geosciences (66 per cent), while biology has a proportion of 30 per cent. The single largest subfield is cryospheric research, followed by atmosphere research and meteorology and marine biology. Many Norwegian institutions and institutes have contributed to Antarctic research articles. NPI is the single largest contributor followed by UiB.

Svalbard research – Norway the major nation

Norway is by far the largest nation in terms of scientific publications related to research in Svalbard. Norway has more than twice as many articles as the second and third largest nations: the UK and Poland. Of all Svalbard articles, more than 40 per cent have at least one co-author from Norwegian institutions.

In total, almost 2,000 Svalbard articles were identified for the seven-year period 2010-2016. The annual production increased from 2010 to 2012, while there has been a minor reduction the recent years.

The citation rate of the Norwegian Svalbard articles is higher than the overall average for Svalbard-articles. Researchers at Norwegian institutions have also contributed to the majority (63 per cent) of the Svalbard articles with particularly high impact.

However, in all the years analysed, the Svalbard articles have been less cited than the average for polar research generally (10-20 per cent below this average). The analysis shows that all the major countries carrying out research in Svalbard, have lower citation rate for their Svalbard articles than for their other polar research articles. Some of the issues described above are also relevant for explaining the relatively low citation impact of the Svalbard articles.

- For almost all countries analysed, the journals used for publishing the Svalbard-articles have lower citation rate (impact factor) than the journals used for publishing polar research articles generally.

- Similarly, at the level of fields and disciplines as well as institutions and institutes there are large differences.

- A large majority of the Svalbard articles are single location studies, i.e. based on research carried out in geographical locations in Svalbard, only. The proportion of such papers is much higher in the set of Svalbard publication than in the set of Norwegian polar articles generally. The analysis shows that such papers on average are less cited than other papers, such as multi location studies. Thus, the relatively low citation impact of Svalbard may partly be explained by the lower proportion of collaborative work involving research also beyond Svalbard.

Approximately three quarters of all Svalbard articles involve terrestrial research, while 26 per cent are marine based (coastal zone). A large part (42 per cent) of the Svalbard articles concerns topics related

to climate, while 9 per cent address pollution. These proportions are quite similar for the subset of Norwegian Svalbard articles.

As for polar research generally, Svalbard research is characterized by a high degree of international collaboration. Still, 43 per cent of the Svalbard articles overall did not involve such collaboration, i.e. they were authored by researchers from one country, only. These articles are less cited than the internationally co-authored articles.

Of the Norwegian Svalbard articles, 69 per cent had co-authors affiliated with institutions abroad. This is on par with the average for Norwegian polar research generally (73 per cent). Thus, the Norwegian Svalbard research is also characterised by extensive international collaboration.

The results of a minor register-based survey indicate that Svalbard plays an important role in the education of polar researchers in Norway and that a large number of foreign scientists also obtain PhDs in polar research through the Norwegian higher education system.

1 Introduction

In 2015, NIFU published a mapping of Norwegian polar research and research in Svalbard (NIFU Report 2015:37 – Norsk polarforsking – forskning på Svalbard). The report contains a variety of indicators covering R&D resources and personnel, as well as scientific publishing of Norwegian polar research and Svalbard research. The Research Council of Norway (RCN) is currently carrying out an evaluation of Norwegian polar research. RCN has asked NIFU to deliver an in depth bibliometric analysis of Norwegian polar research. This analysis will provide factual background information for the committee appointed for carrying out the evaluation. The previous mapping showed that Norwegian polar research articles are cited more frequently than the world average for polar research in general. However, the impact of Norwegian polar research in terms of citation rates, is lower than for several other major polar research nations. Moreover, publications related to Svalbard are in general less frequently cited than the world average for polar research.

In the present assignment, NIFU is asked by RCN to provide further bibliometric analyses of Norwegian polar research and research in Svalbard, particularly concerning the citation impact of the publications. This analysis aims at giving a better understanding of factors influencing the scientific performance measured by citations. Here, special attention is devoted to characterizing publications with low and high citation impact (highly cited papers). Both Norwegian polar research publications in general and Svalbard publications (national and international) are analysed.

The analysis is partly based on the dataset collected as part of the 2015 mapping. The previous mapping report was written in Norwegian and contains several results of relevance also for the present analysis. Therefore, some indicators and analyses have been included in the present report which also appeared in the 2015 report. In addition to providing extensive citation analyses, the report also contains new indicators on other dimensions, such as on collaboration measured through co-authorship and on Norwegian Antarctic research. The latter analyses have been added based on input from the evaluation committee which has requested further information on these aspects of Norwegian polar research.

The report contains two main chapters: one chapter with analyses of Norwegian polar research in general (Chapter 3) and one with analyses of Svalbard research (Chapter 4). The specific research questions, data and methods are described in the next chapter (Chapter 2). A final chapter (Chapter 5) provides a general introduction to bibliometric indicators. This chapter has been included in order to provide background information on this issue, and does not address issues relating to polar research.

It should be noted that when bibliometric analyses are carried out as part of research evaluations, the analyses are usually based on the lists of personnel encompassed by the evaluation and their publications. This is not the case in the present study. Instead the study is based on a specific method

developed for identifying polar research publications (see Chapter 2). This means that the publication set has not been verified by the institutions and institutions encompassed by the evaluation. Some publications an institute or department would count as polar research may be missing, and vice versa. Nevertheless, the advantage of the method is that it is uniform and coherent and removes the problems caused by subjectiveness and respondents different interpretation and delimitation polar research.

As described above, an important aim of the project has been to provide further information on the citation impact of Norwegian polar research and research in Svalbard, specifically. In the recent White paper on Svalbard (St. Meld. 32 2015-2016 - Svalbard) the Norwegian government points out that there is a need to improve the quality of Norwegian research in Svalbard. In the report, we present various findings that cast light on the scientific performance measured by citation indicators. Nevertheless, it should be noted that scientific quality is a broader concept than what is reflected through citation counts. Due to various limitations and biases attached to citation indicators, they cannot replace an assessment carried out by peers.

2 Data & Methods

The present chapter contains an overview of the data and methods applied in the study.

2.1 Definition of polar research

Polar research is not a traditional scientific discipline and encompasses a range of disciplines from the humanities to technology and engineering, although the greatest proportion of research is carried out within the natural sciences. Rather than being defined according to thematic focus, it is geographically delimited, even though the criteria for delimitation may be a matter of controversy. The present study is based on the definition of polar research which for a long time has been adopted by the Norwegian government and the Research Council of Norway (cf. Ministry of the Environment 1993) as well as in NIFU's previous mappings of Norwegian polar research:

Research carried out on the basis of material from the polar areas (Arctic and Antarctic) or concerning phenomena localized in the polar areas.

Arctic: The polar part of the Arctic, including Svalbard, Jan Mayen, the northern part of the Norwegian Sea, the Barents Sea, the Greenland Sea and the Arctic Ocean

Antarctic: The area south of the Antarctic Convergence. This encircles Antarctica, and is where cold, northward-flowing Antarctic waters meet and mix with the warmer waters of the sub-Antarctic. Its position varies, but it normally lies between 50°S and 60°S. Also the sub-Antarctic islands such as Bouvet Island and South Georgia, which may at times be north of the Antarctic Convergence are included.

It should be noted that some other countries and organisations apply a broader definition of polar research. For example, both Arctic and sub-Arctic areas (e.g. northern part of Norway) are included in definition of Arctic developed by AMAP (Arctic Monitoring and Assessment Programme). Applying such a definition would of course significantly increase the volume of Norwegian polar research (see e.g. Aksnes et al. 2016).

2.2 Data and Methods

2.2.1 Procedure for identifying polar research

In contrast to many other areas of science, it is hard to identify polar research from the scientific outlet or journal. Only a limited portion of research findings are published in specialized journals for polar research (e.g. *Arctic*, *Polar Biology*, *Polar Research* etc.). Most of the articles appear in more general scientific journals and thematic journals. In order to identify publications that should be assigned to the category “polar research”, we have used two principles. First, we have included all publications from the journals that entirely or mainly cover polar research.[1] Second, following the geographical delimitation of polar research, we have applied geographical search terms for identifying the publications. We have done a search through the titles and abstracts of all the publications in the database. We assumed that the geographical locality in which the research had been performed would generally appear either in the title or in the abstract. Names of geographical areas in the Arctic and the Antarctic[2] were therefore used as an indication of polar research content. With regard to the Arctic, the names of mainland areas, islands and oceans were included. With regard to the Antarctic, the name of the entire continent was used (antarc*) in addition to the names of the oceans surrounding it.

We believe the method we have applied is adequate for the purpose of providing a general analysis of efforts within polar research. A previous study (Schild 1996) used field-specific search terms (e.g. “sea-ice”, “polar bear” etc.) in addition. We did not consider this necessary, as the geographical locality is usually specified either in the title or in the abstract of the publications. In addition, the use of “Arctic” as general search term identifies a large number of publications, although the meaning of the Arctic across the publications, does not necessarily correspond with the geographical definition applied in this study. This may be a source of error. Moreover, it might be the case that certain relevant publications have not been identified because the articles do not specify where the research has been carried out, or because other geographical names than those included in the study were mentioned. For example, certain space-type research based on equipment localized in the polar regions, for example on solar wind or aurora, might not have geographical names specified, and would be left out by our search strategy. An examination of a subsample of the selected papers using our approach showed high relevance.

Some articles were, however, mistakenly identified and these were removed, for example articles containing the word "subarctic". Furthermore, articles concerning Char (Arctic Charr) were removed if the research was carried out outside the polar regions. The same holds for articles concerning species (primarily) present outside the polar regions.[3]

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

[2] The search included the following names (and spelling variants):
Arctic: 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.
Antarctic: *antarc*, South pole, D’Urville Sea Ross sea, Amundsen sea, Pine Island Bay, Weddel Sea, Davis Sea, south polar, south magnetic pole.

[3] Arctic Bramle, Candida Antarctica, Greenland Halibut, Arctic tern, Gavia arctica, Arctica islandica, E. coli Arctic Express etc. A mutation that causes Alzheimer disease is called "Arctic mutation", and articles concerning this mutation have been removed. Articles referring to a study called Eskimo (Eating Study as a Kiggen Module) have been removed, similar for studies of the Eskimo1 mutant. Articles referring to the polar regions on planets and moons are removed.

In a similar previous study (Dastidar 2007), only search terms present in the titles of the publications were used as a basis for identifying Antarctic research. This resulted in a much lower subset of papers, and such a method would accordingly greatly underestimate the size of the production output. Still, there are limitations also with our approach. The boundaries for polar research may sometimes be difficult to draw, particularly this holds for marine research where research cruises sometimes may encompass both polar and non-polar areas. Overall, the sources of errors and uncertainties mean that the study should be regarded as a crude rather than precise quantification of polar research. This needs to be taken into account when interpreting the figures.

As noted in the introduction, the publication set has not been verified by the institutions and institutions encompassed by the evaluation. Some publications an institute or department would count as polar research may be missing, and vice versa. As part of the evaluation process, each institution has submitted publications they consider most prominent and relevant to their mission. A minor survey was carried out of this set of publications. This showed that of 54 submitted publications, 48 of these articles (89%) were indexed in Web of Science. However, 6 articles did not include any of the search terms used to delineate polar research, and are therefore not included in the analysis (however a couple of these articles would probably not be counted as polar research given the definition used). The analysis showed that the submitted articles on average were highly cited and published in high impact journals.

2.2.2 Procedure for identifying Svalbard research

A similar method has been applied in the publication analysis of Svalbard research. To identify articles containing Svalbard research, we searched for relevant terms in the titles and abstracts of the articles.[4] We assumed that research conducted in Svalbard or relating to Svalbard would usually have the geographical locations in Svalbard listed either in the title or in the abstract of the articles. In addition, we identified all articles with a postal address in Svalbard (e.g. Longyearbyen or Ny-Ålesund) and with the University Centre in Svalbard (UNIS) as one author affiliation.

The resulting list of articles was examined and verified by reading the abstract of the articles. Some articles were removed because they did not contain research carried out in Svalbard (for example, when Svalbard was mentioned just as an example in the abstract). Moreover, not all the UNIS' articles are based on research carried out in Svalbard or relates to Svalbard, and these articles were not included. The territorial border of Svalbard is 12 nautical miles. This means that we have attempted to include research carried out in the coastal zone of the archipelago but not in the oceans surrounding it. The search method is more extensive than the one applied in NIFU's previous mapping which was based on search terms in titles and abstracts, only. As a result, we were able to identify additional articles, and the article numbers are approximately 4 per cent higher than the one presented in NIFU's previous mapping.

The sources of errors attached to the applied method are similar to those for polar research in general. Possibly, some relevant publications are missing because they do not have the geographical names specified in the titles or abstracts. Nevertheless, we believe that the method is adequate for providing an overall analysis of Svalbard research. It should be noted that many of the "Svalbard"-publications report the results of comparative studies that are based on observation/measurements conducted in several different geographical locations in the polar regions, where Svalbard is only one of them. This means that Svalbard will have a more peripheral role.

[4] The following search terms were used (and spelling variants of these): Svalbard, Spitsbergen, Ny Alesund, Longyearbyen, Barentsburg, Hornsund, Hopen, Bjørnøya (Bear island), Kongsfjord.

2.2.3 Database

The study is based on the database Web of Science (Core Collection based on the three citation indexes: Science Citation Expanded; Social Sciences Citation Index; and Arts & Humanities Citation Index). This is a database covering more than 12,000 specialized and multidisciplinary scientific journals with peer review, including all major international journals in the natural sciences, medicine and technology. Also included are journals within the social sciences and humanities, but here the coverage is more limited. Moreover, book publishing plays an important role within these domains, and this publication type is not included in the core edition of Web of Science. This means that the social sciences and humanities will be less well represented in our analysis. At the same time, given the definition of polar research, the research volume within these domains is rather limited. According to the recent 2015 mapping, the social sciences and humanities account for approximately 2 per cent of the total Norwegian polar research measured as work years.

2.2.4 Time period and data processing

The analysis based on the dataset from the 2015 mapping, covers the period 2010-2014. The analysis of Svalbard research has been supplied with data covering the years 2015 and 2016. The bibliographic details of the publications identified were analysed using software developed for the purpose. Only regular articles and review articles are included (not minor contributions like "abstracts", editorials, corrections, "letters" etc.). Each article contains information about the authors' addresses (institutional affiliations). To assess the publication output for individual countries, all articles were classified according to the nationality of the affiliated authors (i.e. the country of their institution addresses). Many papers are multi-authored, with an international list of authors. In the publication analyses concerning relative proportions/contributions, each country was assigned their respective fraction of these papers (fractionalised article equivalents). For example, if an article had one author address from France and one from Germany, each country would receive a value of 0.5. In this way, the publication measures reflect the contribution of individual countries to the international polar research. The indicator can be interpreted as an indirect measure of the size of the countries as polar research nations. However, it should be noted that our survey primarily includes English-language journals. Certain countries, particularly Russia and Latin American countries, may publish their research in non-English-language (e.g. Russian or Spanish) scientific journals. Thus, the true extent of these countries" polar research activities may be larger than reflected in the figures of this study. However, the research results published in such journals would generally have less international impact and would not be available to a global scientific audience.

2.2.5 Citation indicators

The Web of Science database also includes information on how many times the articles have been referred to or cited in the subsequent scientific literature. These data have been used to calculate citation indicators. In absolute counts, the countries with the largest number of articles would of course also receive the highest number of citations – these countries have more papers that can be cited. It is, however, common to use a size-independent measure to assess whether a country's articles have been highly or poorly cited. One such indicator is the *relative citation index* showing whether a country's scientific publications have been cited above or below the world average (=100). Here, each article is compared with the average paper in the respective area of polar research and year, and on this basis an overall index is calculated (therefore, the indicator may more precisely be termed *the field normalised relative citation index)*. We have used accumulated citation counts and calculated an overall (total) indicator for the whole period. Articles from the most recent year (2014) are not included in the citation analysis as these have not been available in the literature for a sufficiently long time to be cited.

In addition to the field normalized citation index we have analysed the articles that are among the 10 per cent most cited and 20 per cent least cited in their fields. The main objective is to analyse whether there are differences between the two sets of articles along various bibliometric variables (see below).

In the calculation of citation indicators whole counting of publications has been applied in most cases, which means that each country in internationally co-authored publications receives full credit for its participation (similar principle applied in the analysis of institutions/institutes). This is the most common way of calculation citation indicators, although it means that an individual country is credited with the contributions of many scientists in other countries. In extreme cases, the majority of the article contributions may actually have been made by international researchers. An alternative is fractionalised publication counting, in which a country is credited a fraction of a publication equal to the fraction of the author addresses from that country. The results of using a fractionalised calculation method are included in some of the analyses.

2.2.6 Collaboration indicators

The fact that researchers co-author a scientific paper reflects collaboration, and co-authorship may be used as an indicator of such collaboration. By definition a publication is co-authored if it has more than one author, internationally co-authored if it has authors from more than one country. Compared to other methodologies, bibliometrics provides unique and systematic insight into the extent and structure of scientific collaboration. A main advantage is that the size of the sample that can be analysed with this technique can be very large and render results that are more reliable than those from case studies. Also, the technique captures non-formalised types of collaboration that can be difficult to identify with other methodologies. In this report, indicators of both international and institutional collaboration have been included.

2.2.7 Parameters and research questions

In the analysis, we have applied available bibliographic information that is relevant for analysing the scientific performance of Norwegian polar research bibliometrically. This includes data of scientific field (journal categories), author positions, author affiliations etc. For example, special attention is devoted to articles having Norwegian first author and/or corresponding author, as Norwegian researchers apparently have leading roles in the research reported in these articles.

In addition to providing a descriptive overview of Norwegian polar research and research in Svalbard along different bibliometric variables, specific attention will be devoted to issues that possibly may explain the relatively low citation impact of Norwegian polar research and research in Svalbard in particular. The following issues will be addressed:

- The degree of international collaboration measured through co-authorship. Such collaboration will generally increase the impact of the research in terms of citation rates.
- Single versus multi-site studies. Some articles are comparative studies that are based on observation/measurements conducted in several different geographical locations in the polar regions, while others are based on one location only. To what extent there is a difference between these two types of contributions when it comes to citation rates, will be investigated empirically.
- The role of Svalbard for the education of polar researchers (training ground), for example PhD-students doing field work or using scientific facilities in Svalbard as part of their doctoral projects. A small survey concerning this issue is carried out to obtain information on the degree of research (publications) involving PhD students and whether the articles have deviating citation statistics.
- Whether the citation rate of the Svalbard publications differ from the one of the other publications the scientists have published (i.e. publications based on research in other areas).

For these analyses, we have used various bibliographic information available from the Web of Science database, such as authorship, institutional affiliations, journal, and discipline. In addition, the articles have been classified manually or semi-automatic based on information available in the titles and

abstracts of the articles. This includes classification of their geographical profile (where the research was carried out, field work, observations, experiments, etc.) and subdisciplines. Moreover, the Svalbard articles have also been classified according to a terrestrial and marine dimension (coastal zone) and by research topics related to climate or pollution. It should be noted that the classification process is challenging, there are many borderline cases, and sometimes difficult to decide how a particular article should be classified. However, it should be noted that the analyses presented in the report concern an aggregated level and provide an overall profile, only.

As described above there are various sources of errors and limitations of the study, for example relating to the coverage of the Web of Science database, the method used for delineating polar research and Svalbard research and concerning the use of citations as performance indicators. It is not possible to quantify the magnitude of these sources of errors. The indicators presented are based on basic descriptive statistics such as average and percentile. In most cases, we have complete data for the populations (within the universe of the Web of Science database), i.e. the study is not based on samples. We have not applied inferential statistics or tests of statistical significance. In studies based on data of the total population, significance tests have no meaning in the sense of classical statistical inference, although this topic still is a matter of debate.

3 Norwegian Polar Research

This chapter contains a general overview of Norwegian polar research. As described in the previous chapter, the analysis is mainly based on the dataset from the 2015-mapping and covers the period 2010-2014. Some indicators are based on the whole period while others focus on the most recent year(s).

3.1 Publication volume

The USA is by far the largest contributor in terms of publications on both the Arctic and the Antarctic (Figure 3.1). Then follow UK and Canada with an article production of almost equal size. Germany and Norway rank as the fourth and fifth largest contributor, respectively. There are large differences among the countries in their geographical profile. The research output of certain countries primarily focuses on the Arctic (Canada, Norway, Russia, Kingdom of Denmark[5]), while the output of others mainly relates to the Antarctic (Australia, Italy). Research output in several countries is more evenly distributed (the USA, the UK, Germany).

[5] Denmark, Greenland, and the Faroe Islands.

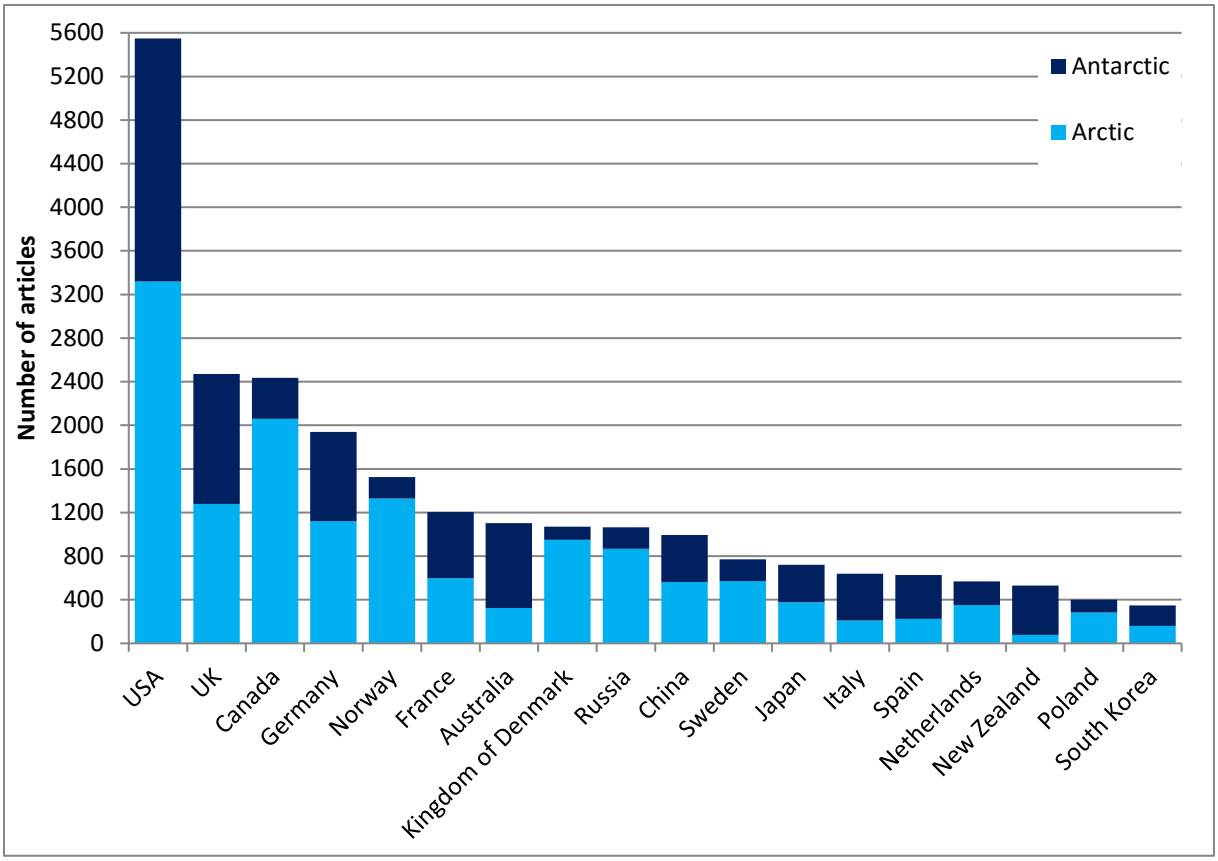

Figure 3.1 Number of polar research articles by country and geographical area, 2012-2014.

Source: NIFU / Web of Science.

Norway is the third largest nation in terms of publications on the Arctic, only the USA and Canada have higher numbers. In the period 2012-2014, Norway contributed to 8.3 per cent of the global article production relating to the Arctic. On Antarctic research, Norway is a significantly smaller contributor and ranks as the 21st largest research nation in terms of publication volume with a proportion of 1.2 per cent.

The Norwegian article production has grown markedly during the 10-year period 2005-2014 (Figure 3.2). Measured in fractionalised article equivalents (i.e. corrected for international co-authorship), the number has increased by 86 per cent. This growth is stronger than for the other major polar research nations, except China (which has a 259 per cent increase). Some of the increase can probably be attributed to the International Polar Year (IPY, 2007-2008) which represented a major international and national campaign to strengthen research activities in the polar regions.

Of the Norwegian polar article production, a relatively small share relates to Antarctic, in 2014 approximately 60 articles (but some of them also relate to the Arctic), while 450 articles relate to Arctic. The production of Antarctic articles has in relative terms increased more than production related to the Arctic (Figure 3.2). In 2014, 12 per cent of the Norwegian polar article production related to Antarctic. The corresponding figure for 2005 was 9 per cent.

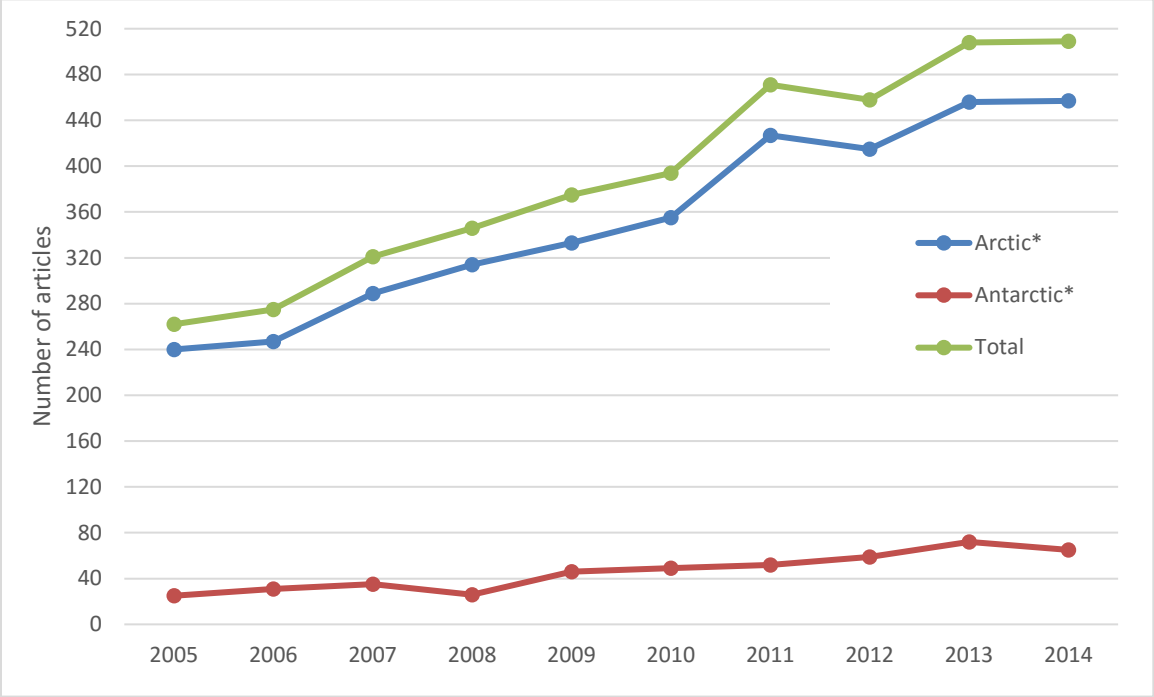

Figure 3.2 Number of polar research articles, Norway, by geographical area, 2005-2014.

*) Some articles deal with or are based on research conducted in both the Arctic and Antarctic, these articles are included under both categories.
Source: NIFU / Web of Science.

Biology and geosciences are the two dominant disciplines of polar research, but there is also research in a variety of other disciplines. The Norwegian profile, based on 2012-2014 data, is shown in Figure 3.3. Geoscience accounts for almost half (47 per cent) of the Norwegian polar article production, while biology has a proportion of 37 per cent. Technology as well as biomedicine, medicine & health have proportions of 4 per cent. There are few publications within the social sciences (and humanities). This may partly be explained by the limited coverage of the Web of Science database in these fields (cf. Chapter 2). However, according to the recent 2015 mapping, the social sciences and humanities account for approximately 2 per cent of the total Norwegian polar research measured as work years.

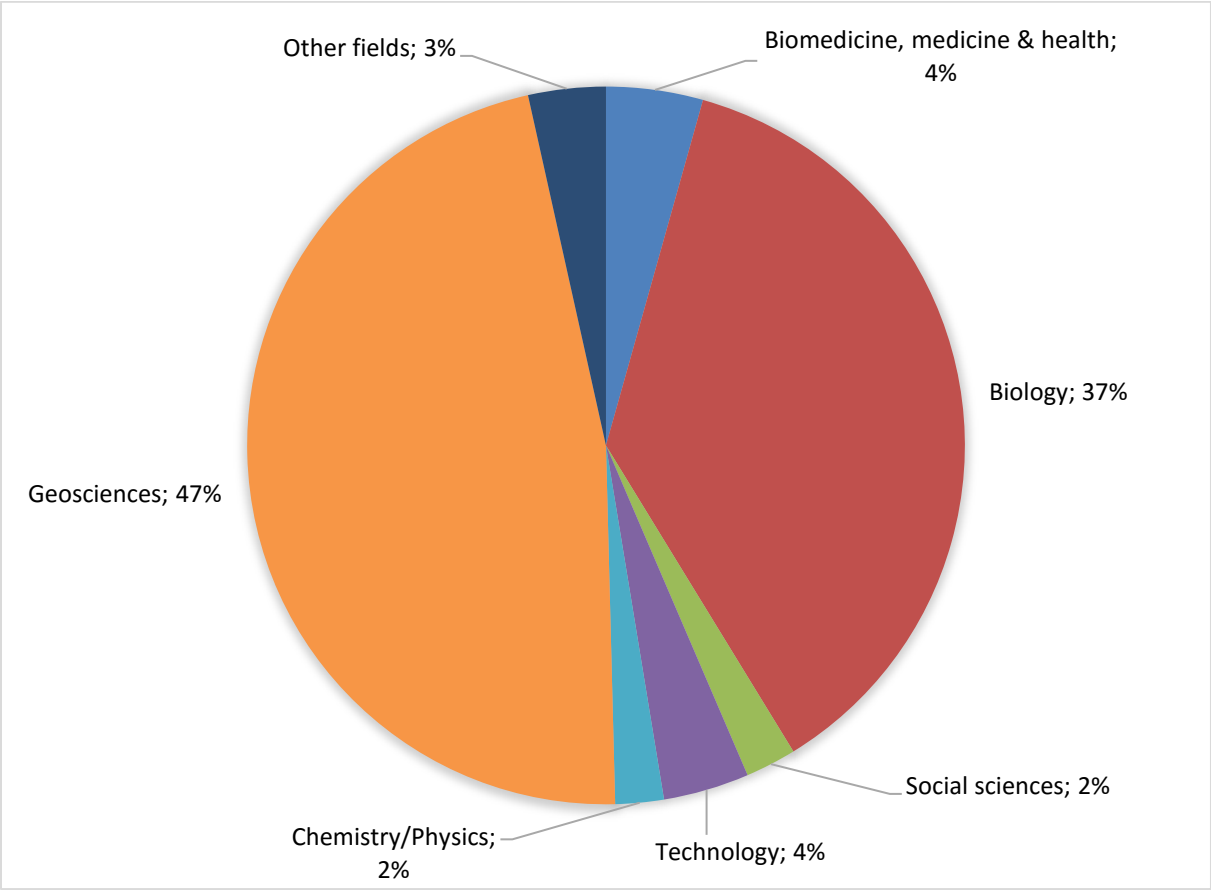

Figure 3.3 Relative distribution of polar research articles by fields, Norway 2012-2014.

Source: NIFU / Web of Science.

Table 3.1 shows how the articles are distributed among research performing institutions and institutes. The Arctic university of Norway (UiT) is the largest contributor with more than 560 articles in the 5-year period 2010-2014. Then follow the University of Bergen (UiB), the University of Oslo (UiO) and the Norwegian Polar Institute (NPI) with an article production ranging from 400 to 470 articles. The University Centre in Svalbard (UNIS) has almost 320 articles, while the Norwegian University of Science and Technology (NTNU) and the Norwegian University of Life Sciences (NMBU) have fewer articles (191 and 114, respectively). Other institutions in the higher education sector contributed to less than 80 articles and are not shown in the table.

In the institute sector, the Institute of Marine Research (IMR) is the second largest contributor with nearly 210 articles, followed by the Norwegian Institute for Air Research (NILU), the Norwegian Institute for Nature Research (NINA) and Uni Research (UNI) with a publication number ranging from 100 to 130. In addition, there is a large number of articles from other institutes in the sector, these institutes contributed to a total of 480 articles. Among the largest we find the Geological Survey of Norway, Nansen Environmental and Remote Sensing Center, and the Norwegian Meteorological Institute. Companies in the business sector accounted for approximately 200 articles. Here main contributors are the research company Akvaplan-niva[6] and Statoil.

Table 3.1 Number of polar research articles by institution/institute/sector,* 2010-2014.

	Institution	Number		Institute/sector	Number
HE sector	UiT	565	Institute sector	NPI	403
	UiB	468		IMR	208
	UiO	427		NILU	130
	UNIS	316		NINA	111
	NTNU	191		UNI	99
	NMBU	114		Other institute sector	482
	Other HE-institutions	79		Business sector	209
				Other	94
				Total	2 340

*) Only units with more than 90 articles are shown separately in the table. Articles with contributions from several institutions/institutes will be included in more than one category. The figures in the report are based on the organizational structure in 2014. This means that for example Norwegian University of Life Sciences (NMBU) includes the former institutions Agricultural University of Norway and Norwegian School of Veterinary Science, moreover, Finnmark University College is included under the Arctic University of Norway.
Source: NIFU / Web of Science.

[6] Previously, Akvaplan-niva has been classified as part of the business enterprise sector in the Norwegian R&D statistics. However, in 2015 it was transferred to the institute sector. As these figures cover the 2010-2014 period, the institute is classified according to its previous sector classification.

In Figure 3.4 the publication numbers in Table 3.1 are shown as proportions of the national total.

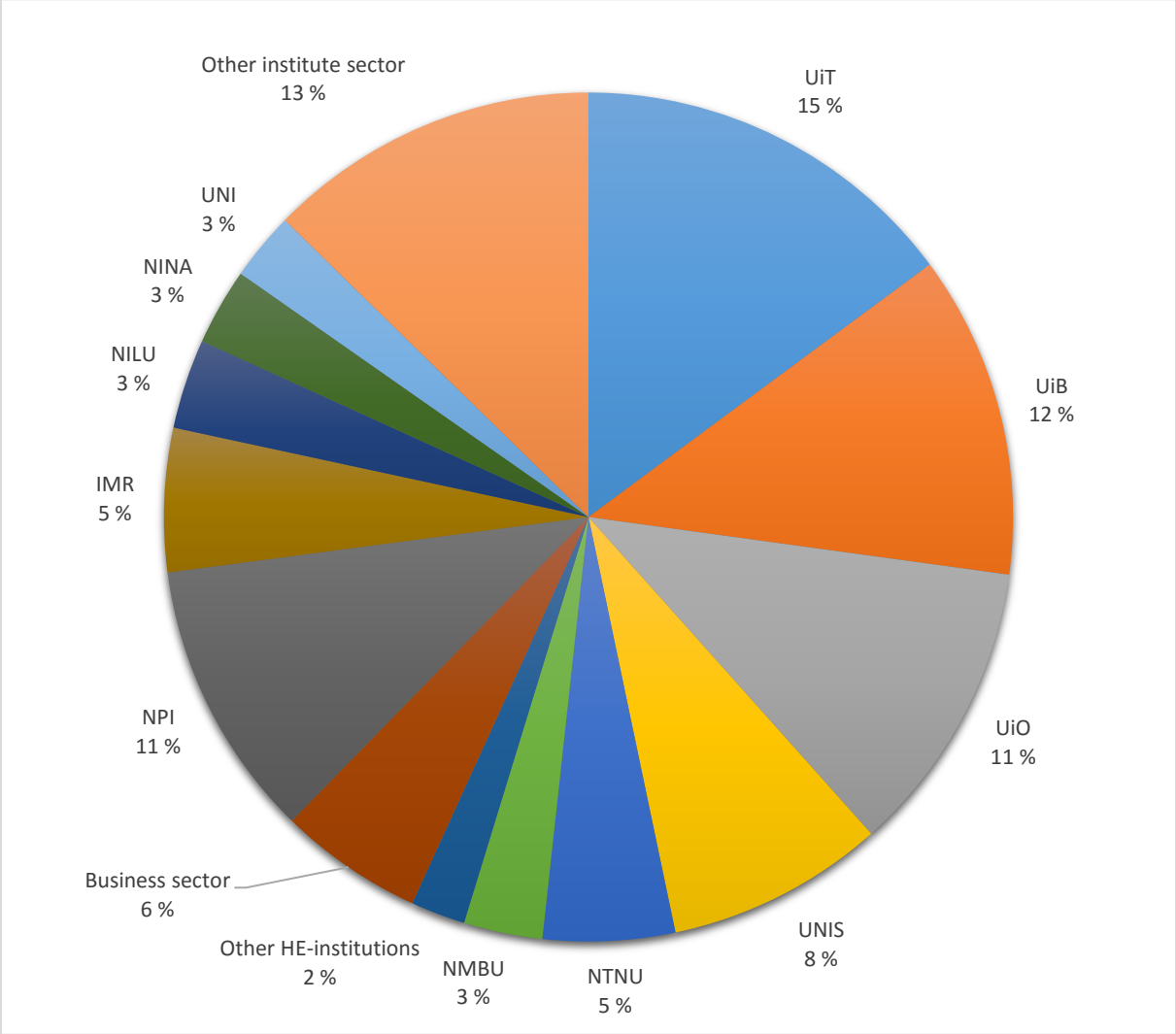

Figure 3.4 Relative contribution to the Norwegian article production in polar research by institution/institute/sector, 2010-2014.

Source: NIFU / Web of Science.

3.2 Scientific collaboration – co-authorship

Increasing collaboration in publications is an international phenomenon and is one of the most important changes in publication behaviour among scientists during the last decades. This chapter analyses the collaboration patterns of polar research based on co-authorship data. Both national collaboration (publications having author addresses from other Norwegian institutions) and international collaboration (publications with domestic and foreign author addresses) are analysed.

The extent of scientific cooperation has increased significantly in recent decades, both in general and in polar research in particular. In the early 1980s, less than 10 per cent of polar research articles involved international co-authorship (Aksnes & Hessen, 2009). In 2005, this proportion increased to 37 per cent, while it was 45 per cent in 2013/2014. Global polar research is thus characterized by a high degree of international collaboration. This applies to both the Arctic and Antarctic research.

There are quite large differences across countries in terms of the extent to which polar research involves international collaboration. This is shown in Figure 3.5, based on data from the period 2012-2014. Switzerland and the Netherlands are the countries with the highest proportion of articles with international co-authorship, respectively 91 and 89 per cent. At the opposite end of the scale, India has a proportion of 34 per cent. Norway ranks roughly in the middle among the countries shown in the figure with a share of 73 per cent. This means that of four "Norwegian" polar articles, three had co-authors from other countries. Of the large polar nations, Germany has the highest share with 79 per cent, followed by the UK with 77 per cent.[7]

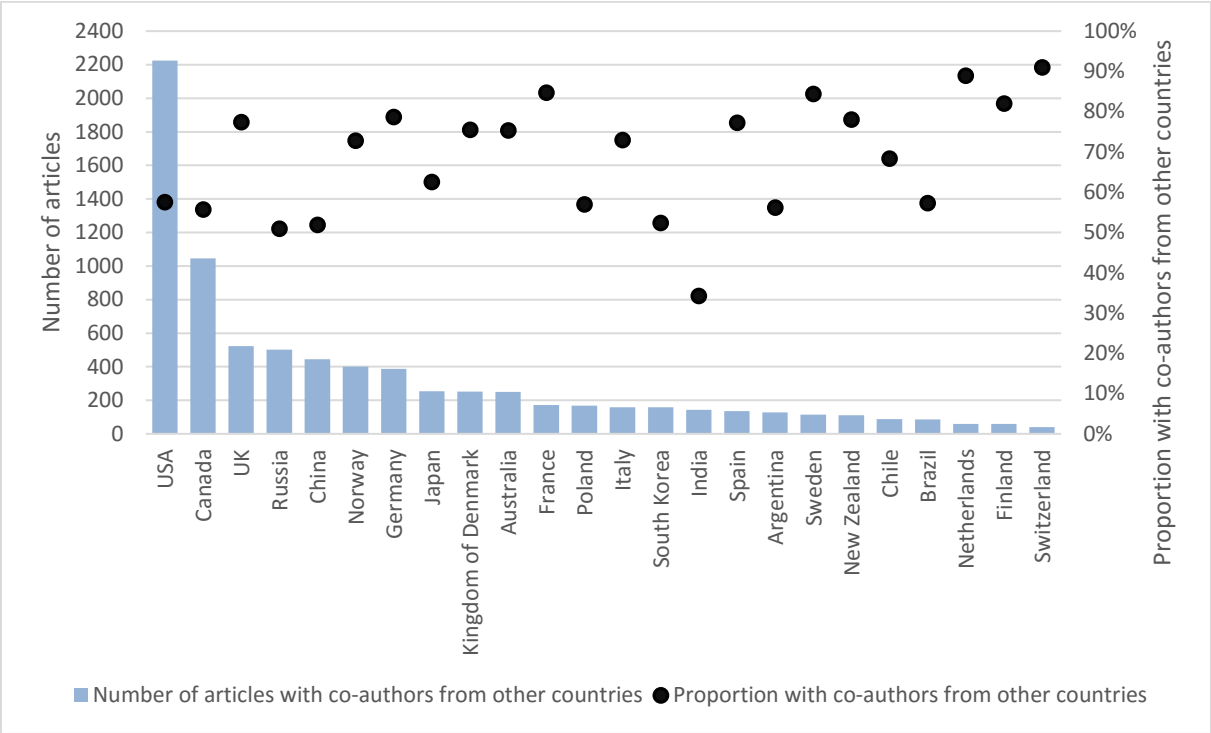

Figure 3.5 International collaboration in polar research (total). Number and percentage of articles with international co-authorship by country, 2012-2014.

Source: NIFU / Web of Science.

[7] As is evident, almost all countries have proportions above the global average of 45 per cent in 2013/2014. This has a methodological explanation, as the internationally co-authored articles will be counted for more than one country. The table below illustrates this point. Here 1 of 3 articles (33 per cent) are internationally co-authored, but the proportions for each country are 50 and 100 per cent.

Article	Country A	Country B	Country C
Article 1	X	X	X
Article 2		X	
Article 3			X
Total number of articles	1	2	2
Number of internationally co-authored articles	1	1	1
Proportion of internationally co-authored articles	100%	50%	50%

We have also analysed the collaboration patterns in polar research across countries. Here we have limited the analysis to Arctic research, since this is most relevant for Norway. Table 3.2 shows an overview of the largest countries in Arctic polar research for the period 2012-2014. The US is the most important partner of all countries, which is not surprising considering the country's size as polar research nation. Of the Norwegian Arctic publications, 19 per cent had co-authors from the United States. This is a considerably smaller proportion than the other nations, with the exception of Russia. The other countries have proportions in the range of 26 to 35 per cent. Russian research is characterized by low international collaboration compared with other nations. Canada is by far the most important collaborative partner for US polar researchers.

Table 3.2 International collaboration across countries in Arctic polar research. Percentage of co-authored publications by country, 2012-2014.*

	Collaborating country									
Country	USA	Canada	Nor-way	UK	Germany	Russia	Den-mark**	France	Other cty	Total*
USA		17 %	8 %	12 %	9 %	5 %	8 %	6 %	29 %	3 320
Canada	27 %		7 %	10 %	7 %	3 %	8 %	7 %	19 %	2 059
Norway	**19 %**	**12 %**		**17 %**	**14 %**	**9 %**	**13 %**	**9 %**	**37 %**	**1 328**
UK	31 %	16 %	18 %		16 %	5 %	16 %	12 %	45 %	1 280
Germany	26 %	13 %	17 %	19 %		13 %	11 %	10 %	44 %	1 120
Russia	18 %	6 %	13 %	7 %	16 %		4 %	3 %	24 %	868
Denmark**	26 %	17 %	18 %	21 %	13 %	4 %		9 %	42 %	949
France	35 %	23 %	19 %	25 %	19 %	5 %	15 %		47 %	598
Other cty	27 %	11 %	14 %	16 %	14 %	6 %	11 %	8 %		3 611

*) Total number of articles. **) Kingdom of Denmark
Source: NIFU / Web of Science.

The numbers in Table 3.2 are graphically illustrated in Figure 3.6. In the figure, the surface area of the circles is proportional to the total publication output in Arctic polar research, while the breadth of the lines is proportional to the number of collaborative articles.

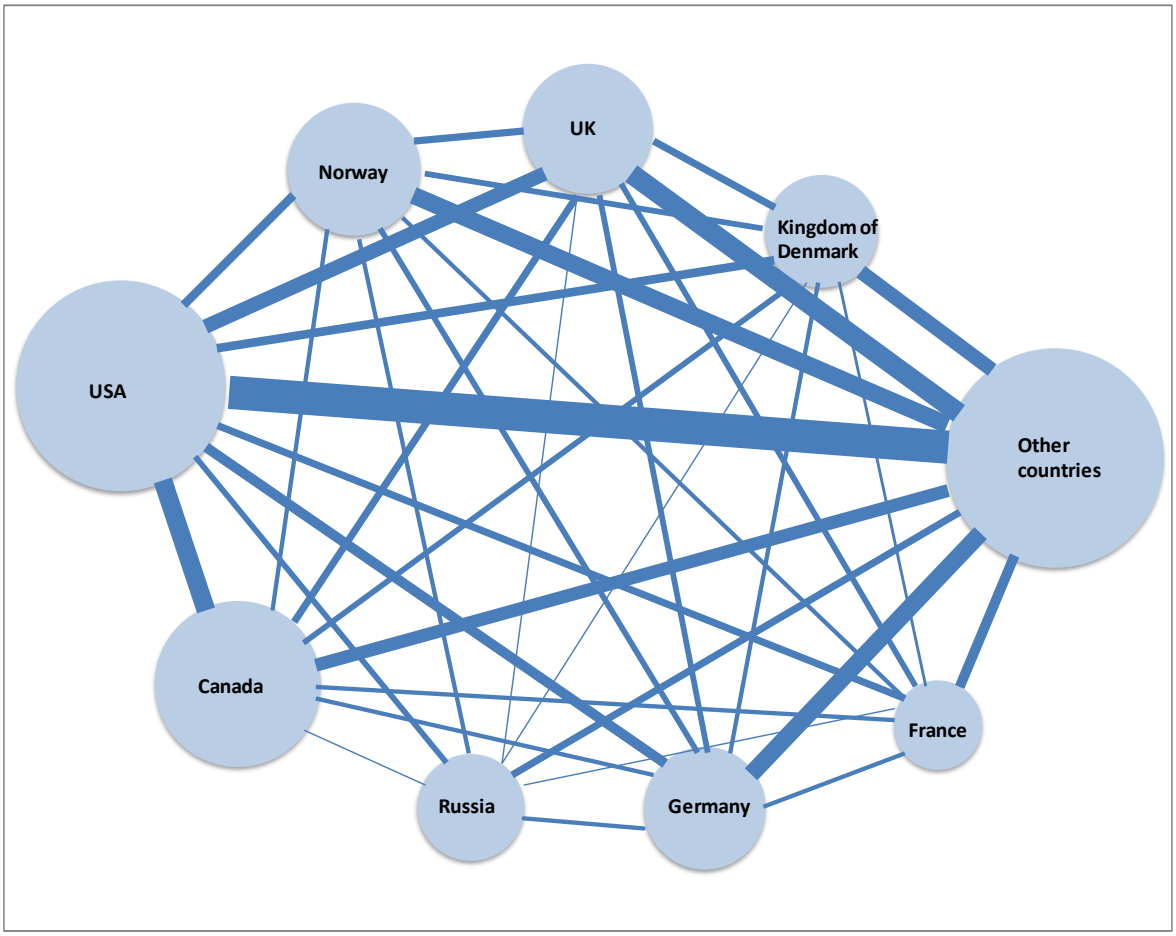

Figure 3.6 International collaboration in Arctic polar research based on co-authorship, 2012-2014. *

*) The area of the circles is proportional to the total size of the polar nations in the Arctic (in terms of number of publications), while the width of the lines is proportional to the number of joint publications between countries.
Source: NIFU / Web of Science.

In Table 3.3 we have shown the extent of co-authorship for the countries Norwegian researchers collaborate most frequently with, based on figures for 2009-2011 and 2012-2014. In contrast to Table 3.2 and Figure 3.6 this table includes all polar research publications, not only articles relating to the Arctic. The USA is the most important collaboration partner, and in 2012-2014, 21 per cent of the Norwegian polar research articles were co-authored with researchers from this nation. In other words, roughly every fifth Norwegian polar research article also had co-authors from the United States. Of almost equal importance is collaboration with the UK, and 19 per cent of the Norwegian article production involved collaboration with British researchers in the period 2012-2014. Then follow Germany, Kingdom of Denmark, Canada, France and Sweden.

Compared with the period 2009-2011, the extent of international collaboration as measured by co-authorship has increased, and most countries have increased the proportion of articles co-authored with Norwegian researchers.

Table 3.3 Collaboration by country 2009-2011 and 2012-2014. Number and proportion of the Norwegian article production in polar research with co-authors from the respective countries.

	2009-2011		2012-2014	
Country	Number of articles	Proportion	Number of articles	Proportion
USA	207	18.5 %	315	21.4 %
UK	195	17.4 %	283	19.2 %
Germany	142	12.7 %	224	15.2 %
Kingdom of Denmark	118	10.5 %	183	12.4 %
Canada	129	11.5 %	160	10.8 %
France	71	6.3 %	136	9.2 %
Sweden	93	8.3 %	134	9.1 %
Russia	62	5.5 %	116	7.9 %
Netherlands	41	3.7 %	87	5.9 %
Australia	23	2.1 %	83	5.6 %
Finland	54	4.8 %	78	5.3 %
Japan	33	2.9 %	64	4.3 %
Spain	24	2.1 %	57	3.9 %
Switzerland	30	2.7 %	56	3.8 %
Italy	27	2.4 %	54	3.7 %
Poland	28	2.5 %	50	3.4 %
Belgium	21	1.9 %	42	2.8 %
Austria	15	1.3 %	42	2.8 %
Iceland	26	2.3 %	39	2.6 %
China	15	1.3 %	38	2.6 %
South Africa	14	1.3 %	32	2.2 %
New Zealand	14	1.3 %	25	1.7 %
Ireland	9	0.8 %	14	0.9 %
Czech Republic	7	0.6 %	13	0.9 %
Estonia	3	0.3 %	12	0.8 %
Chile	4	0.4 %	11	0.7 %
Portugal	6	0.5 %	11	0.7 %
Other countries	31	2.8 %	122	8.3 %
Total	760	67.9 %	1 074	73.0 %

Source: NIFU / Web of Science.

In Figure 3.7 we have illustrated Norwegian-foreign collaboration in Arctic polar research for the main Norwegian partners (2012-2014). Here, the area of the circles is proportional to the countries' size, i.e. their total number of Arctic polar research articles. Canada is for example more than twice as large as the Kingdom of Denmark, while the number of joint articles with Norwegian researchers still is higher for Denmark.

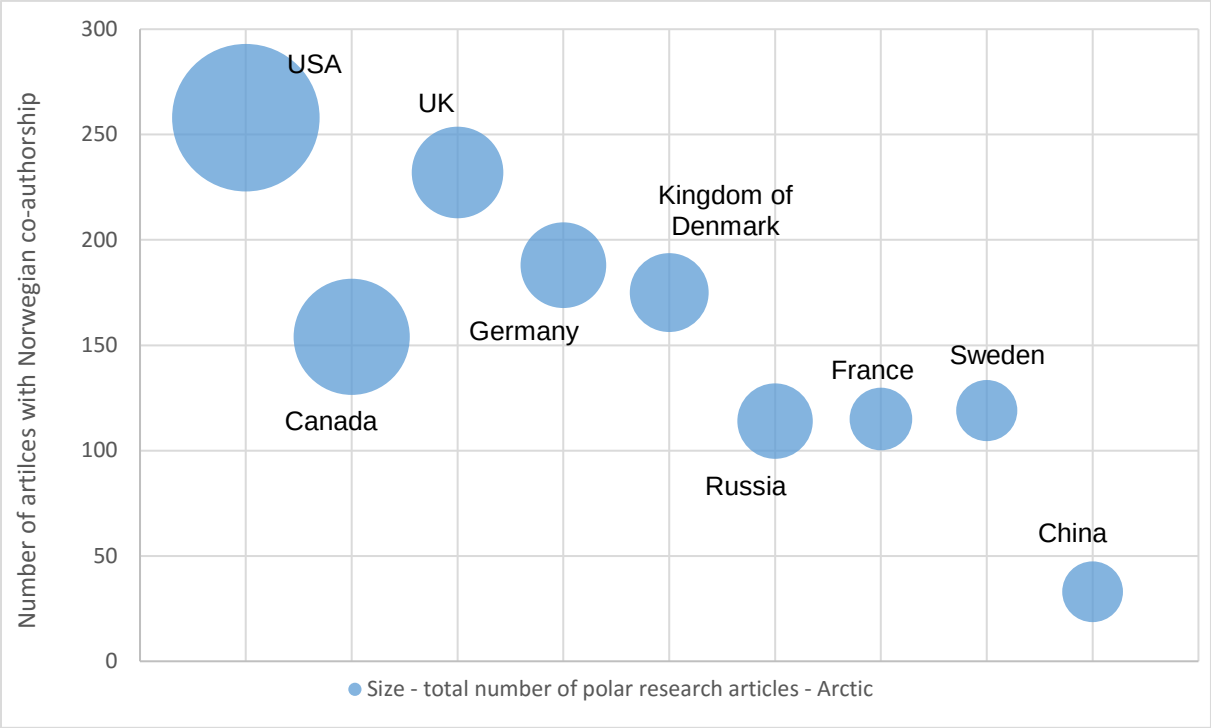

Figure 3.7 International collaboration with Norway in Arctic polar research. Number of co-authored articles with Norway, 2012-2014 and country "size" (total number of polar research articles - Arctic)

Source: NIFU/Web of Science.

The incidence of national and international collaboration varies across the individual institutions and institutes, cf. Table 3.4. However, for all units, the large majority of the publications have either national and/or foreign co-authors. The proportion of publications lacking external co-authors is very low, ranging from 0 to 13 per cent.

Table 3.4 National and international collaboration by institution/institute. Percentage of articles with various types of co-authorship, 2012-2014.

	Institution/institute	Publications with internal* authorship only	Publications with national co-authorship	Publications with international co-authorship	Publications with national and international co-authorship	N- Total number of publica-tions
HE sector	UiT	13%	57%	62%	33%	565
	UiB	6%	60%	74%	39%	468
	UiO	8%	63%	68%	39%	427
	UNIS	1%	72%	75%	48%	316
	NTNU	12%	71%	54%	37%	191
	NMBU	8%	75%	65%	48%	114
	Other HE-institutions	6%	61%	70%	37%	79
Institute sector	NPI	2%	64%	78%	45%	403
	IMR	11%	69%	55%	34%	208
	NILU	2%	50%	84%	36%	130
	NINA	6%	78%	58%	42%	111
	UNI	0%	88%	71%	59%	99
	Other institute sector	10%	67%	59%	37%	482
	Business sector	3%	80%	57%	41%	209
	Other	3%	74%	66%	44%	94

*) Colleagues from same institution
Source: NIFU / Web of Science.

Table 3.5 shows the international collaboration profile for each institution/institute, limited to the largest collaborative research nations. For example, the proportion of collaborative articles with UK is much higher for UiB (23 per cent) than for UiT (13 per cent).

Table 3.5 Collaboration by institution/institute. Percentage of articles with co-authorship from various countries, 2012-2014.

	Institution/institute	USA	UK	Germany	Kingdom of Denmark	Canada	Sweden	France	Russia
HE sector	UiT	13%	13%	10%	9%	10%	7%	5%	8%
	UiB	21%	23%	20%	10%	8%	8%	8%	7%
	UiO	28%	17%	11%	10%	10%	9%	9%	8%
	UNIS	22%	25%	11%	17%	8%	11%	3%	9%
	NTNU	15%	12%	6%	12%	13%	9%	9%	7%
	NMBU	11%	12%	11%	20%	17%	21%	4%	4%
	Other HE-institutions	25%	22%	8%	23%	5%	9%	3%	5%
Institute sector	NPI	26%	15%	18%	13%	20%	12%	10%	6%
	IMR	12%	14%	10%	9%	11%	6%	4%	14%
	NILU	33%	18%	25%	9%	18%	18%	22%	8%
	NINA	6%	19%	4%	11%	14%	14%	17%	4%
	UNI	24%	29%	21%	6%	2%	6%	13%	6%
	Other institute sector	14%	14%	14%	10%	8%	7%	7%	5%
	Business sector	15%	11%	11%	9%	7%	4%	3%	7%

Source: NIFU / Web of Science.

Table 3.6 gives further information on the national collaboration profile of the institutions and institutes based on data for 2012-2014. We have used colour scale to illustrate the intensity of the collaboration measured by proportion of joint co-authored articles.[8] Note that some of the publications will have co-authors from more than one institution or institute and will therefore be multiply counted. For example, UiT (left column) published 355 articles during the period 2012-2014 (N). Of these, 19 per cent were co-authored with NPI, and 17 per cent with UNIS. These two institutions are UiT's two largest Norwegian collaborators measured by co-authorship. Similarly, NPI published 246 publications of which 27 per cent involved co-authorship with researchers from UiT. The proportion is lower for UiT than vice versa because UiT has the highest number of total publications (cf. N), while the number of collaborative publications the proportions are calculated from, is identical for the two institutions.

Table 3.6 National collaboration per institution/institute, 2012 to 2014. Percentage of articles with joint co-authorship.

Collbora-ting inst.	Institution/institute													
	UiT	UiB	UiO	UNIS	NTNU	NMBU	Other HE-inst	NPI	IMR	NILU	NINA	UNI	Other inst sector	Busin ess
UiT		5 %	5 %	31 %	15 %	20 %	19 %	27 %	13 %	15 %	31 %	7 %	12 %	28 %
UiB	5 %		14 %	17 %	11 %	11 %	12 %	4 %	30 %	1 %	1 %	82 %	22 %	15 %
UiO	4 %	13 %		20 %	10 %	17 %	0 %	15 %	17 %	15 %	6 %	11 %	18 %	14 %
UNIS	17 %	12 %	15 %		16 %	24 %	8 %	11 %	5 %	8 %	6 %	11 %	6 %	25 %
NTNU	5 %	4 %	4 %	9 %		12 %	6 %	10 %	5 %	13 %	24 %	1 %	8 %	10 %
NMBU	4 %	3 %	5 %	9 %	8 %		10 %	8 %	1 %	10 %	10 %	3 %	4 %	2 %
Other HE inst	3 %	2 %	0 %	2 %	3 %	7 %		3 %	1 %	0 %	6 %	1 %	2 %	2 %
NPI	19 %	3 %	13 %	13 %	20 %	26 %	13 %		9 %	16 %	31 %	4 %	9 %	22 %
IMR	5 %	15 %	9 %	3 %	7 %	1 %	2 %	6 %		5 %	6 %	16 %	9 %	5 %
NILU	3 %	0 %	4 %	3 %	8 %	11 %	0 %	5 %	3 %		9 %	0 %	2 %	1 %
NINA	7 %	0 %	2 %	2 %	16 %	11 %	10 %	10 %	3 %	9 %		1 %	5 %	2 %
UNI	2 %	20 %	3 %	4 %	1 %	3 %	2 %	2 %	9 %	0 %	1 %		8 %	4 %
Other inst sector	10 %	22 %	20 %	8 %	19 %	17 %	12 %	11 %	18 %	9 %	21 %	30 %		20 %
Business	10 %	7 %	7 %	16 %	11 %	4 %	4 %	12 %	4 %	1 %	3 %	7 %	9 %	
N*	355	303	276	202	119	76	52	246	151	79	78	73	301	132

*) Total number of articles (includes publications with and without national co-authorship).
Source: NIFU/Web of Science.

3.3 Citation indicators

3.3.1 Overall relative citation index

The extent to which the articles have been referred to or cited in the subsequent scientific literature is often used as an indicator of scientific impact and international visibility of the research. In absolute numbers, the countries with the largest number of articles also receive the highest numbers of citations. It is however common to use a size-independent measure to assess whether a country's

[8] The indicator expresses the collaboration intensity between institutions/institutes. It should be noted that people with positions at more than one department/institute (e.g. Adjunct Professors) might have listed more than one author address. In the analyses, such articles will also be counted as collaborative.

articles have been highly or poorly cited. One such indicator is the relative citation index showing whether a country's scientific publications have been cited above or below the world average (=100).[9]

In Figure 3.8 we have calculated the relative citation index of the largest polar research nations (in terms of number of publications), based on the citations to the publications from the four-year period 2010–2013. Norway ranks as number 12 of the countries included in the comparison, with a citation index of 113. This means that the Norwegian articles have been cited 13 per cent above the world average. In other words, the performance of Norwegian polar research in terms of citations is somewhat below that of the leading countries. Still, the Norwegian citation index is clearly above world average, although this average does not constitute a very ambitious reference standard as it includes publications from countries with less developed science systems.

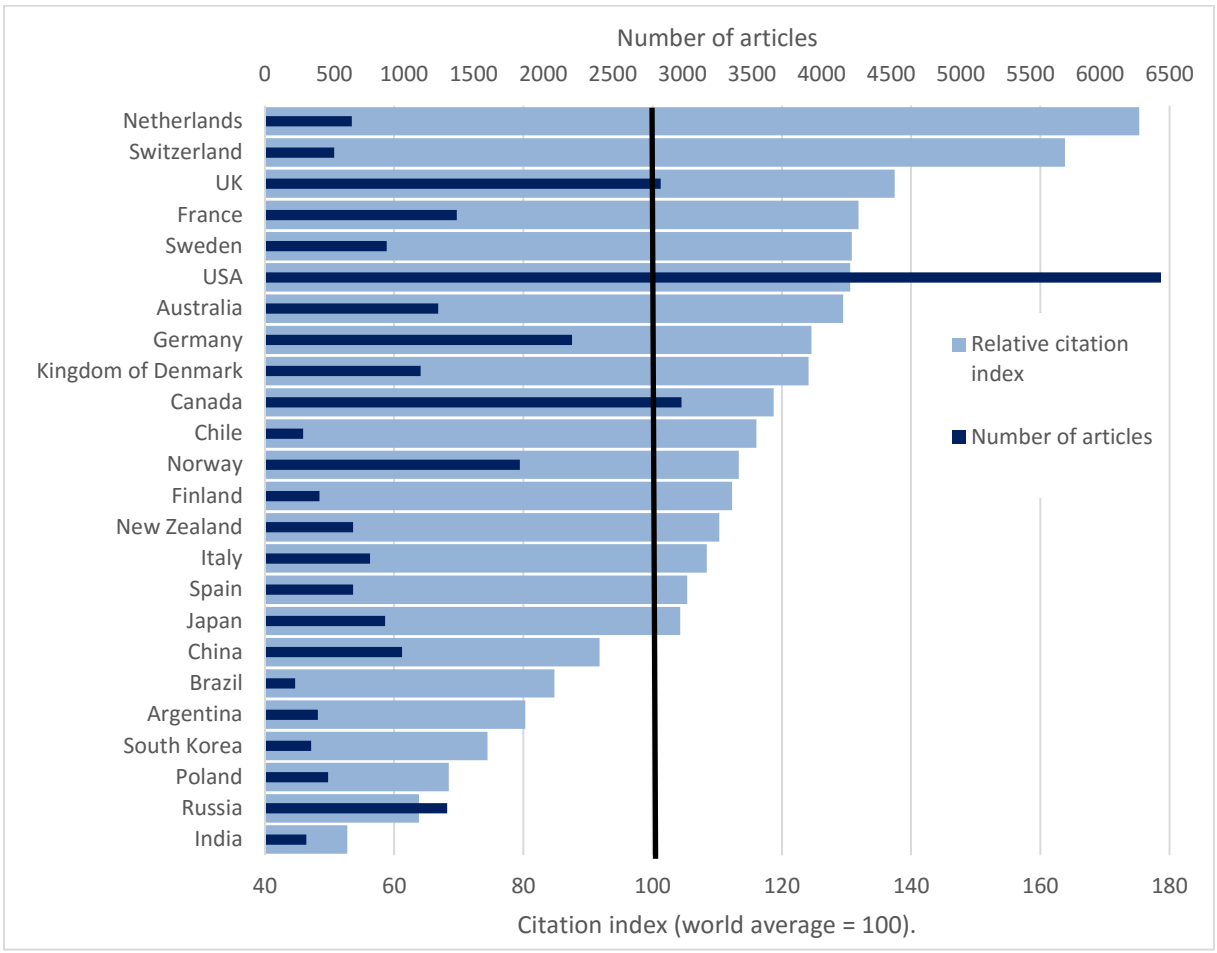

Figure 3.8 Relative citation index and the number of articles of the 24 largest polar research nations, 2010-2013.

Source: NIFU / Web of Science.

Netherlands and Switzerland are the countries that during this period achieved the greatest scientific impact, measured by the number of citations. The articles of these countries were cited 75 and 64 per cent, respectively, more than the world average. However, these nations are minor contributors to

[9] We refer to Chapter 5 for a further discussion on what citations "measure" and the use of this indicator as performance measure. There are various sources of errors, some of which are more relevant at micro than at macro level. For example, self-citations are sometimes considered as problematic because they account for a quite large share of all citations and because they do not reflect the impact of a work on the scientific community (Aksnes 2003). However, self-citations are not usually considered to be a problem at aggregated levels. Generally, for any country a disproportionally high fraction of the citations is "domestic" i.e. citations in which the national affiliations of the citing and the cited paper are identical. To what extent this affects the use of citations as performance measure is a matter of debate.

polar research, and the citation index is based on a relatively small number of articles. Of the larger nations, the United Kingdom, France and the United States have the highest citation index (131-137). Among the countries included in the figure with lowest citation index we find India, Russia and Poland (citation index values: 53-68).

Figure 3.9 shows the citation index of the seven largest polar research nations for the two periods 2005-2009 and 2010-2013. All countries, except Canada have increased their citation rate from 2005-2009 to 2010-2013. The Norwegian index increased marginally from 110 in 2005-2009 to 113 in 2010-2013. However, in both periods Norway ranks as the country with the lowest citation index (of the seven selected countries).

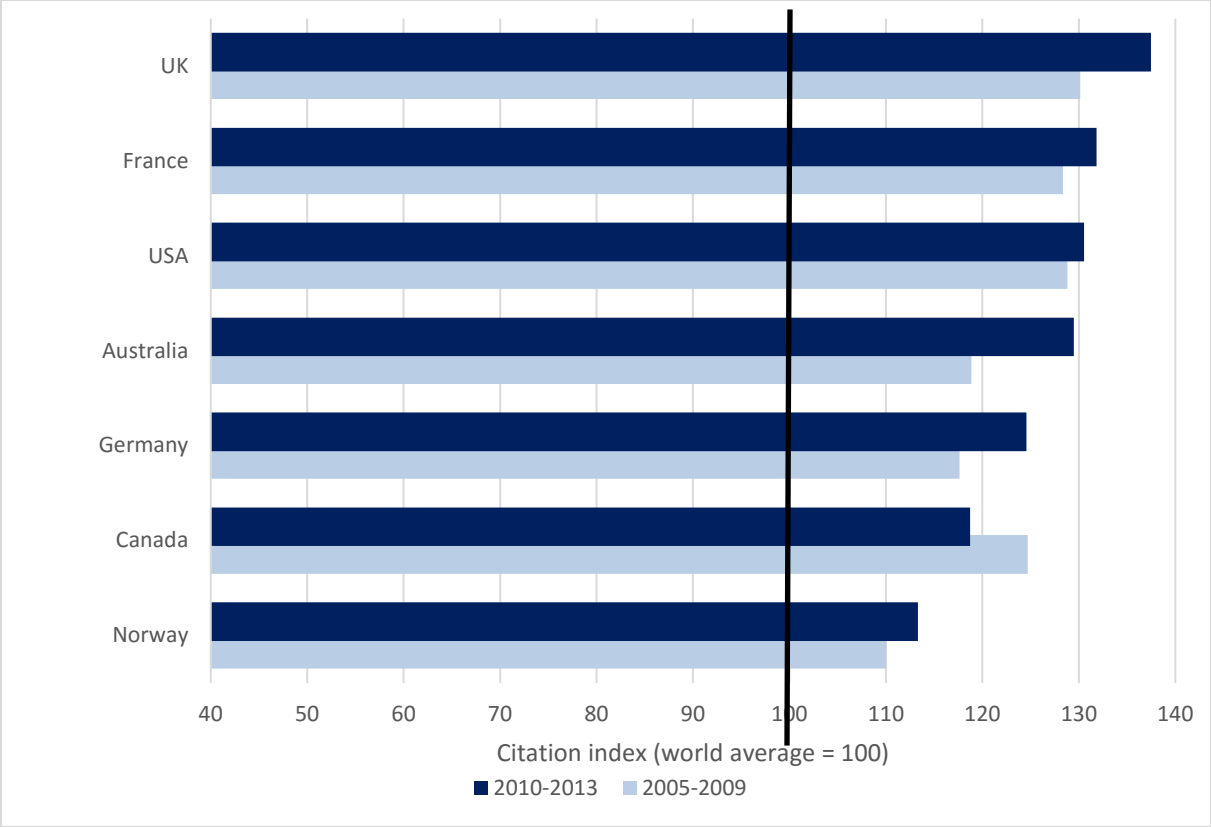

Figure 3.9 Relative citation index for the seven largest polar research nations, 2005-2009 and 2010-2013.

Source: NIFU / Web of Science.

Polar research is characterised by extensive national and international collaboration. As shown above, the majority of the articles have co-authors from more than one country. The citation indicators are based on the set of publications that have at least one author address from a country. In the calculation of citation indicators, whole counting of publications has been applied, which means that each country in internationally co-authored publications receives full credit for its participation. This is the most common way of calculating citation indicators, although it means that an individual country is credited with the contributions of many scientists in other countries. In extreme cases, the majority of the article contributions may actually have been made by international researchers. An alternative is fractionalised publication counting, in which a country is credited a fraction of a publication equal to the fraction of the author addresses from that country.

The results of using a fractionalised calculation method is shown in Figure 3.10. As can be see, the relative citation scores based on fractionalised counting generally yield lower values than whole counting because internationally co-authored publications tend to have higher citation rates than nationally authored publications. When using this method Norway's citation index is 94, in other words below the world average. Norway ranks as number 12 of the countries in the figure which is identical to the ranking based on the whole count method.

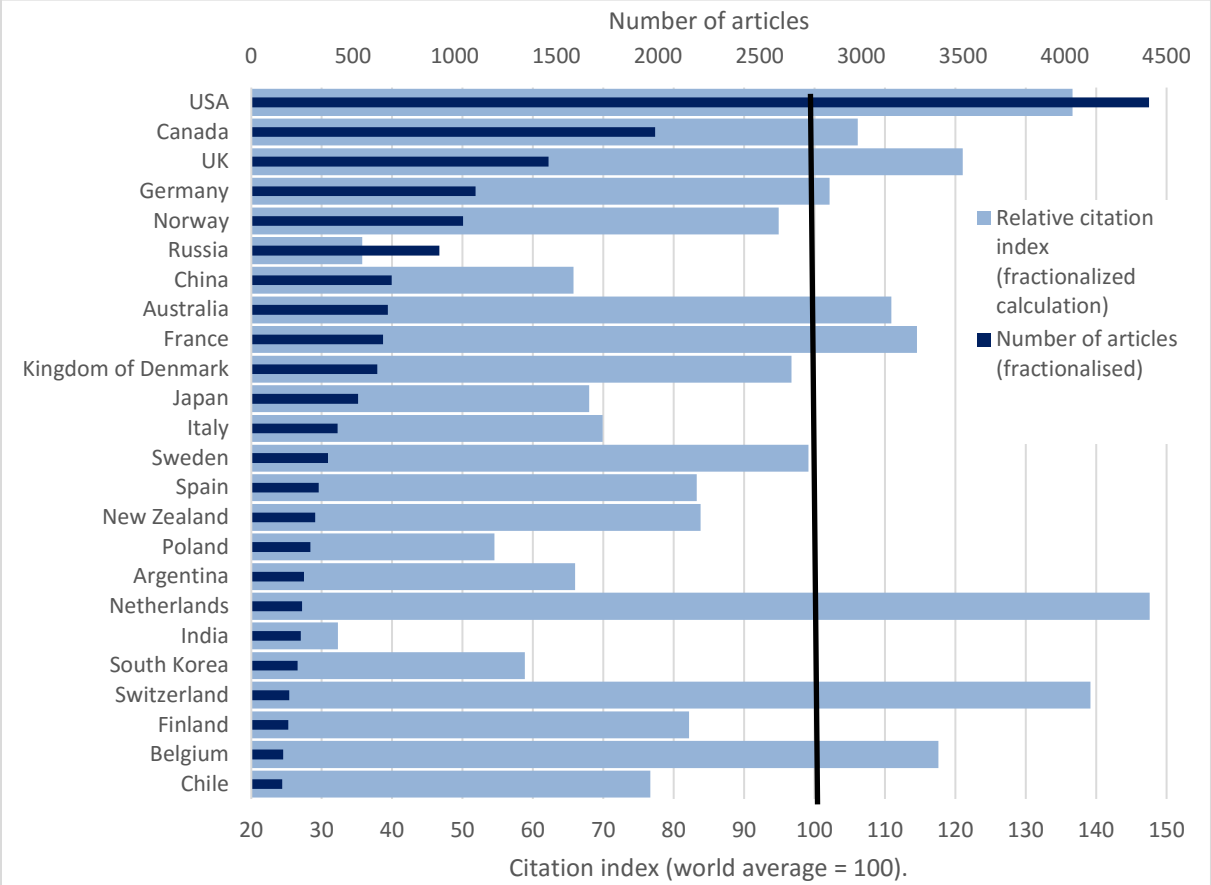

Figure 3.10 Relative citation index and the number of articles of the 24 largest polar research nations based on fractionalized counts, 2010-2013.

Source: NIFU / Web of Science.

Another alternative is to identify the articles which have first author or corresponding author from a particular country. The norms for author listing or crediting may vary. However, a commonly used system is that the first author is the researcher who has undertaken the largest part of the work while the corresponding author is the senior researcher being responsible or leading the work presented. This means that it may be of particular interest to calculate national citation indicators based on the articles with first author and/or corresponding author, as researchers from the respective countries may be assumed to have key roles in these papers. Such an indicator for the period 2010-2013 is shown in Figure 3.11, here the countries have been ranked according to article volume (number of articles with first author and/or corresponding author).

Among the largest polar research nations, USA has the highest relative citation index (129) followed by the UK (125). Most countries obtain a lower citation index, when the indicator is calculated based on these articles, only. This also holds for Norway for which the citation index drops to 94. Of the ten largest research nations, only China and Russia have lower index values than Norway.

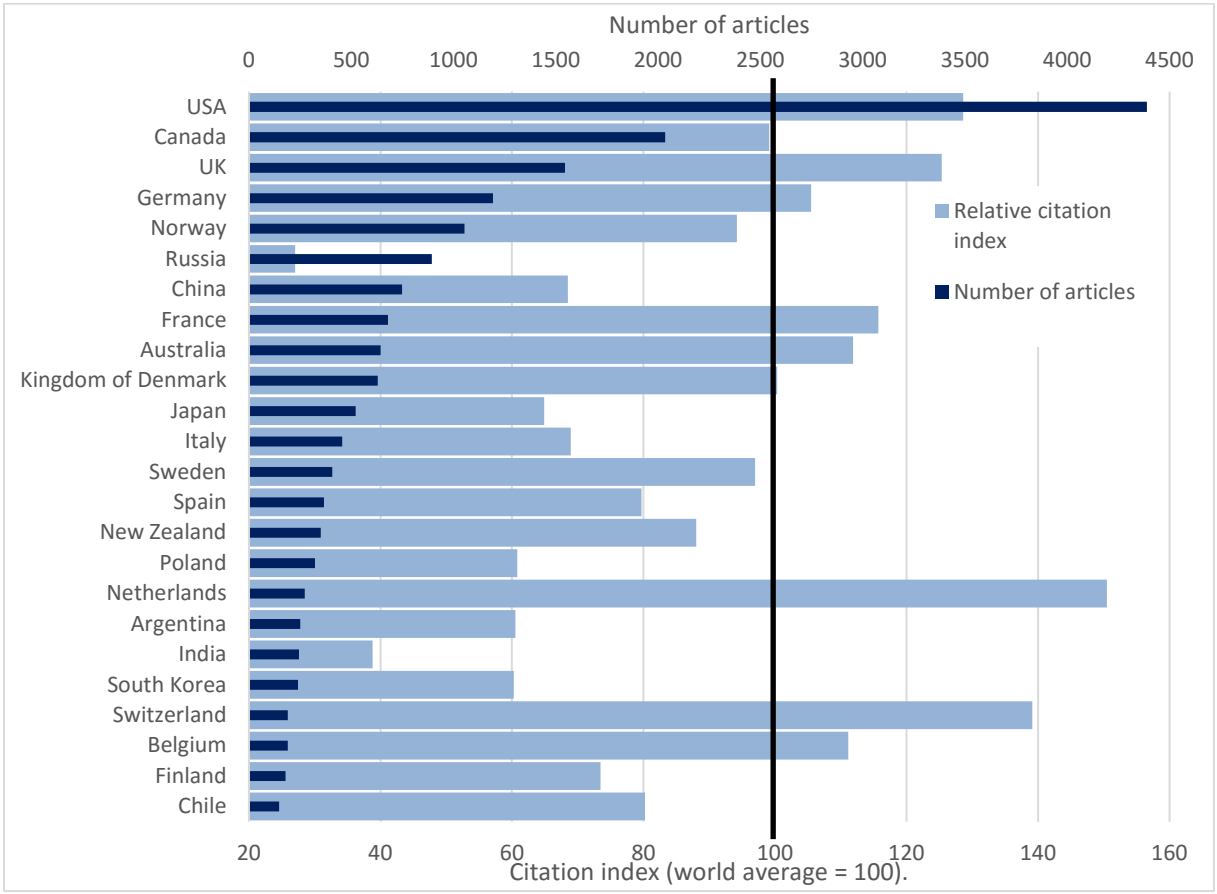

Figure 3.11 Relative citation index. Articles with first author/corresponding author by country, 2010-2013.

Source: NIFU / Web of Science.

Another complementary picture may be obtained by analysing the publications with national authors only, i.e. the publications from each country that do not involve co-authorship with authors from other countries. Generally, internationally co-authored papers are much more cited than publication with authors from one country, only, and this also holds for polar research. Figure 3.12 shows the indicator for the eight largest polar nations measured in article volume. Norway has approximately 500 such publications from the period 2010-2013, and these have been cited below the world average and receive a citation index of 86. It should be noted that the other countries, except the US and UK, have citation indexes below the world average.

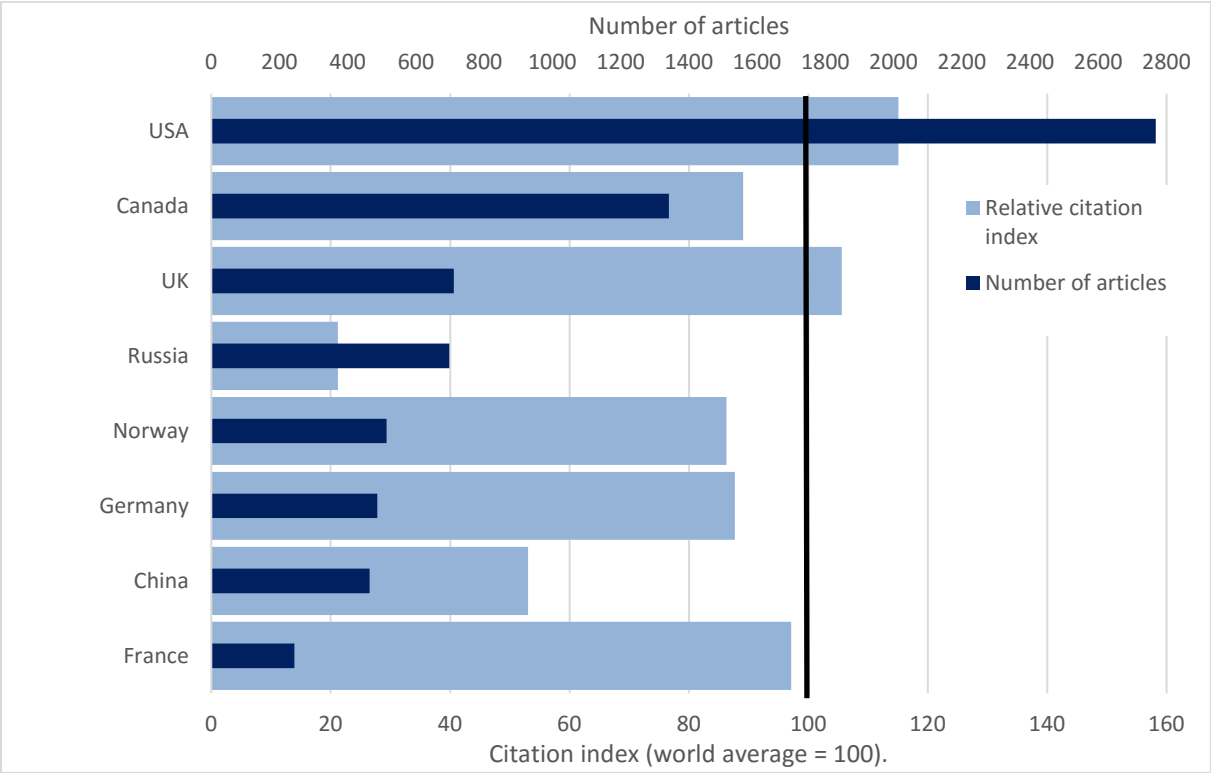

Figure 3.12 Relative citation index, articles with national authors only ("domestic" articles), 2010-2013.

Source: NIFU / Web of Science.

3.3.2 Journal profile and citation indicators

The relative citation index described above is based on field normalisation (*the field normalised relative citation index*) and is the most commonly used indicator for assessing scientific impact. This indicator can also be calculated for journals, which is related to the so called "journal impact factor". The impact factor is probably the most widely used and well-known bibliometric product. It was originally introduced by Eugene Garfield as a measure of the frequency with which the average article in a journal has been cited. In turn, the impact factor is often considered as an indicator of the significance and prestige of a journal. Although there are several problems attached to the use of the indicator (not to be discussed here), the citation rate of journals may provide interesting supplementary information regarding the citation impact of polar research.

In the analysis below we have calculated for each country a citation index for the journal set where the articles have been published. The indicator is adjusted for the number of articles per journal and publication year. A journal citation index is calculated by dividing the average citation rate of the journals in which the country's articles were published by the average citation rates of the subfields

covered by these journals. Thus, if this indicator exceeds 100 one can conclude that the country publishes in journals with a relatively high impact.

As expected, there is a relatively strong correlation between the relative citation index of a country and their corresponding journal profile (Figure 3.13). The nations with highest citation indexes such as Switzerland, the Netherlands and the UK tend to publish more in high impact journals than countries with low citation indexes. Norway ranks as number 13 of the 27 countries shown in the figure. The citation index of the journals used by Norwegian researchers is 121.

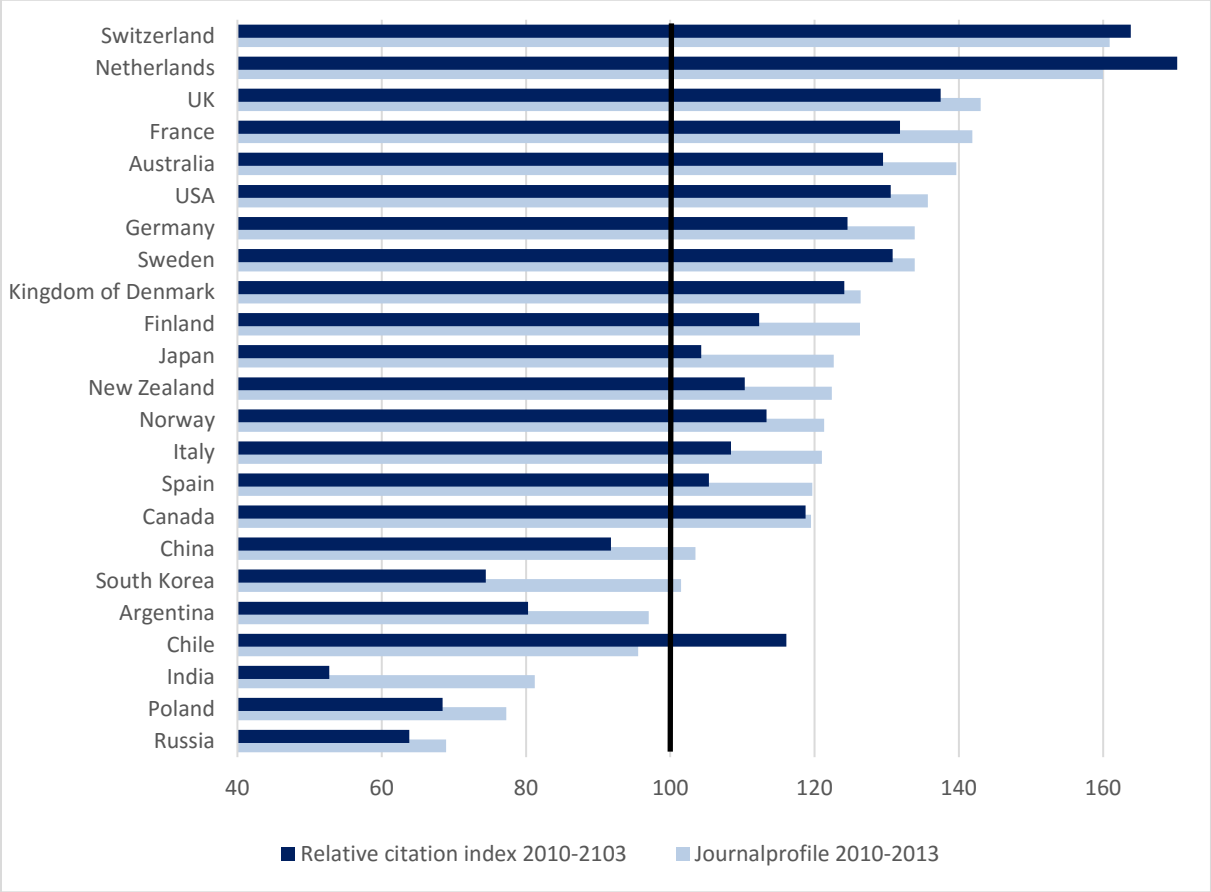

Figure 3.13 Relative citation index for the 24 largest polar research nations, 2010-2013 compared with the relative citation index for the journals used.

Source: NIFU / Web of Science.

In order to provide further insight into the publication profile of Norwegian polar research, we have listed the most frequently used journals in terms of number of publications and two citation indexes in Table 3.7. One, the relative journal citation index, corresponds with the one used for calculating the journal profile above. The other, the relative citation index (Norwegian polar articles) shows the citation index for the Norwegian polar articles published in the respective journals. On the top of the list we find the journal *Polar Biology* with 81 polar articles published by Norwegian researchers during the period 2010-2013. The articles in this journal are generally cited below the average for corresponding biology articles, which is indicated by the relative journal citation index of 66. The relative citation index for the Norwegian polar articles published in this journal is 81. In other words, these articles are cited slightly above the average for papers published in *Polar biology* but still below the world average of the field.

As can be seen, on the top of the list we find both journals with high and low citation rate. The second most frequently used journal is *Atmospheric Chemistry and Physics*, which is a quite highly cited

journal with a relative citation index of 183. The Norwegian polar articles published in this journal are also highly cited (citation index 166).

Table 3.7 Journal profile of Norwegian polar research, 2010-2013. Number of articles and relative journal citation index, ranked by publication frequency.

Journal	Number of Norwegian polar articles	Relative journal citation index (all articles)*	Relative citation index (Norwegian polar articles)
POLAR BIOLOGY	81	66	81
ATMOSPHERIC CHEMISTRY AND PHYSICS	52	183	166
JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS	39	140	115
QUATERNARY SCIENCE REVIEWS	39	184	174
JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	37	125	85
POLAR RESEARCH	37	54	47
MARINE ECOLOGY PROGRESS SERIES	34	106	111
CRYOSPHERE	29	209	262
PLOS ONE	27	64	44
SCIENCE OF THE TOTAL ENVIRONMENT	27	130	265
ANNALS OF GLACIOLOGY	26	88	82
NORWEGIAN JOURNAL OF GEOLOGY	26	94	68
GEOPHYSICAL RESEARCH LETTERS	25	166	151
JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	23	64	20
ICES JOURNAL OF MARINE SCIENCE	21	120	141
JOURNAL OF GLACIOLOGY	19	120	127
MARINE BIOLOGY RESEARCH	17	64	126
PALAEOGEOGRAPHY PALAEOCLIMATOLOGY PALAEOECOLOGY	16	127	121
PROGRESS IN OCEANOGRAPHY	16	211	172
BIOGEOSCIENCES	15	154	200
ENVIRONMENTAL SCIENCE & TECHNOLOGY	15	165	118
AMBIO	14	101	104
BOREAS	14	103	78
CLIMATE DYNAMICS	14	162	123
COLD REGIONS SCIENCE AND TECHNOLOGY	14	60	45
GEOLOGY	14	222	181
INTERNATIONAL JOURNAL OF CIRCUMPOLAR HEALTH	14	45	71
JOURNAL OF MARINE SYSTEMS	14	132	109
CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES	13	131	97
MARINE AND PETROLEUM GEOLOGY	13	113	101
TECTONOPHYSICS	13	114	99
MARINE POLLUTION BULLETIN	12	106	53
DEEP-SEA RESEARCH PART I-OCEANOGRAPHIC RES PAPER	11	130	121
GEOPHYSICAL JOURNAL INTERNATIONAL	11	108	86
GLOBAL CHANGE BIOLOGY	11	282	320
JOURNAL OF GEOPHYSICAL RESEARCH-EARTH SURFACE	11	149	86
POLAR RECORD	11	21	13
PROCEED OF THE NATIONAL ACADEMY OF SCIENCES OF USA	11	182	156
QUARTERLY JOURNAL OF ROYAL METEOROLOGICAL SOC	10	194	26

*) Weighted by number of articles and year (Norwegian).
Source: NIFU / Web of Science.

When interpreting the table one should also take into consideration that there are limitations attached to the use of the relative journal citation index as performance indicator. Interestingly, *Journal of*

Geophysical Research - Space Physics which has a relatively low citation index is classified as a "level 2" journal[10] in the Norwegian performance based funding system.[11]

Most of the journals listed are traditional subscription-based journals, but at least one is open access: *PLOS One*. The issue on the relation between open access and citation is complex and will not be discussed here. Generally, most open access journals are recently established and tend to have lower than average impact factor/relative citation index.

It may be interesting to compare the Norwegian journal profile with the one of other countries. In Table 3.8 we have shown similar figures for Russia and USA as examples. While Russian polar publications generally are poorly cited, USA ranks much better in terms of citation rates. As is evident from the table, there are large differences among these two nations in their journal profiles. Russian scientists tend to publish in low impact journals i.e. journals that are little cited. Several of the journals are by Russian publishers or are mainly publishing Russian research. It should also be noted that Russian science generally is less well represented in the Web of Science database, and many journals used by Russian scientist are not indexed (e.g. Russian language journals). In contrast, the most frequently used journals by US scientists are generally highly cited.

Table 3.8 Journal profile of polar research, Russia and USA, 2010-2013. Number of articles and relative journal citation index, ranked by publication frequency.

Russia			USA		
Journal	**Number of Russian polar articles**	**Relative journal citation index (all articles)***	**Journal**	**Number of US polar articles**	**Relative journal citation index (all articles)***
OCEANOLOGY	92	20	*GEOPHYSICAL RESEARCH LETTERS*	273	190
DOKLADY EARTH SCIENCES	70	20	*JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES*	240	97
RUSSIAN METEOROLOGY AND HYDROLOGY	50	6	*JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS*	179	150
RUSSIAN GEOLOGY AND GEOPHYSICS	44	53	*JOURNAL OF CLIMATE*	162	207
ZOOLOGICHESKY ZHURNAL	42	14	*ATMOSPHERIC CHEMISTRY AND PHYSICS*	159	171
IZVESTIYA ATMOSPHERIC AND OCEANIC PHYSICS	31	20	*DEEP-SEA RESEARCH PART II-TOPICAL STUDIES IN OCEANOGR*	145	140
RUSSIAN JOURNAL OF MARINE BIOLOGY	26	18	*POLAR BIOLOGY*	136	77
GEOMAGNETISM AND AERONOMY	23	17	*QUATERNARY SCIENCE REVIEWS*	126	157
BIOLOGY BULLETIN	23	10	*JOURNAL OF GLACIOLOGY*	111	123
POLAR BIOLOGY	20	65			

*) Weighted by number of articles and year (Russian or US).
Source: NIFU / Web of Science.

As is evident from the analysis above, the journal profile of a country is important to take into consideration when interpreting the citation indexes. There is strong correlation between these citation indexes and the journal profile. Countries with low citation indexes will typically have publication

[10] In this system, the publication outlets are divided into two levels. The outlets given extra weight are those defined to be the leading and most selective international journals, series and publishers (limited to about 20 per cent of the publications). The national councils in each discipline or field of research participate annually in determining and revising the highest level under the guidance of the Norwegian Association of Higher Education Institutions

[11] The articles in this journal are overall slightly less cited than for example the articles in *Journal of Geophysical Research – Atmosphere*. The citation rates of these journals are normalized based on the fields Astronomy and Astrophysics and Meteorology & Atmospheric Sciences, respectively. As the average citation rate of the first field is higher than the one for the latter field, this also contributes to the low relative journal citation index of *Journal of Geophysical Research - Space Physics.*

profiles with many articles in low impact journals. Norway has an average position in terms of journal profile with a mix of high, medium and low impact journals, while the high performing countries publish relatively more of their publications in high impact journals.

The citation rate or impact factor of a journal is influenced by many factors. High impact journals may have high rejection rates or tend to publish seminal papers in a field, which will be reflected in the citation rates. At the same time, other factors are at play. Each year, more than one million scientific and scholarly publications are published. In such a context, the publishing strategy will have great importance for the visibility and citation rate of the publications. In an ideal world, an article would get the same citation count regardless of which journal it has been published in. However, this not the case – the readership, audience, publication language, accessibility, visibility, prestige etc. of a journal will also be influential.

The fact that the journal profile of Norway is below the profile of the leading countries in terms of citation rate may have different possible explanations: a) Norwegian polar research has a distinctive scientific profile which means that it less often is suitable for being published in the most prestigious journals, b) Norwegian polar researchers are not sufficiently ambitious when they select journals for their publications, c) the scientific quality of part of Norwegian polar research is too low for getting into the most prestigious journals. It is not within the scope of the present report to assess the likeliness of the various explanations. However, we will conclude by arguing that there are good reasons for attempting to increase the proportion of Norwegian polar research in the leading or high impact scientific journals.

3.3.3 Relative citation index – national profiles

In this subsection, we will analyse the relative citation index at the levels fields and institutions within Norway. Figure 3.14 shows the index for selected fields for the periods 2005-2009 and 2010-2013. The index is based on publications that were published during the two periods. In the most recent period (2010-2013), the citation index is above the world average in both the geosciences and biology, which by far are the largest fields in terms of publication numbers (Figure 3.3). Here, the citation index is 116 and 118, respectively. Technology has the lowest citation index (86), while biomedicine has an index value of 98. In the latter two fields, which are small in a polar research context, the citation frequency has declined compared with the previous period (2005-2009). In geoscience and biology, the index has increased slightly.

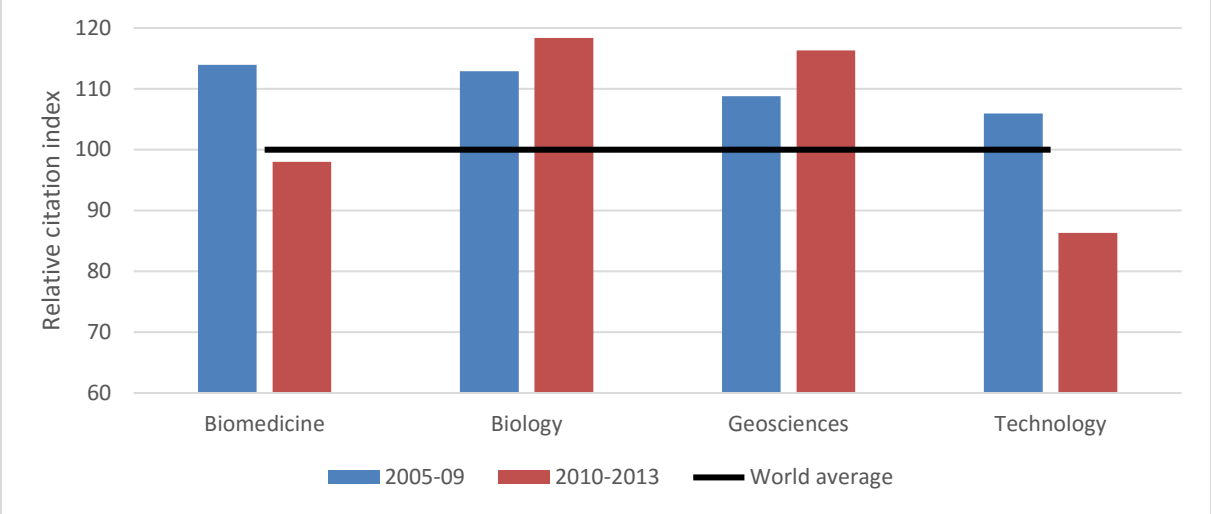

Figure 3.14 Relative citation index for Norwegian polar research in various fields based on articles from 2005-2009 and 2010-2013.

Source: NIFU / Web of Science.

Figure 3.15 shows the citation index of the largest Norwegian institutions and institutes within polar research (i.e. those with the highest number of articles during the period). Of the universities, UiO has the highest index value (126), while in the institute sector, NILU ranks highest with an index of 141, followed by NPI (129). Articles authored by business and industry are least cited, with index value of 89, in other words, slightly below the world average.

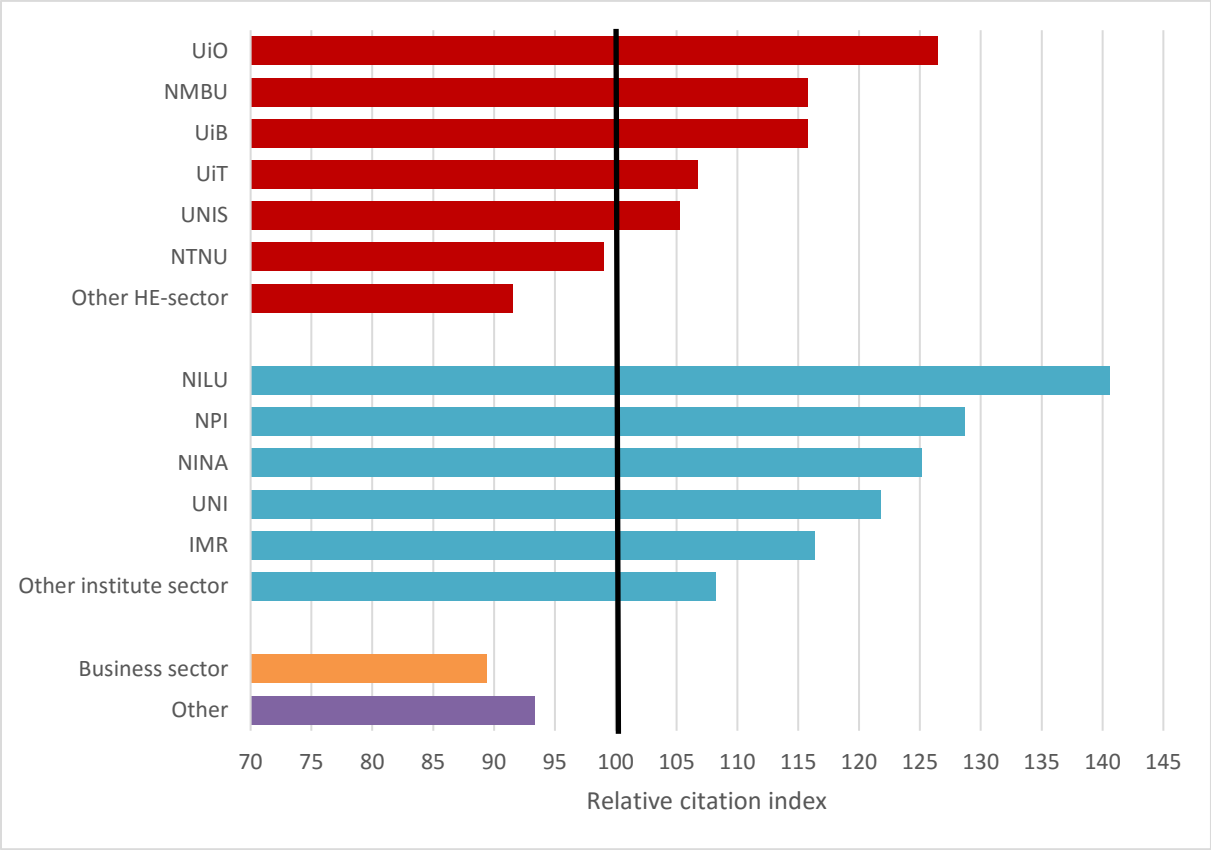

Figure 3.15 Relative citation index for Norwegian polar research by institution/institute/sector, 2010-2013.

Source: NIFU / Web of Science.

The geographical profile of Norwegian polar research was analysed in the 2015 mapping. The Svalbard related articles appeared to be less cited than both the world average and the average for Norwegian polar research. In Figure 3.16 we have shown the citation index for the Norwegian Svalbard related articles, for Norwegian polar research in total and for Norwegian polar research, excluding the Svalbard related articles. The Svalbard related articles have a citation index of 89 (2010-2013). When these articles are removed, the Norwegian citation index increases from 113 to 123. Thus, this would also improve Norway's citation ranking among the polar research nations.

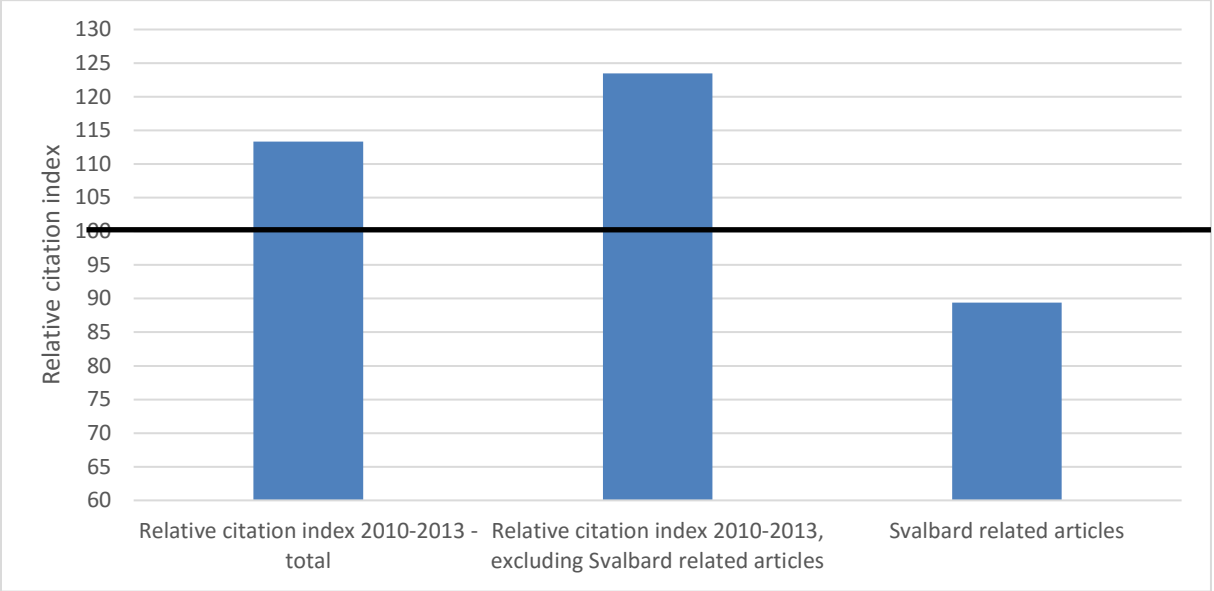

Figure 3.16 Relative citation index for Norwegian polar articles, total, Svalbard related, and total excluding Svalbard related, 2010-2013.

Source: NIFU / Web of Science.

The Norwegian citation index may be analysed according various parameters. Based on the findings above we may conclude that there are not large differences in the citation index at macro fields for the two main areas: geoscience and biology. The other fields analysed are clearly less cited but these fields contribute little to the overall Norwegian polar research. We do find large differences in the citation index at the level of institutions. Moreover, the Svalbard articles are less cited than other Norwegian polar research and this issue will be further analysed in the Chapter 4.

We have also analysed the citation rate of the articles involving international collaboration by country (Figure 3.17). Generally, collaboration also influences the impact of publications. Multi-authored papers are on average more highly cited than single-author papers. High citation rates have been found to correlate strongly with number of authors (Aksnes, 2003). Similar effects have been identified with respect to international collaboration (van Leeuwen, 2009). Various factors explain these higher citation rates. First, the quality of research may improve thanks to the involvement of more scientists with complementary competences, more technical resources and laboratory facilities. Moreover, large scale cross-national analyses are enabled by such collaboration. Such papers tend to represent more important scientific contributions and are therefore more highly cited. Second, international co-authorship introduces the publication to multiple local audiences, hence greater potential for dissemination. In practice, both effects occur simultaneously.

At country level, we see similar patterns, with internationally co-authored publications having a citation rate higher than the average for all papers produced by that country. The analysis shows that articles involving co-authorship between Norwegian and French or Norwegian and Dutch scientists obtained the highest citation rate. These articles obtained citation indexes of 204 and 203, respectively (Figure 3.17). Articles involving Norwegian-Russian cooperation obtained the lowest citation frequency (of the countries shown in the figure) (citation index 143). Still these articles were cited more frequently than the world average. It should be noted that the number of articles with the different countries varies considerably (black dot in the figure). Moreover, for each country both bilateral and multilateral collaborative articles are included. As an example, this means that some of the Norwegian-Russian articles have authors from other countries in addition.

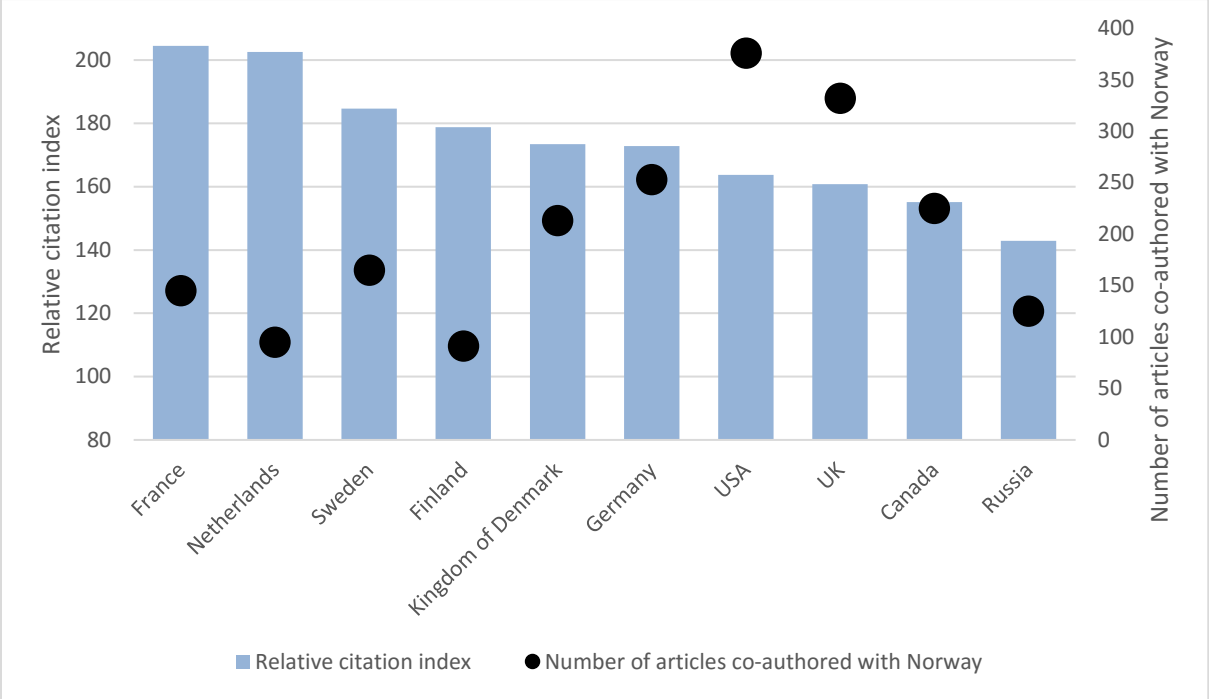

Figure 3.17 Relative Citation Index for articles with Norwegian-foreign co-authorship per country, 2010-2013.

Source: NIFU/Web of Science.

3.4 Further analyses of Norwegian publications with high and low impact measured by citations

3.4.1 Citation distributions

Citation distributions are generally very skewed. A large part of the scientific articles are never or seldom cited in the subsequent scientific literature. On the other hand, some articles receive a very large number of citations. The overall citation index is usually interpreted as an indicator of a country's general performance in a field. However, due to the skewed distribution of citations, a relatively small proportion of highly cited articles contribute heavily to the overall citedness of a country. In order to obtain further insight into the research performance measured by citations, it is therefore of particular interest to analyse this tail of the citation distribution.

Figure 3.18 clearly illustrates this skewed distribution. As an example, we have shown how the citations to the 2010 world total of all polar articles are distributed. As can be seen, the least cited half

of the articles contribute to approximately 12 per cent of the citations, only, while 14 per cent of the papers have received half of the citations.

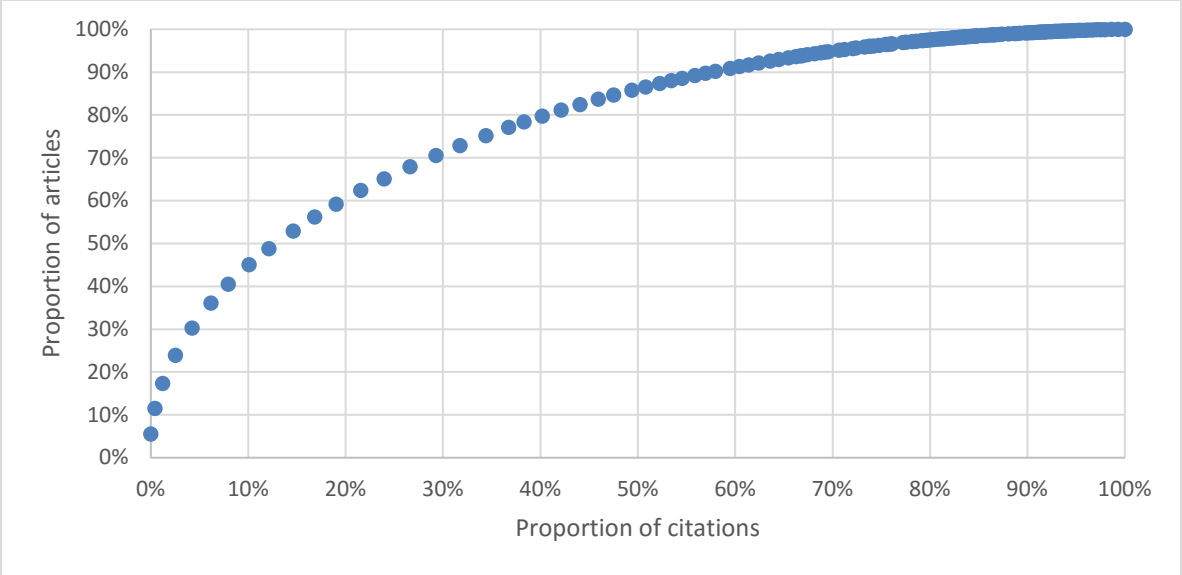

Figure 3.18 Distribution of article proportions and citation proportions, accumulative frequencies by increasing citation numbers, 2010 publications (citations 2010-2014).

Source: NIFU / Web of Science.

The underlying numbers of Figure 3.18 are shown in Figure 3.19. As can be seen, 6 per cent of the articles have not been cited (during the period 2010-2014), while 11 per cent of the papers received more than 30 citations.

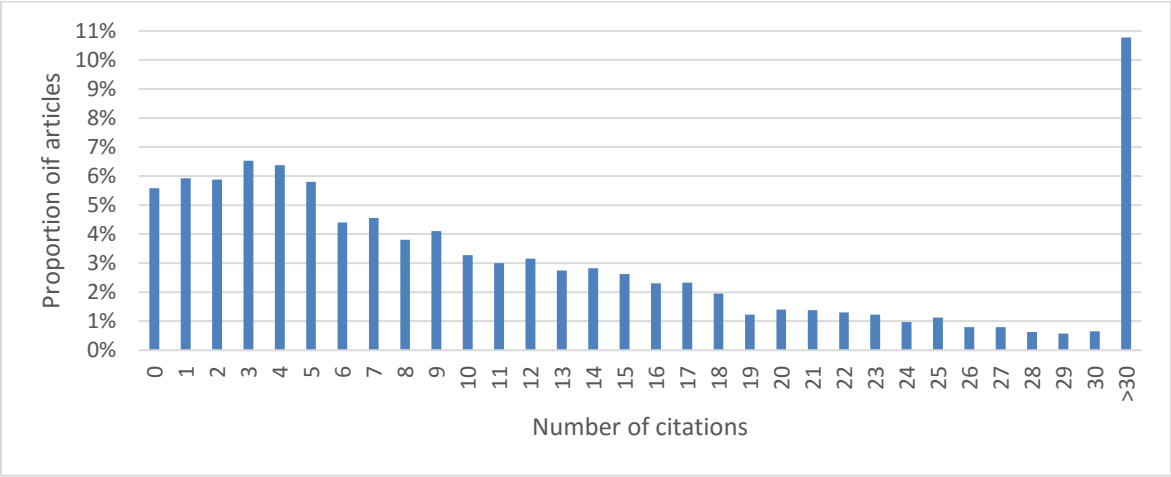

Figure 3.19 Distribution of article proportions by number of citations, 2010 publications (citations 2010-2014).

Source: NIFU / Web of Science.

3.4.2 International comparisons

To provide further insight into how Norway performs by high and low impact publications, we have calculated the number and proportion of articles that are among the 10 per cent most cited (10 percentile) and 20 per cent least cited. The results are shown in Figure 3.20 and Figure 3.21, respectively. In absolute counts, the rank order based on number of high and low impact publications to a certain extent correspond with the total production of polar research articles. Norway ranks as the fifth largest country on all indicators.

Measured by proportion, 12 per cent of the Norwegian polar articles from the period 2010-2013 were among the 10 per cent most cited articles in the world. This means that Norway ranks as number 13 of the 24 countries included in Figure 3.20. In comparison, Norway ranks as number 12 based on the overall relative citation index (Figure 3.8). Thus, the Norwegian performance is almost identical on these two indicators, and also in terms of proportion of high impact publications, Norway is not among the leading polar research nations. It should be noted that most countries have a similar ranking position on the 10 percentile and the overall relative citation index.

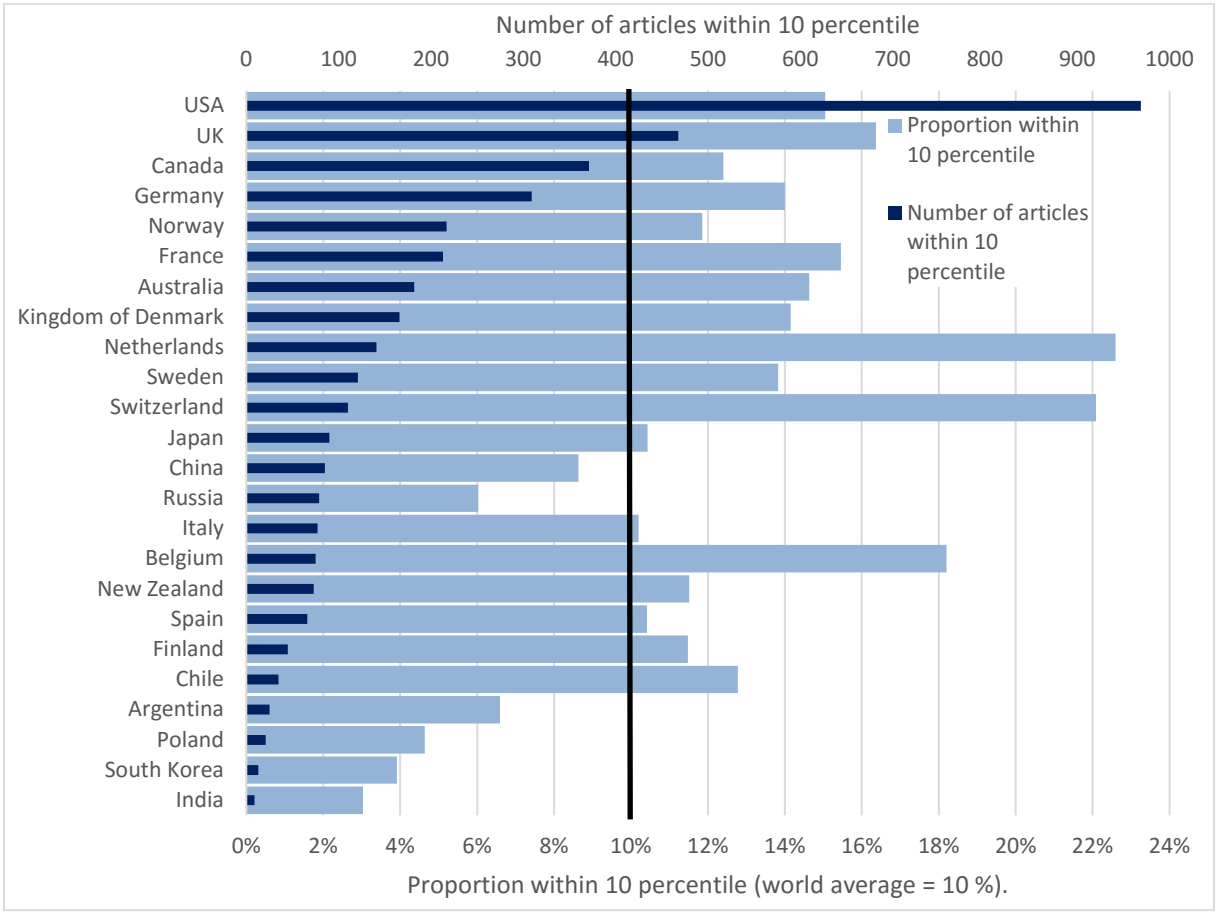

Figure 3.20 High impact publications. Proportion and number of publications within the 10 percentile by country, 2010-2013.

Source: NIFU / Web of Science.

Naturally, when looking at the other tail of the citations distribution, the least cited papers, an inverse pattern is found. Countries with few highly cited papers, in relative terms, tend to have many little cited papers and vice versa. Russia and India have 43 and 39 per cent, respectively, of their publications among the 20 per cent least cited, while this proportion is 6 per cent for Switzerland. The Norwegian proportion is 13 per cent. Of the largest polar research nations, only Canada has a higher proportion (15 per cent).

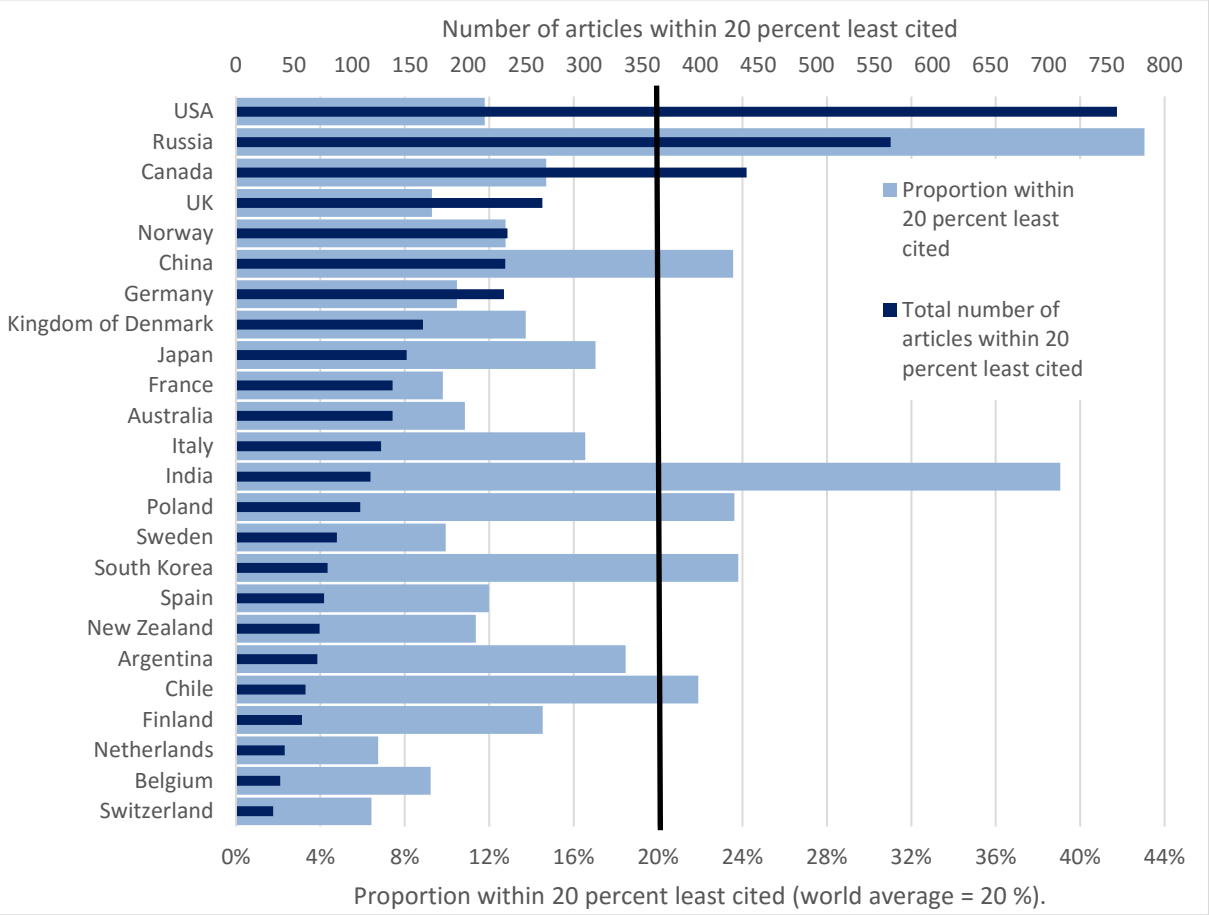

Figure 3.21 Low impact publications. Proportion and number of publications within the 20 per cent least cited, 2010-2013.

Source: NIFU / Web of Science.

In Table 3.9 we have compared the Norwegian citation profile with the one of the two largest nations in publication volume: USA and UK, see Table 3.2. In this analysis, citation numbers in absolute counts are used (i.e. number of citations per article). Since the citation window varies and is the longest for the oldest articles, the analysis was conducted separately for three years: 2010, 2011 and 2012. Although these figures are not field normalized, they may indicate why Norway has lower citation index than the other two nations. As seen, Norway generally has a higher percentage of articles that are uncited or little cited. Similarly, Norway has a lower percentage of highly cited articles. For example, 5 per cent of the Norwegian articles from 2010 obtained more than 50 citations. The corresponding figures for USA and UK were 8 and 9 per cent, respectively. It should be noted that for all countries the production from 2012 has the highest proportion of little cited articles and the lowest percentage of highly cited articles. This is expected since these articles have the shortest citation windows.

Table 3.9 Number of citations per article for Norway, UK and USA. Relative distribution of polar articles in citation intervals for the years 2010, 2011 and 2012.

Number of citations	2010			2011			2012		
	USA	UK	NOR	USA	UK	NOR	USA	UK	NOR
0-2	11 %	7 %	10 %	13 %	12 %	18 %	21 %	18 %	24 %
3-5	16 %	15 %	15 %	16 %	17 %	18 %	21 %	21 %	25 %
6-10	18 %	19 %	22 %	22 %	21 %	24 %	25 %	25 %	24 %
11-20	26 %	27 %	30 %	25 %	28 %	25 %	20 %	21 %	19 %
21-50	21 %	25 %	17 %	19 %	18 %	12 %	11 %	11 %	6 %
>50	8 %	9 %	5 %	5 %	5 %	3 %	3 %	3 %	1 %
N-no articles	1348	598	394	1637	674	471	1689	774	458

Source: NIFU / Web of Science.

3.4.3 Publication characteristics

As is evident from the figures presented above, Norway performs less well than several other major polar nations on these indicators. Therefore, it is of interest to analyse further characteristics of the Norwegian high and low impact publications. Below we present an analysis where additional parameters have been investigated such as field distribution, geographical distribution, type of studies etc.

Table 3.10 gives an overview of the articles Norwegian researchers have contributed to with particularly high citation count, either in terms of total number of citations (more than 100 in the period) or by percentile (among the 1 per cent most cited in their fields). Some of the articles are published in high impact prestigious journals like *Nature* and *Science*. It should be noted that some of the articles have a very large number of authors, and the contribution made by Norwegian scientists may be rather limited. This is indicated by the column “Number of collaborating countries”.

The articles are from many different fields, and the majority address urgent environmental issues such as climate change and pollution. The bibliographic details indicate that the articles tend to be based on large scale projects involving participants from many different countries. Moreover, several of them apparently are addressing more general topics, issues of broader interest or provide overviews of current knowledge on a specific topic (review papers or systematic overviews). This suggests that in order to obtain high citation scores, participating in such projects may be very beneficial.

Table 3.10 Overview of the most cited* articles with contributions by Norwegian authors, 2010-2013.

Title	Journal	Pub year	Vol (page)	Art type	No collab countries	No citations**
Brominated flame retardants in the Arctic environment - trends and new candidates	SCIENCE OF THE TOTAL ENVIRONMENT	2010	408 (2885-2918)	Article	3	240
Bedmap2: improved ice bed, surface and thickness datasets for Antarctica	CRYOSPHERE	2013	7 (375-393)	Article	14	200
A Reconciled Estimate of Glacier Contributions to Sea Level Rise: 2003 to 2009	SCIENCE	2013	340 (852-857)	Article	10	166
Shrub expansion in tundra ecosystems: dynamics, impacts and research priorities	ENVIRONMENTAL RESEARCH LETTERS	2011	6 (-)	Article	11	148
Footprints of climate change in the Arctic marine ecosystem	GLOBAL CHANGE BIOLOGY	2011	17 (1235-1249)	Review	3	146
Plot-scale evidence of tundra vegetation change and links to recent summer warming	NATURE CLIMATE CHANGE	2012	2 (453-457)	Article	12	130
Permafrost Thermal State in the Polar Northern Hemisphere during the International Polar Year 2007-2009: a Synthesis	PERMAFROST AND PERIGLACIAL PROCESSES	2010	21 (106-116)	Article	3	120
Atmospheric monitoring of organic pollutants in the Arctic under the Arctic Monitoring and Assessment Programme (AMAP): 1993-2006	SCIENCE OF THE TOTAL ENVIRONMENT	2010	408 (2854-2873)	Article	7	115
The International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3.0	GEOPHYSICAL RESEARCH LETTERS	2012	39 (-)	Article	11	110
Sharply increased mass loss from glaciers and ice caps in the Canadian Arctic Archipelago	NATURE	2011	473 (357-360)	Article	4	103
Enhanced Modern Heat Transfer to the Arctic by Warm Atlantic Water	SCIENCE	2011	331 (450-453)	Article	3	102
Arctic Ocean Warming Contributes to Reduced Polar Ice Cap	JOURNAL OF PHYSICAL OCEANOGRAPHY	2010	40 (2743-2756)	Article	8	94
Radiative forcing in the ACCMIP historical and future climate simulations	ATMOSPHERIC CHEMISTRY AND PHYSICS	2013	13 (2939-2974)	Article	6	87
Co-registration and bias corrections of satellite elevation data sets for quantifying glacier thickness change	CRYOSPHERE	2011	5 (271-290)	Article	1	85
Continental-scale temperature variability during the past two millennia	NATURE GEOSCIENCE	2013	6 (339-346)	Article	25	75
What are the toxicological effects of mercury in Arctic biota?	SCIENCE OF THE TOTAL ENVIRONMENT	2013	443 (775-790)	Review	6	47
Temporal biomass dynamics of an Arctic plankton bloom in response to increasing levels of atmospheric carbon dioxide	BIOGEOSCIENCES	2013	10 (161-180)	Article	3	34
Organic carbon transformations in high-Arctic peat soils: key functions and microorganisms	ISME JOURNAL	2013	7 (299-311)	Article	2	34

*) The overview includes articles that have been cited at least 100 times during the period analysed or are among the 1 per cent most cited in their fields.
**) Number of citations in the core edition of Web of Science by 31.12.2015.

Source: NIFU / Web of Science.

In the further analyses, we have looked specifically at the Norwegian articles that are among the 10 per cent most cited (10 percentile) and the proportion among the 20 per cent least cited from the period 2010-2013. These articles have been termed “high impact” and “low impact” publications, respectively. There are almost 200 Norwegian articles in each group. The articles have been field classified according to a simplified version of the category system used in the 2015 mapping (see box below).

Cosmic geophysics and space research	Includes studies of physical and chemical processes in the part of the atmosphere and near space located outside 50 kilometers above the earth (the upper atmosphere)
Atmosphere research and meteorology	Includes meteorology and studies of climate, as well as the composition, chemistry and pollution and of the atmosphere.
Oceanography and geophysics	Includes studies of the dynamics (transport of water masses) and structure (temperature and salinity) of the ocean (the polar regions) as well as other geophysics
Cryospheric sciences	Includes studies of all frozen water and land on the surface of the earth, including sea ice, freshwater ice, snow, glaciers, frozen ground and permafrost.
Geology	Includes research on both the bedrock and soils (in polar areas)
Terrestrial biology	Includes the study of plant and animal life on land (in polar areas)
Basic marine biology	Includes studies of sea life (in polar areas). Note: excluding fisheries biology which is classified in a separate category
Fisheries biology/marine resources	Includes studies of marine resources in polar areas (aquaculture, fisheries, bioprospecting etc) and research for utilization of these resources
Medicine	Includes biomedical and clinical studies related to humans living in polar areas. Also included are public health, social medicine and psychology.
Engineering	Includes technology research related to polar regions
Social sciences & humanities	Includes social science and humanities studies of polar regions, societies, culture, humans and activities of humans living in polar areas

Figure 3.22 shows how the articles in each category are distributed by fields. As can be seen, the high and low impact articles are distributed differently. Of the Norwegian high impact publications, 24 per cent are within cryospheric sciences while this field accounts for 16 per cent of the low impact publications. A similar difference is found for terrestrial biology, which accounts for 21 per cent of the high impact publications and 13 per cent of the low impact publications. In other fields, there is an inverse relationship with higher proportions for the low impact publications. There are few high impact publications in the social sciences & humanities, while these fields account for 11 per cent of the low impact publications. However, it should be noted that there are more limitations attached to citation indicators in these fields. Similarly, there are no high impact articles classified within cosmic geophysics and space research, while this field accounts for 7 per cent of the low impact publications. There are also relatively fewer high impact publications in technology.

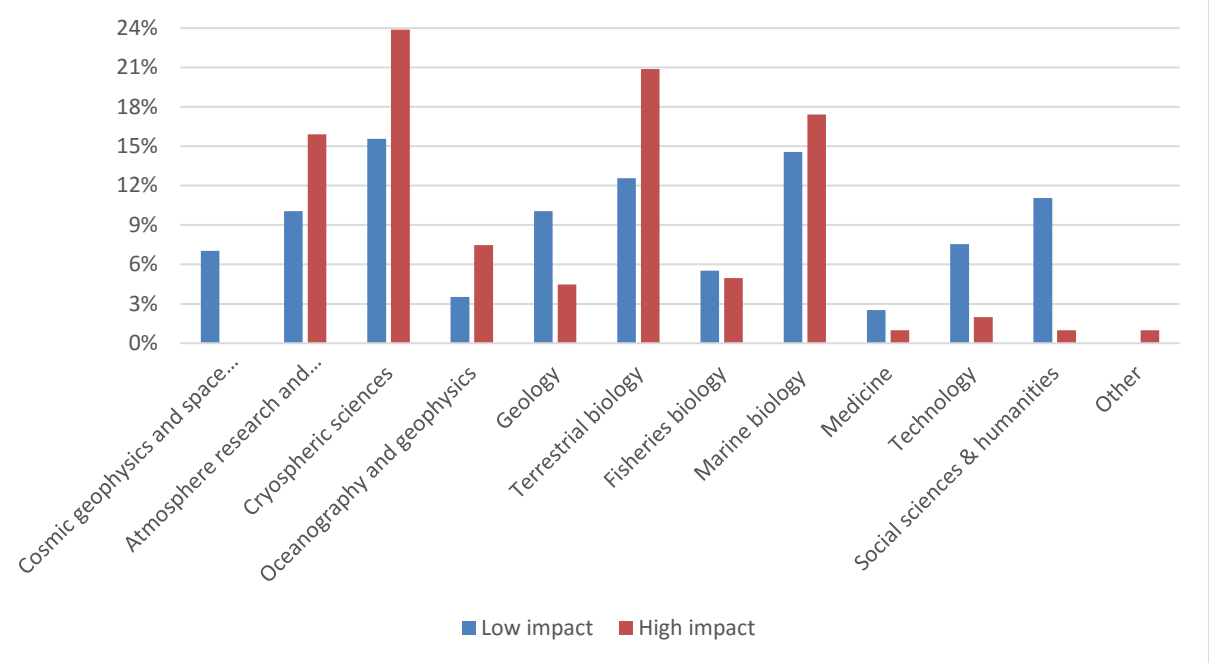

Figure 3.22 Proportion of publications with low and high impact, by field, 2010-2013, Norway.

Source: NIFU / Web of Science.

Evidently, within almost all fields, Norwegian researchers have contributed to publications with high impact. Although based on a limited sample, the results suggest that Norwegian polar research has been more successful in some fields than others in contributing to research with high impact. Here, cryospheric sciences, terrestrial biology, and atmospheric research and meteorology stand out while there are relatively fewer such papers in the social sciences & humanities, technology, and cosmic geophysics and space research.

Table 3.11 shows how the high impact polar articles from the period 2010-2013 were distributed among institutions and institutes in Norway. It is interesting to observe that the articles are distributed broadly, which means that in all parts of the Norwegian research system research is published which achieves particularly high scientific impact as measured by citations.

Still there are differences, and some institutions and institutes have higher numbers and proportions of highly-cited articles than others. Measured as proportion of highly cited publications, NILU ranks on the top with 18 per cent, followed by NPI and NINA with 16 per cent and UNI with 15 per cent. In contrast, the national average is 12 per cent. In absolute counts, the number of publication is highest for NPI and UiT.

Tabell 3.11 Number and proportion of high impact articles (10 percentile) by institution/ institute/sector, 2010-2013.

	Institution/institute/sector	Number of high impact articles	Proportion high impact articles	Proportion of all Norwegian high impact articles
HE sector	UiT	50	12%	15%
	UiO	37	11%	11%
	UiB	36	10%	11%
	UNIS	25	10%	7%
	NTNU	13	8%	4%
	NMBU	8	9%	2%
	Other HE-institutions	5	9%	1%
Institute sector	NPI	53	16%	15%
	NILU	18	18%	5%
	IMR	17	11%	5%
	NINA	14	16%	4%
	UNI	11	15%	3%
	Other institute sector	34	9%	10%
	Other	8	10%	2%
	Business sector	13	8%	4%
	TOTAL NORWAY	201	12 %	100%

Source: NIFU / Web of Science.

As seen above, a large majority of the Norwegian polar research articles have co-authors from other countries. This also holds for the high impact publications. Here, 84 per cent had co-authors from other countries, compared with 63 per cent for the low impact publications.

Figure 3.23 shows how foreign co-authors contributed to the highly cited articles. The fractional contribution of Norwegian authors was 42 per cent. The articles were co-authored by researchers from many different countries, but the main Arctic research nations accounted for the largest fractions: USA with 13 per cent, UK with 8 per cent, and Canada with 7 per cent. The ranking list of countries is quite similar to the one found for Norwegian polar research in total (Table 3.3). Thus, one may conclude that the high impact publications do not deviate in collaboration pattern from the regular Norwegian polar research articles.

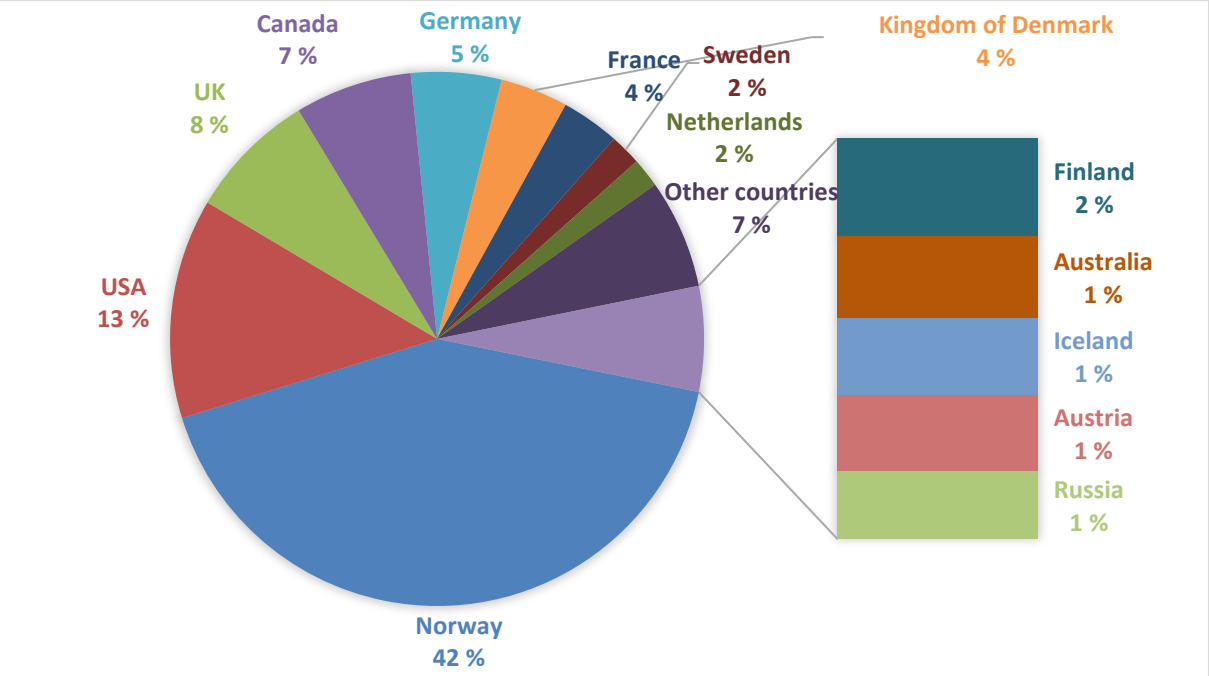

Figure 3.23 Distribution of co-authors in Norwegian high impact publications (10 percentile) by country affiliations, 2010-2013.

Source: NIFU / Web of Science.

To obtain further insights into the characteristics of the high and low impact publications, we performed an analysis of their geographical profile. Based on information available in the titles and abstracts of the publications, we classified each article according to where the research was carried out (field work, observations, experiments, etc.). Many publications were based on research carried out in one specific geographical location, for example Svalbard. These publications were termed “single location publications”. Others were based on research in more than one location (for example Svalbard and Greenland), these were termed “multi location publications”. Then other publications addressed more general subjects or were not based on research carried out in specific areas, these were termed “general study publications”. Finally, some publications were impossible to classify due to lacking information on geographical location in the titles and abstracts (unspecified location).

The results of this classification are shown in Figure 3.24. There are quite large differences in the geographical profile of the high and low impact publications. Single location publications account for a much higher share of the low impact publications than of the high impact publications (61 per cent versus 38 per cent, respectively). On the other hand, there are more multi location publications and general studies among the high impact publications.

These findings suggest that single location studies more often result in publication with low impact and that multi location studies are advantageous in terms of providing high impact publications. Still it should be noted that single location studies also account for the largest proportion of the publications with high impact. Moreover, there are several multi location and general studies also among the poorly cited publications.

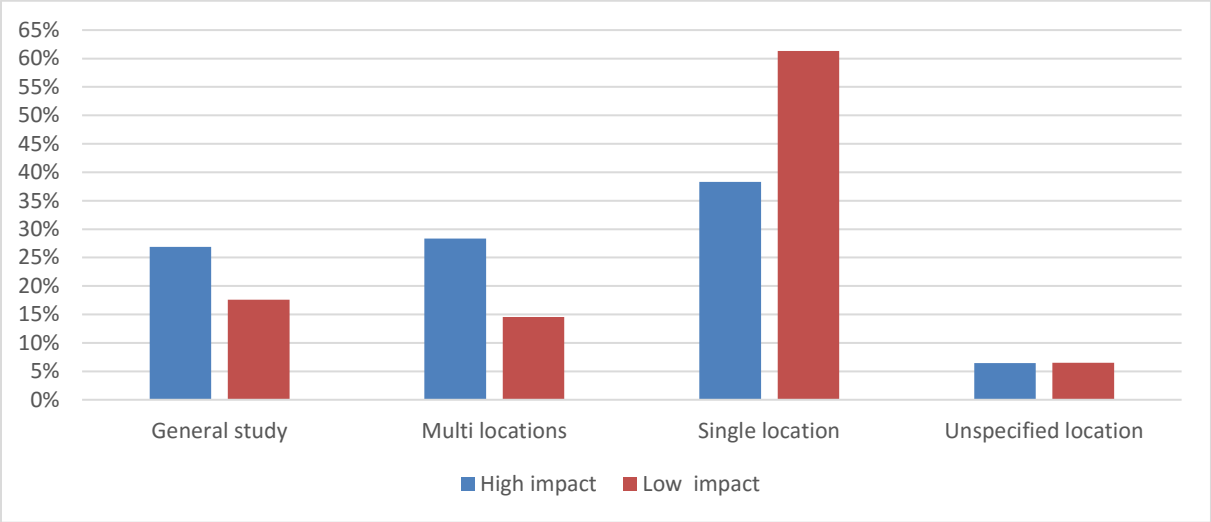

Figure 3.24 Proportion of publications with low and high impact, by type of geographical location (field work, observations, experiments, etc.), 2010-2013, Norway.

Source: NIFU / Web of Science.

The publications were also classified according to main geographical area. Here we restricted the analysis to the single location publications. In total the analysis is based on almost 200 articles in the two categories.

Based on the results in the previous chapters, it is perhaps not surprising that there are more Svalbard articles among the low impact publications than among the high impact publications. In the two groups, Svalbard articles have proportions of 56 and 39 per cent, respectively. Also articles relating to Russian Arctic show a similar pattern, with proportions of 12 and 3, respectively. In all other regions, there are relatively more high impact than low impact publications.

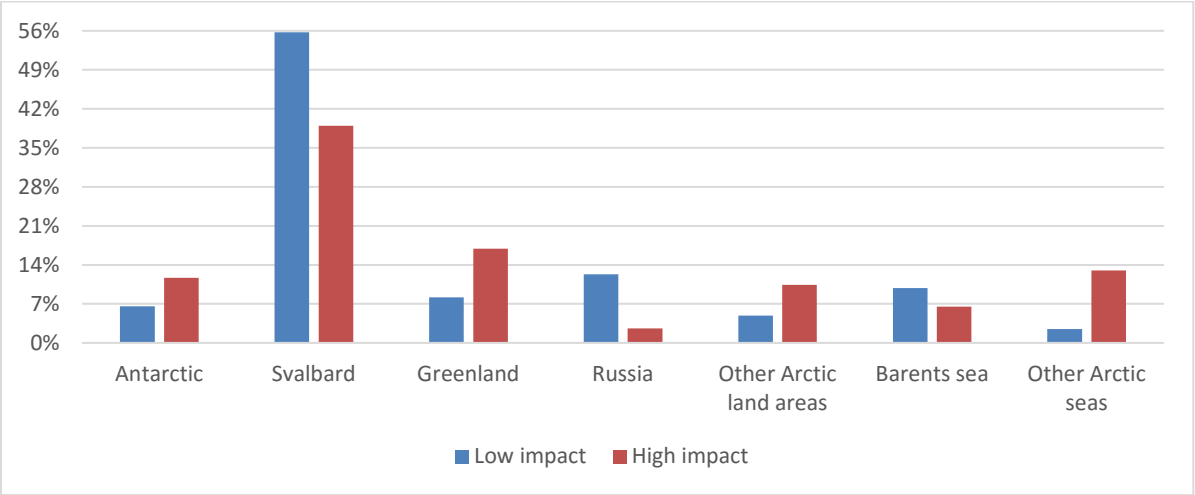

Figure 3.25 Distribution of single location articles by geographical area, low and high impact articles, Norway, 2010-2013.

Source: NIFU / Web of Science.

Finally, we have looked specifically at funding from the Research Council of Norway (RCN). RCN is by far the largest external funder of Norwegian polar research and contributed to 19 per cent of the total funding in 2014, according to the previous mapping. The Web of Science database also includes bibliographic data on funding: funding sources that are listed by the authors in the articles are indexed in the database. Although these data have varying quality (sometimes a researcher may have received funding without notifying this in the article), they provide interesting information on the role of funders.

Of approximately 1,800 Norwegian polar research articles, RCN was listed as one funding source in 700 of them (38 per cent). Thus, although the majority of the articles were not based on projects receiving RCN funding, the proportion is much higher than for the financial resources (19 per cent in 2014). This suggest that RCN funding has large influence and importance for Norwegian polar research.

The analysis shows that RCN has funded a larger part of the high impact publications than of the low impact publications (Figure 3.26), 42 and 29 per cent, respectively. This is perhaps not surprising since RCN funding usually involves peer assessments of the proposals. At the same time, RCN funding encompasses many different programs and funding instruments in which scientific quality may be attributed different weights.

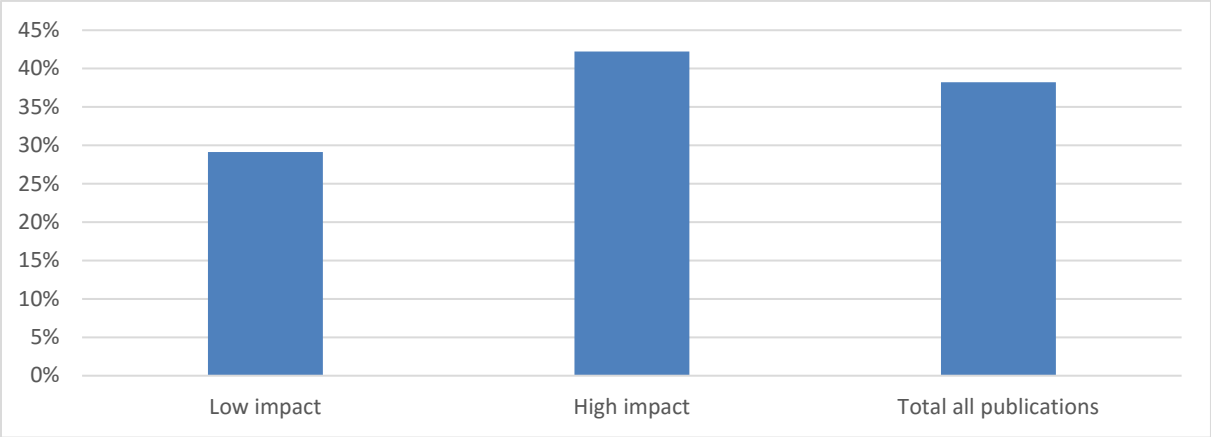

Figure 3.26 Proportion of publications where RCN is listed as funding source, low and high impact publications and total all publications, 2010-2013, Norway.

Source: NIFU / Web of Science.

Figure 3.27 provides further details on the funding of the high and low impact publications. In addition to RCN funding, the proportion of EU funding and other funding sources are shown. The two sets of articles have very different funding structure. This is related to the fact that the high impact publications tend to have contributors from many different countries while international co-authorship is less frequent in the low impact publications. Therefore, many high impact publications have received funding from funding agencies in several countries. The high impact publications have more than twice as many listed funding sources as the low impact publication. In the set of low impact publications, 37 per cent were unfunded – or at least did not specify any external funding sources. The corresponding figure for the high impact publications were 11 per cent, only.

EU was listed as funding source in 30 per cent of the high impact publications and in 11 per cent of the low impact publications. Thus, as seen for RCN, EU has funded more of the high impact publications than the low impact publications. However, it should be noted the receivers of this EU funding may be researchers in Norway and/or other countries. The research has been funded by numerous other sources than RCN and EU (for example research councils in other countries, research foundations, etc.). In fact, 78 per cent of the high impact publications had other funding sources listed while this proportion was 52 per cent for the low impact publications.

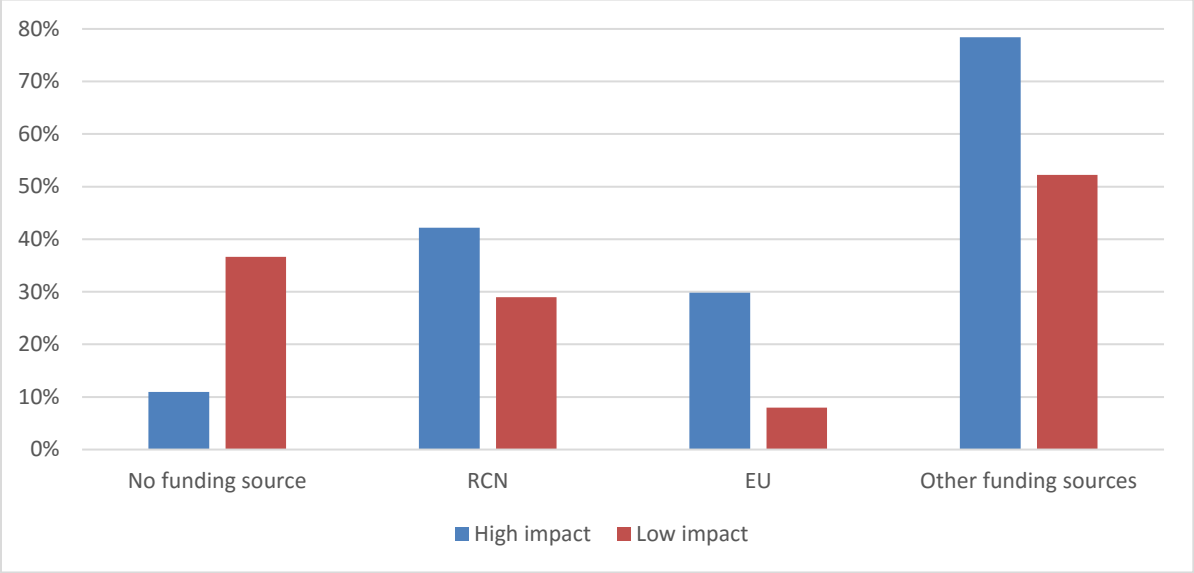

Figure 3.27 Proportion of publications by funding sources, low and high impact publications, 2010-2013, Norway.

Source: NIFU / Web of Science.

3.4.4 Concluding remarks

In this chapter and in Chapter 3.3, the citation impact of Norwegian polar research has been further investigated. The analysis shows that impact of Norwegian polar research in terms of citation rates is lower than for several other major polar research nations. This pattern is consistent across several ways of measuring this impact: full and fractionalised publication and citation counts, first-author/corresponding author publications, high impact papers etc. Nevertheless, Norway ranks higher than many other countries and has a score above the world average on several indictors. Thus, there is no reason to conclude that Norwegian polar research is poorly cited. Still, considering Norway's position as a major polar research nation with substantial funding of this research, one might have expected an even better position. Below we have summarised some findings that are relevant for explaining the citation rate of Norwegian polar research.

- Compared with the highest performing countries, Norwegian polar research is less present in the leading and prestigious scientific journals, to the extent this is reflected through the journals' impact factors.

- Svalbard has a key role in the Norwegian polar research, and many Norwegian polar research articles relate to Svalbard. For some reason, the Svalbard-articles are less cited than other polar research articles. This issue is further investigated in the next chapter.

- The citation rate varies across Norwegian institutions and institutes. Thus, there are differences in scientific impact of the polar research reflected through citations at an organisational level. In the report, we have used aggregated figures. It should be taken into consideration that *within* an institution there are usually similar internal differences, i.e. some research groups with high citation impact and others with low.

- At the dimension of fields and disciplines there are also differences, although the citation rate for the two main areas of polar research, geosciences and biology is almost identical. Within almost all fields, Norwegian researchers have contributed to publications with high impact, but in cosmic geophysics and space research, the social sciences and humanities, as well as technology, there are relatively fewer such articles.

- Polar research is characterised by extensive international collaboration and Norway is strongly embedded in the international networks of polar research. Of the Norwegian polar research articles (2012-2014), 73 per cent also had co-authored from other countries. Still, this proportion is even higher in several other countries. Internationally co-authored articles are generally much more cited than articles which have authors from one country, only. This means that the citation impact of a country usually will rise if the extent of international collaboration increases. Thus, strengthening the international collaboration pattern of Norwegian polar research even further, would most likely contribute to a higher citation rate. The high performing polar research nations are potentially particularly beneficial collaborators; however, the issue needs to be addressed at the level of fields and institutions.

- The analysis shows that single location studies more often result in publication with low citation impact and that multi location studies are advantageous in terms of providing high impact publications. Thus, increasing the extent of the latter type of projects and publications would have been beneficial from such a perspective.

The conclusions above draw on bibliometric evidence, only. As described previously, citations have limitations as performance measures. In order to evaluate scientific quality and the content of the research, examinations by peers are required. Possibly, peers may arrive at other conclusions than what is suggested by citation measures. This is not only due to the limitations of citation indicators, but also because a peer-evaluation may involve assessments of factors besides scientific quality or factors that are not likely to be reflected through citation counts.

3.5 Norwegian Antarctic research

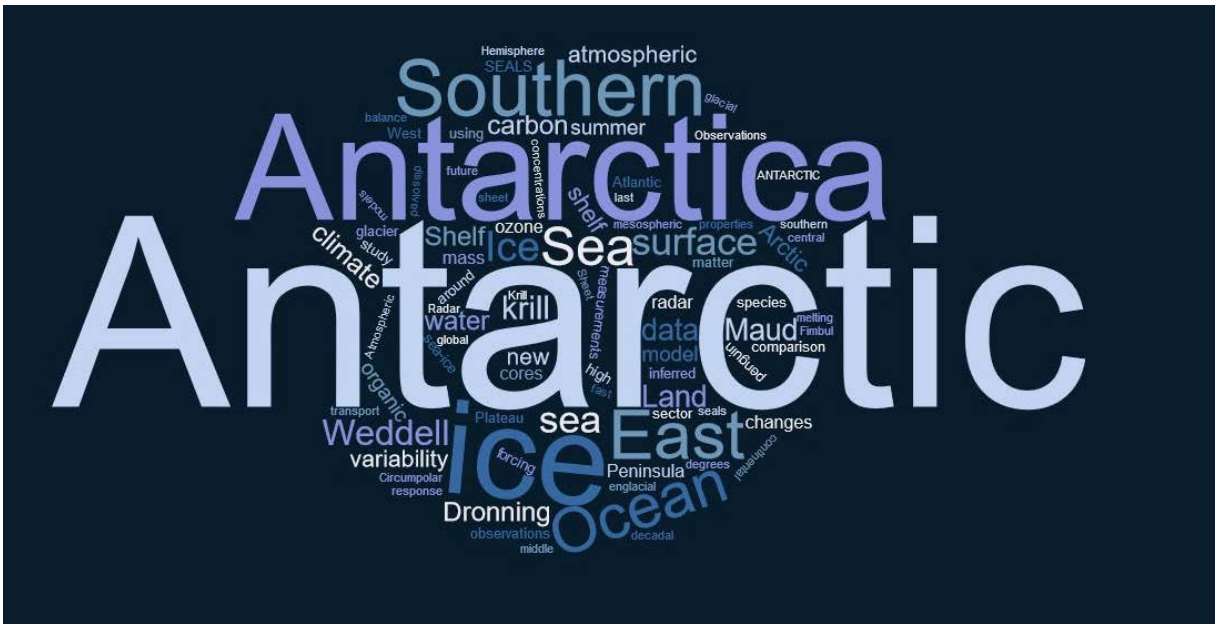

Figure 3.28 Most frequently appearing words in the Norwegian Antarctic publication titles, 2010-2014.

Source: NIFU / Web of Science.

This chapter provides additional analyses of the Norwegian publications relating to Antarctic. As we did not want to include the more peripheral Antarctic contributions in the analysis, the publications identified in the overall part were re-examined (cf. Figure 3.2). We removed some peripheral articles and kept the publications that apparently were based on material or data from/concerning the Antarctic continent or the oceans surrounding it (cf. the definition).[12] We were then left with 230 articles from the period 2010-2014.

Figure 3.28 and Figure 3.29 provide an overview of frequently appearing words in the article titles/abstracts. In addition to geographical names, *ice* in various combinations and expressions appears frequently. The most frequently appearing biology term is *Antarctic krill*. Interestingly, only 18 of 230 articles have *Troll* in the title or abstract (the Norwegian research station in Antarctica). The extent of research related to the Troll station is obviously larger than indicated by this number. Nevertheless, this figure indicates that there is considerably Norwegian research relating to Antarctic which are not affiliated with the Troll station.

[12] It should be noted that the articles are not necessarily based on research stays in the Antarctic.

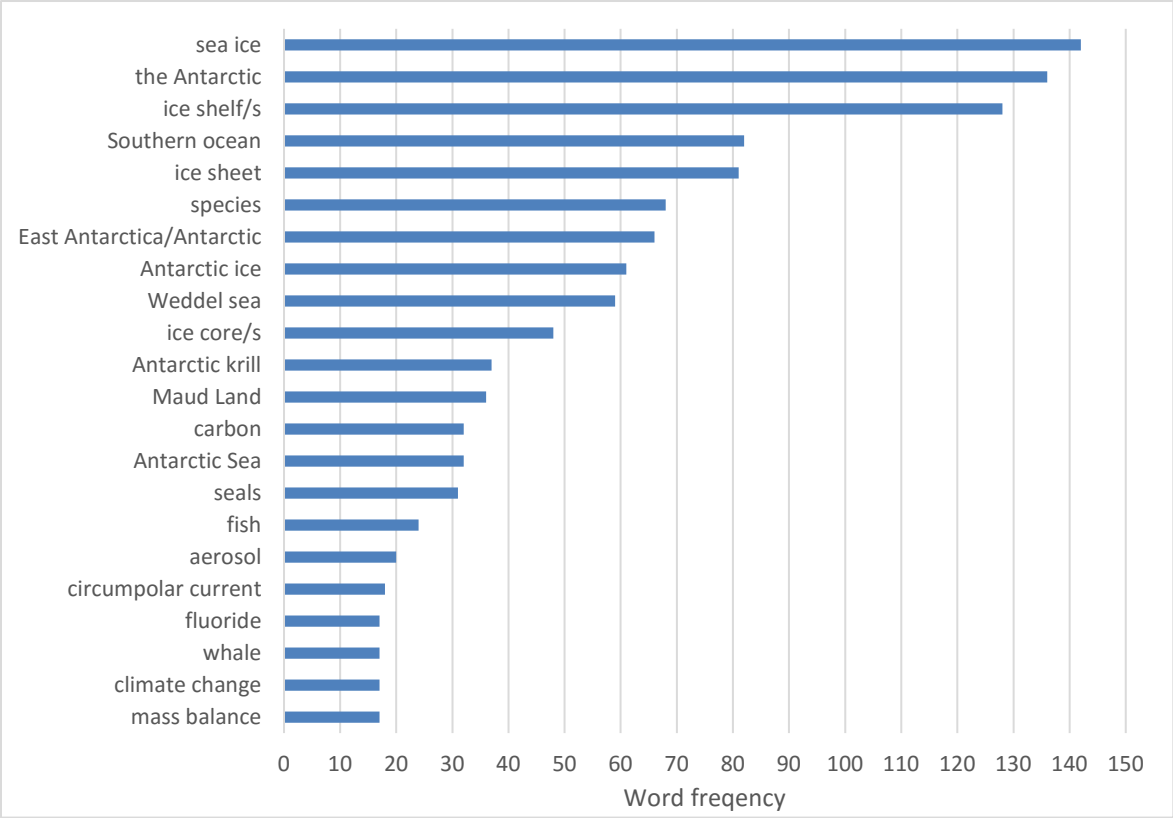

Figure 3.29 Most frequently appearing words/expressions in the Norwegian Antarctic publication titles and abstracts, 2010-2014.

Source: NIFU / Web of Science.

In Figure 3.30 we have shown the distribution of Norwegian Antarctic articles by field. As can be seen, there is research in a variety of fields. The majority of the publications are within geosciences (66 per cent), while biology fields in total have a proportion of 30 per cent. The single largest field is cryospheric research with a proportion of 26 per cent, followed by atmosphere research and meteorology and marine biology, both with 17 per cent.

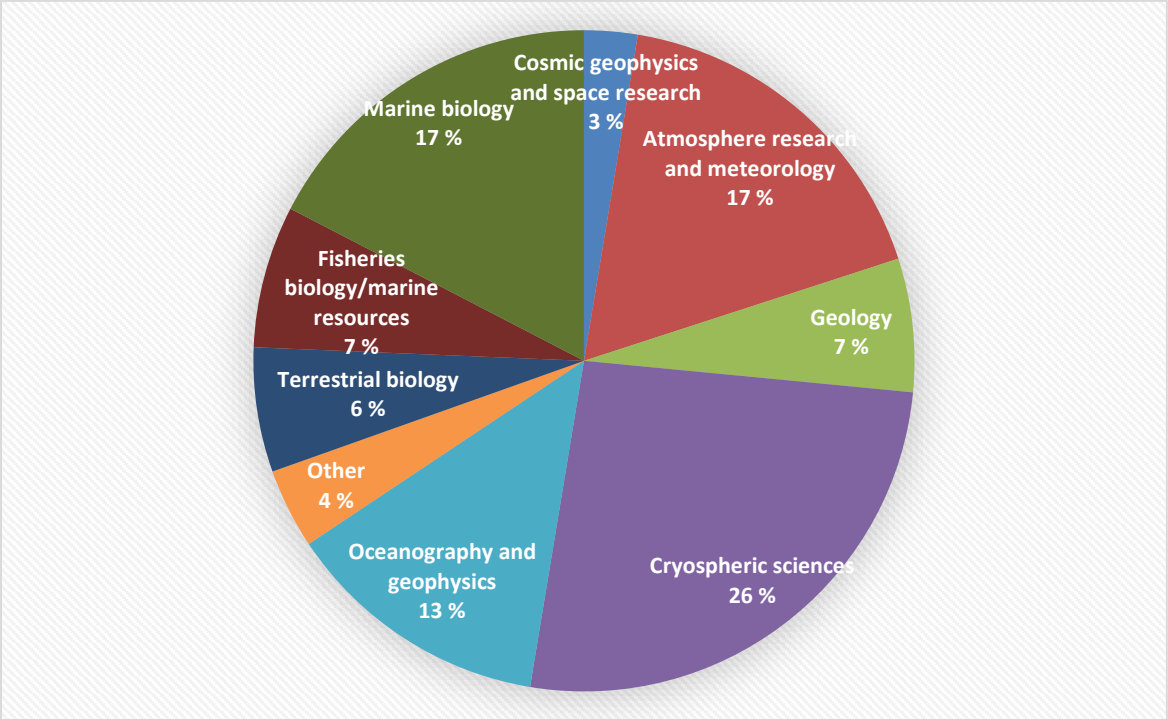

Figure 3.30 Relative distribution of Norwegian Antarctic research articles by fields, 2010-2014.

Source: NIFU / Web of Science.

Figure 3.31 shows how the Antarctic articles are distributed among research performing institutions and institutes. Many different Norwegian institutions and institutes have contributed to such articles. NPI is the largest contributor and accounts for 22 per cent of the Norwegian article production. Then follows the UiB with 17 per cent.

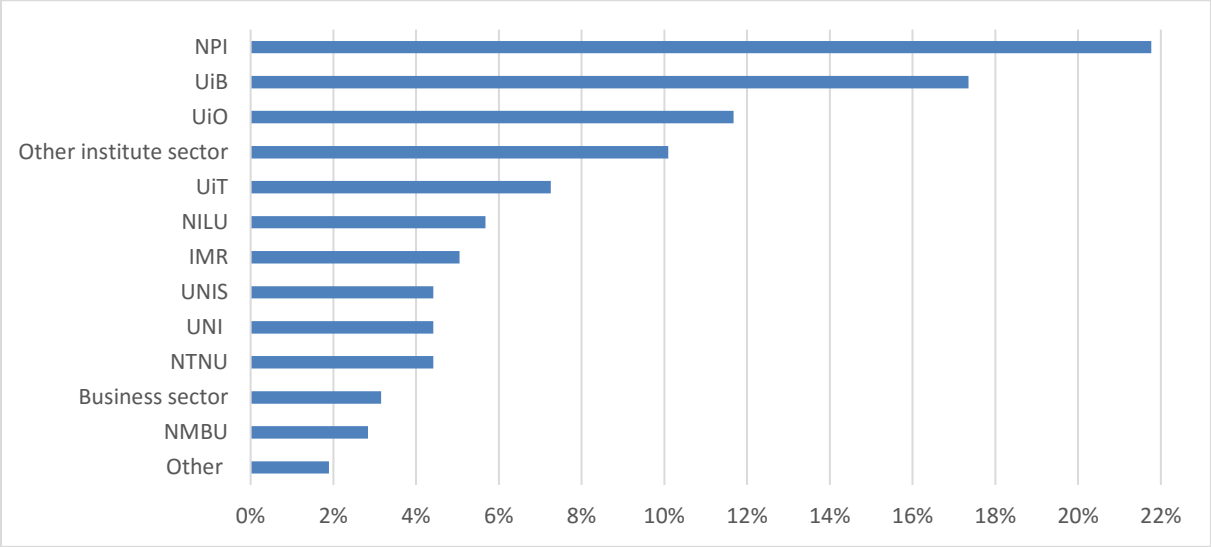

Figure 3.31 Relative contribution to the Norwegian Antarctic article production by institution/institute/ sector, 2010-2014.

Source: NIFU / Web of Science.

The Norwegian Antarctic articles obtain a relative citation index of 129 (Figure 3.32), this is above the Norwegian average for polar research which is 113. Also, the proportion of highly cited papers (10 percentile) is above the Norwegian average, although the difference is not large, 13 and 12 per cent, respectively. Thus, even though only a small fraction of the Norwegian polar research relates to the Antarctic, the impact of the research is somewhat higher than for the other Norwegian polar research.

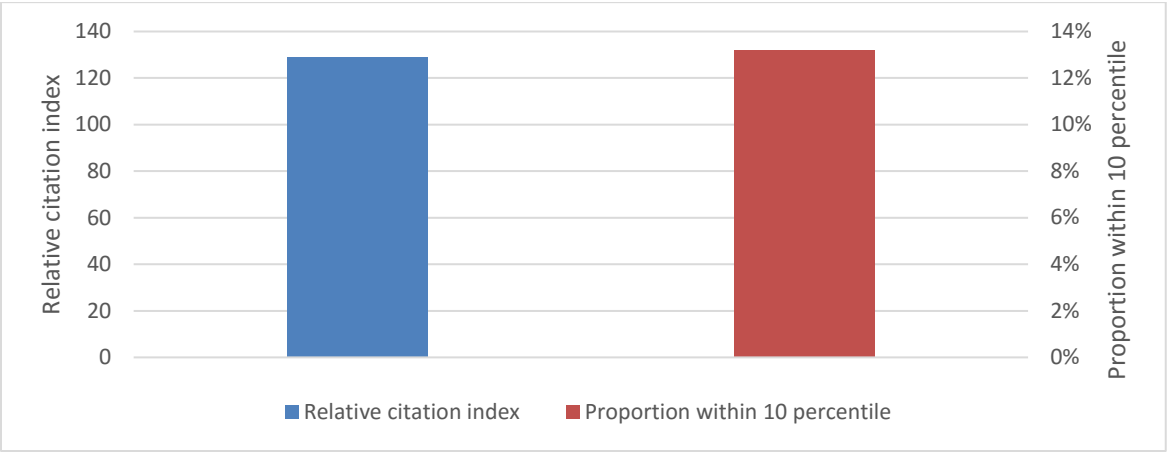

Figure 3.32 Relative citation index for Norwegian polar articles, relating to Antarctic and proportion within 10 per centile, 2010-2013.

Source: NIFU / Web of Science.

4 Research in Svalbard

In this chapter publication indicators for research in Svalbard are presented. We refer to Chapter 2 for a description of the methods applied for identifying the Svalbard publications. The analysis encompasses publications from all countries, although the main focus is on the publications with Norwegian co-authors. It should be noted that the analysis is based on a new survey, and the results will not be directly comparable with the previous NIFU mapping.

4.1 Publication volume

In total, almost 2,000 Svalbard articles were identified for the seven-year period 2010-2016. During the period, the annual production has varied from 252 to 316 articles (Figure 4.1). The number increased from 2010 to 2012, while there has been a minor reduction the recent years. It should be noted that complete publication data for 2016 was not available at the time when the publication analysis was conducted, therefore the 2016 figures are probably slightly underestimated.

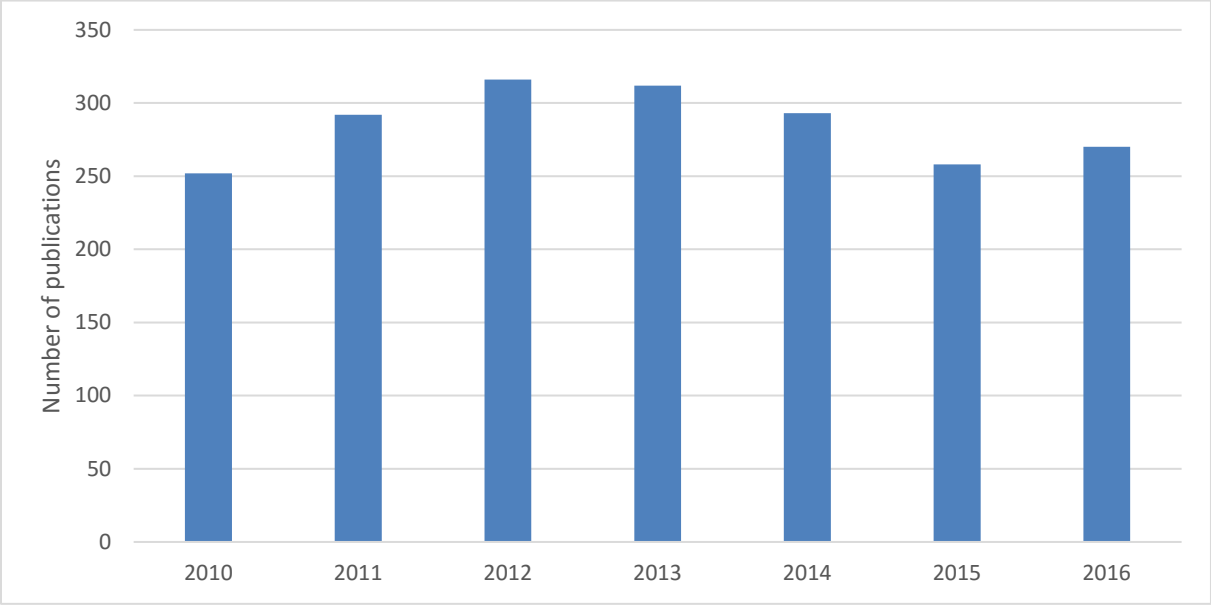

Figure 4.1 Number of Svalbard articles, 2010-2016.

Source: NIFU / Web of Science.

Norway is by far largest nation in terms of scientific publications related to research in Svalbard. Figure 4.2 shows the number of articles by two year periods for the largest countries in terms of article production. In total, Norway has more than twice as many articles as the second and third largest nations: the UK and Poland. The central role of Norway is also indicated by the fact that of all Svalbard articles, more than 40 per cent have least one co-author from Norwegian institutions (Figure 4.3).

However, the Norwegian article production has decreased during the period, from 313 in 2011-2012 to 223 in 2015-2016. The temporal trend for the other countries varies. For most countries, it has been fairly stable, for some countries there is a decline (Russia, USA) while there is an increase for Poland. The reason for the Norwegian decline has not been further investigated. Possibly, the termination of the international polar year (IPY) has contributed negatively in this respect. In addition, as noted above, the 2016 figures might be slightly underestimated in this survey. The previous mapping showed an increasing in the Norwegian article productions since 2005.

The figure is limited to the countries with the largest number of articles. However, many additional countries have contributed with Svalbard publications. Among the largest in this group we find Denmark, the Netherlands, Finland, Japan, and Italy.

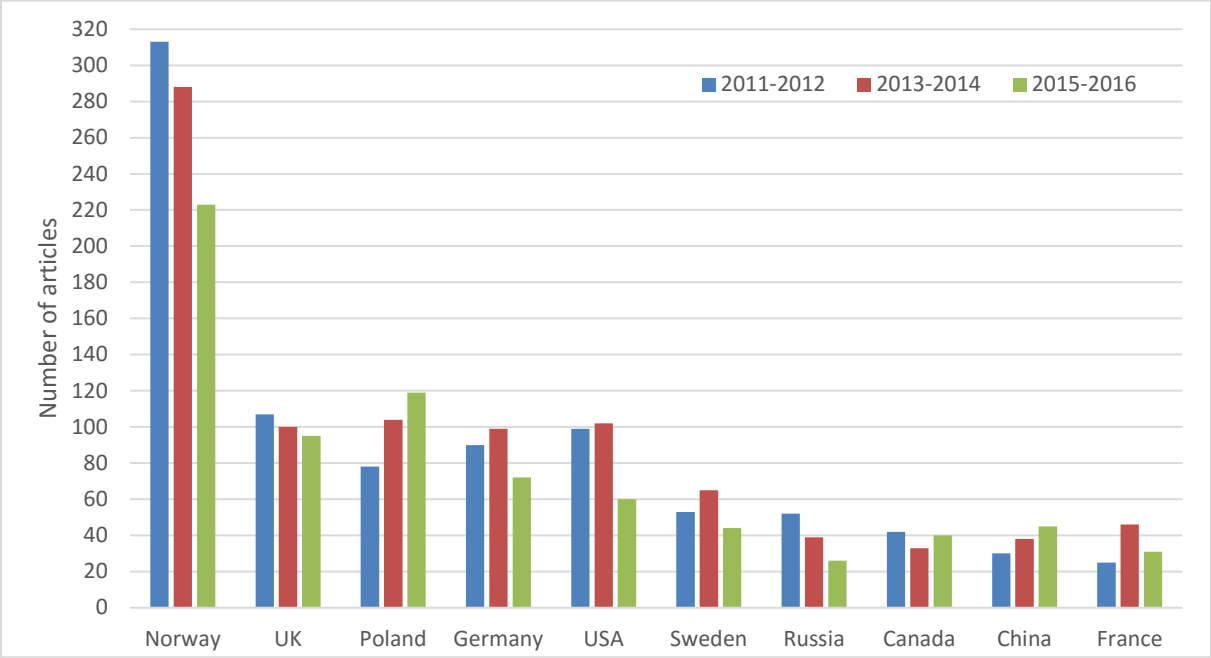

Figure 4.2 Number of Svalbard articles, by country per two year periods, 2011-2016.

Source: NIFU / Web of Science.

When interpreting the numbers above, it is important to emphasize that Svalbard research does not happen in a "vacuum". A large part of the articles has the character of being comparative studies or studies that are based on observations/measurements carried out in several different geographical locations, where Svalbard is one of them. An example would be collaboration between Norwegian and US scientists where the Norwegians have contributed with data from Svalbard, and the Americans with data from localities in Alaska. This will result in one "Svalbard publication" for the USA, although the American researchers have not stayed in Svalbard. Thus, the publication numbers are not direct measures of the volume of the research in Svalbard carried out by the different countries.

Figure 4.3 shows the proportion of Svalbard publications with co-authors from Norwegian institutions using two calculation methods: whole and fractionalized article counting. In 2015-2016, 42 per cent of all Svalbard articles had at least one co-author from a Norwegian institution. When the contributions of each country were fractionalised, the Norwegian proportion was 25 per cent (See Chapter 2.2.4 for an explanation of these calculation methods).

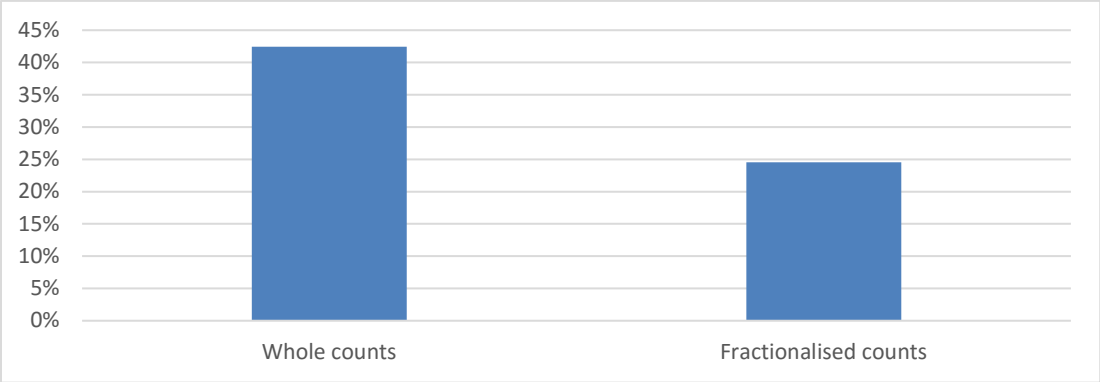

Figure 4.3 Proportion of Svalbard articles with co-authors from Norwegian institutions, whole and fractionalised counts, 2015-2016.

Source: NIFU / Web of Science.

Figure 4.4 shows the distribution of the articles (2015-2016) based on the country affiliations of the first author or corresponding author. As described previously, the researchers from the respective countries may be assumed to have key roles in these papers. Norway has a proportion of 24 per cent when measured in this way, followed by Poland with 18 per cent.

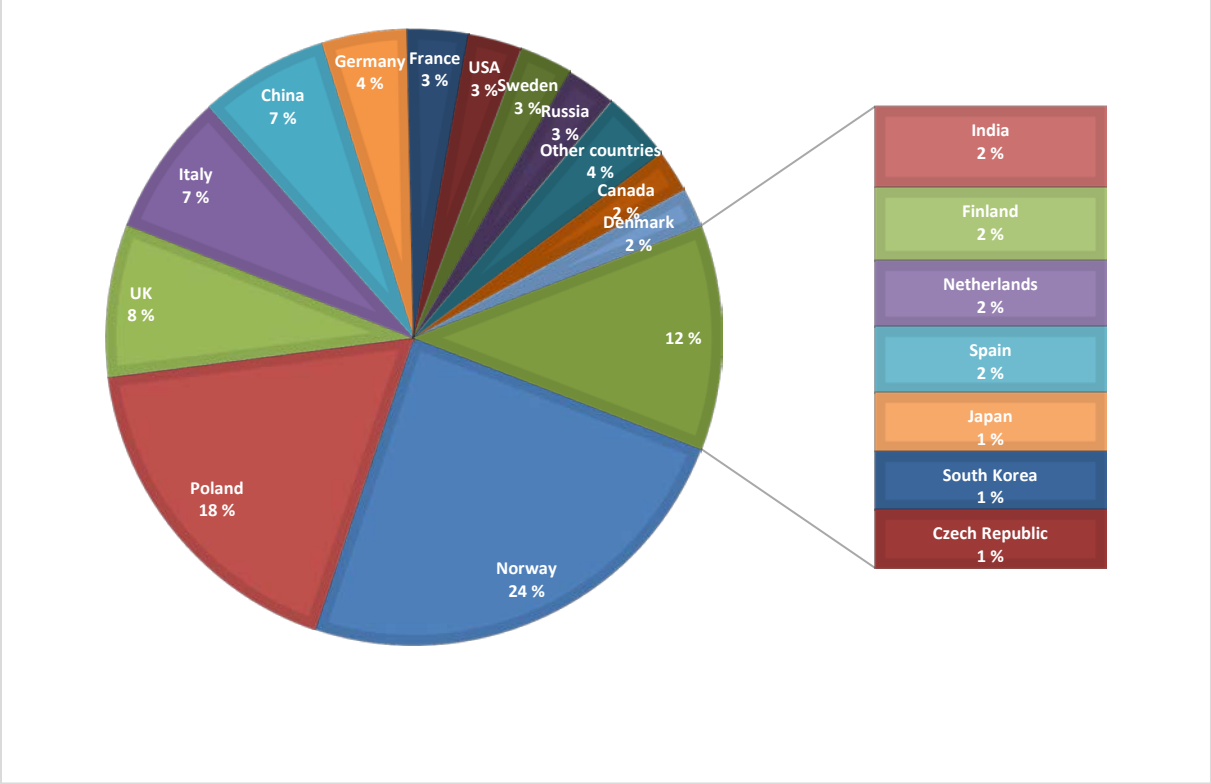

Figure 4.4 Distribution of Svalbard articles with first author/corresponding author by country, 2015-2016.

Source: NIFU / Web of Science.

In Table 4.1, we have shown how the Norwegian "Svalbard publications" were distributed at the level of institutions, institutes and sectors. The table covers the entire 2010-2016 period. UNIS accounts for the largest number of articles, in total almost 350 or 19 per cent of the Norwegian Svalbard production. Then follow UiT and NPI which are almost equal in size and account for 15 and 14 per cent of the production. Also the UiO is a large contributor to the Svalbard research publications with about 220 articles. The other two general universities, UiB and NTNU, have a smaller Svalbard procuction.

Next to the NPI, Akvaplan-niva, NINA and NILU are the single largest contributors in the institute sector (50-60 articles). In addition to the insituttes which are listed separately in the table, there are also many articles from other institutes. Here we find institutes such as SINTEF, the Norwegian Meteorological Institute, the Geological Survey of Norway (NGU), NORSAR, Norut and the Nansen Environmental and Remote Sensing Center.

Units in the business sector account for approximately 50 articles. Here we find many different companies with Statoil as the main contributor.

In conclusion, the analysis shows that many Norwegian institutions, institutes and companies are involved in Svalbard research. However, the three largest contributors, UNIS, UiT, and NPI together account for approximately half of the Norwegian publications output.

Table 4.1 Number and proportion of Svalbard articles by institution/ institute/sector, 2010-2016.

	Institution/institute/sector	Number of articles	Proportion
HE sector	UNIS	346	19%
	UiT	278	15%
	UiO	222	12%
	UiB	127	7%
	NTNU	90	5%
	NBMU	54	3%
	Other HE-institutions	30	2%
Institute sector	NPI	262	14%
	Akvaplan-niva	63	3%
	NINA	57	3%
	NILU	51	3%
	Other institute sector	159	9%
	Other	32	2%
	Business sector	53	3%

*) Only units with more than 50 articles are shown separately in the table. Articles with contributions from several institutions/institutes will be included in more than one category.
Source: NIFU / Web of Science.

Figure 4.5 shows the distribution of the Norwegian Svalbard-articles by field (2010-2014 figures). Terrestrial biology is the single largest field and accounts for 20 per cent of the articles, followed by cryospheric sciences with 19 per cent and basic marine biology with 17 per cent.

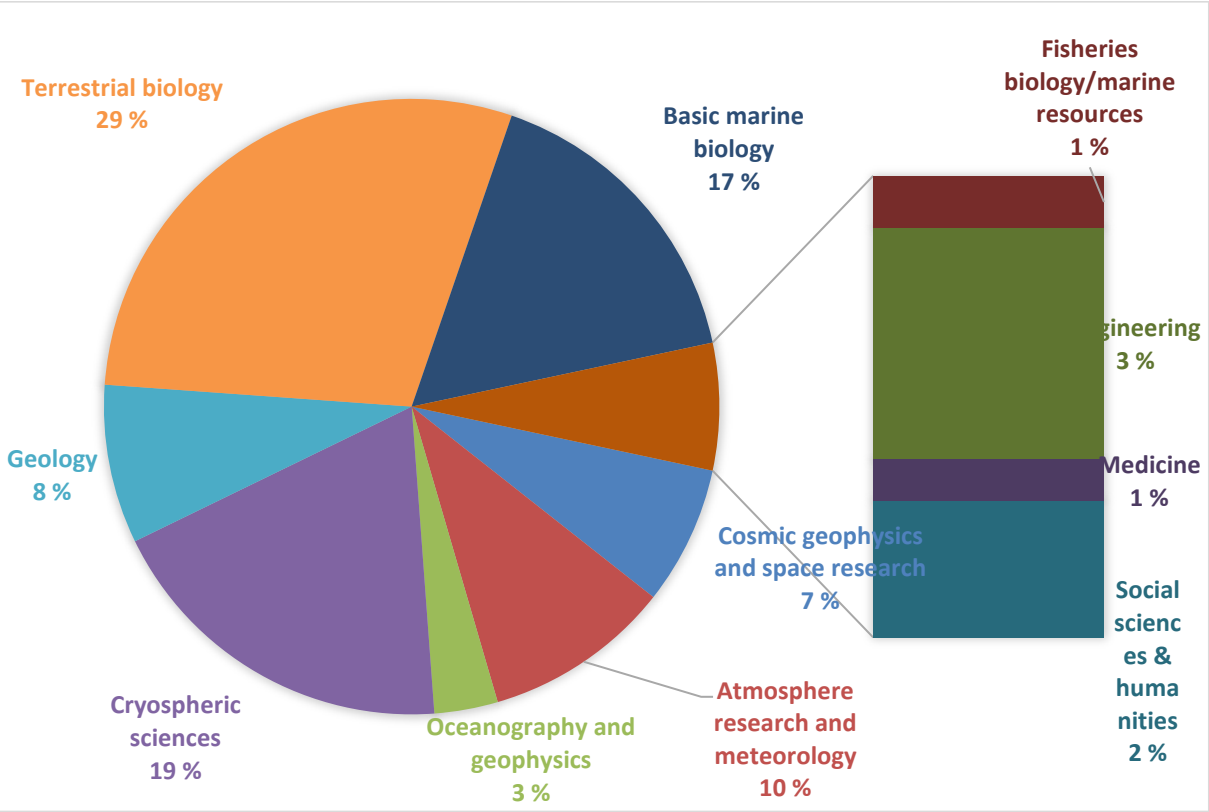

Figure 4.5 Distribution of the Norwegian Svalbard-articles 2010-2014 by field.

Source: NIFU / Web of Science.

Terrestrial biology is also the largest field when the Svalbard publications of all countries are considered (Figure 4.6). Norway contributes to 30 per cent of the terrestrial biology articles (2010-2014), measured as fractionalised article contributions. The Norwegian proportion varies across fields, in the large fields (by article numbers) it ranges from 18 per cent (cosmic geophysics and space research) to 32 per cent (basic marine biology).

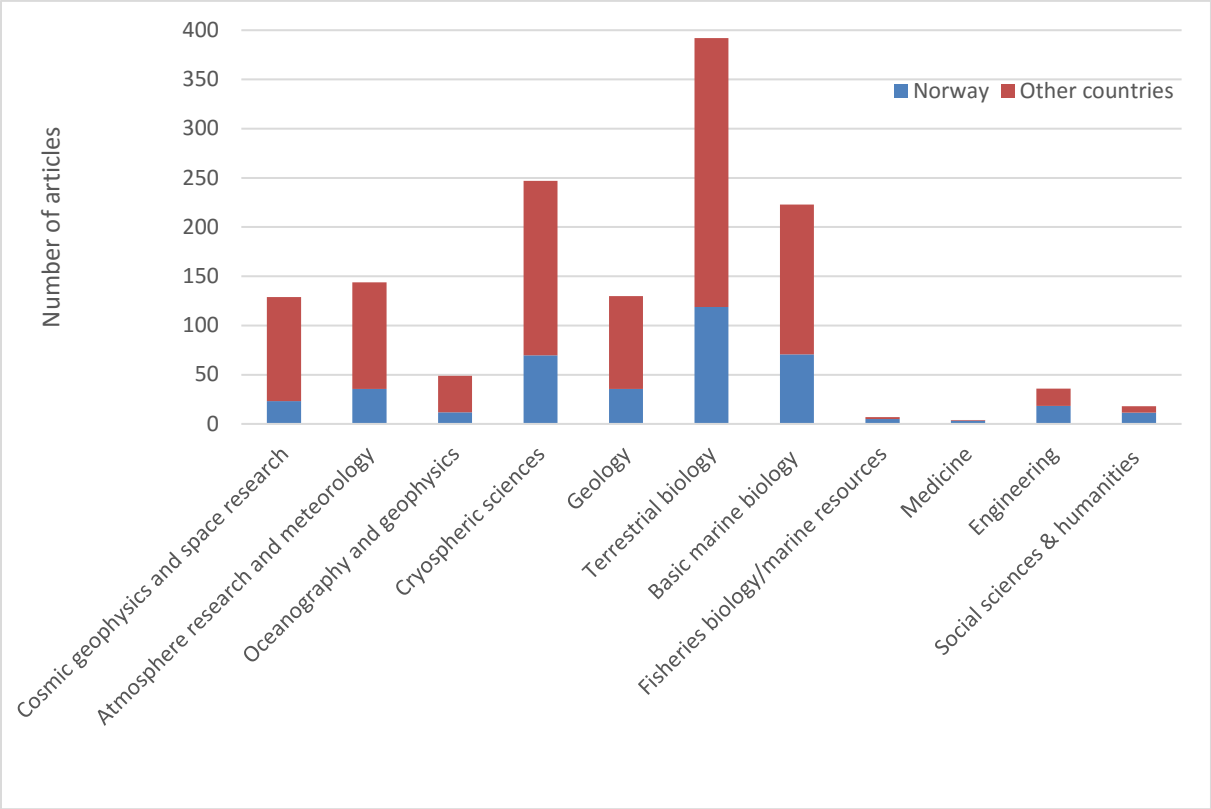

Figure 4.6 Number of Svalbard-articles, fractionalised contributions by country and field, 2010-2014.

Source: NIFU / Web of Science.

The articles have also been classified according to a terrestrial and marine dimension and by research topics related to climate or pollution. The results are shown in Figure 4.7. Approximately three quarters of the Svalbard articles involve terrestrial research (in terms of topic, data collection, observations etc.) while 26 per cent are marine based (coastal zone). This proportion is also calculated for the Norwegian articles. The Norwegian distribution shows minor deviations from the total, only. This also holds for the articles when classified according to a climate and pollution dimension. As can be seen in the figure, a large part (42 per cent) of the Svalbard articles concern topics related to climate, while 9 per cent address pollution.

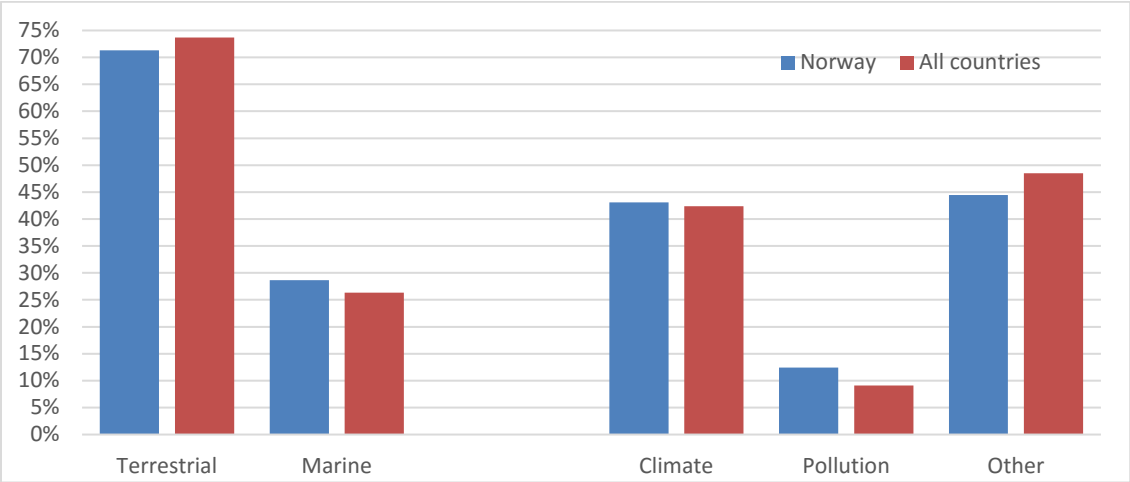

Figure 4.7 Proportion of Svalbard-articles Norway and all countries by type of research (terrestrial and marine; climate, pollution and other), 2010-2014.

Source: NIFU / Web of Science.

The distribution of the climate and pollution articles by field is shown in Figure 4.8. The largest number of the climate articles is in cryospheric sciences followed by atmosphere research and meteorology but there are also many such articles in biology.

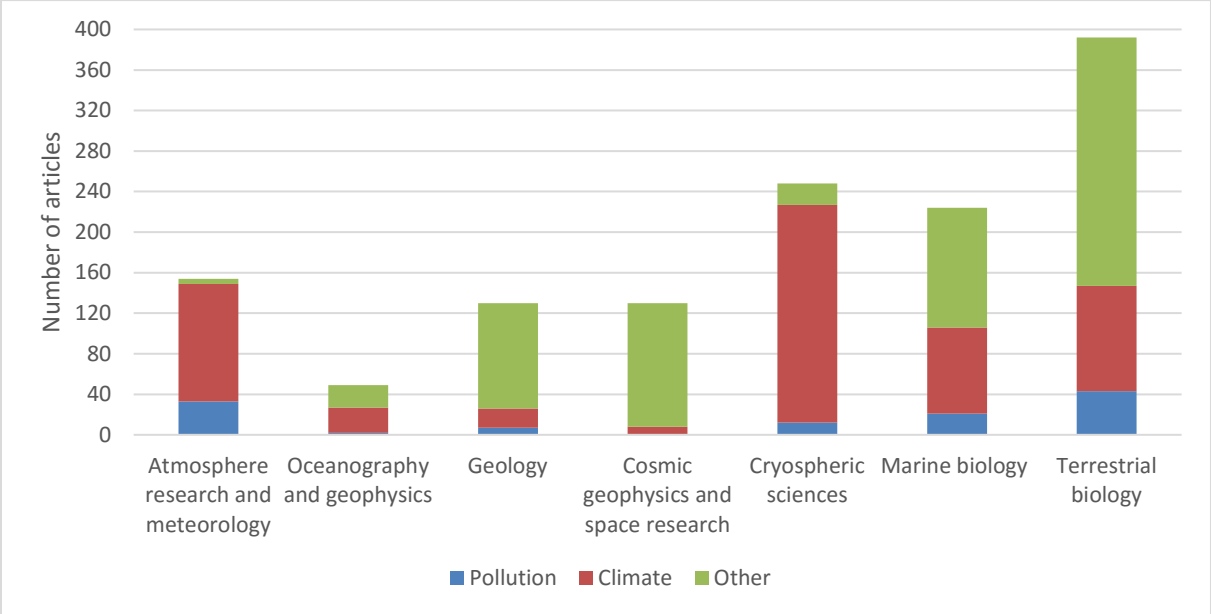

Figure 4.8 Distribution of the Svalbard-articles 2010-2014 by field and topic (climate and pollution), total (all countries).

Source: NIFU / Web of Science.

4.2 Citation indicators

In this chapter we analyse the citation rate of the Svalbard articles. As descriped in the introduction, the previous mapping showed that these articles were less cited than the average for polar research, and here we present various analyses that investigate this issue bibliometrically.

4.2.1 Overall relative citation index

Figure 4.9 shows the annual relative citation index for the Svalbard articles for the years 2010-2014. Although there are annual fluctuations in the index, the articles have constantly been less cited than the average for polar research, typically, 10-20 per cent below this average.

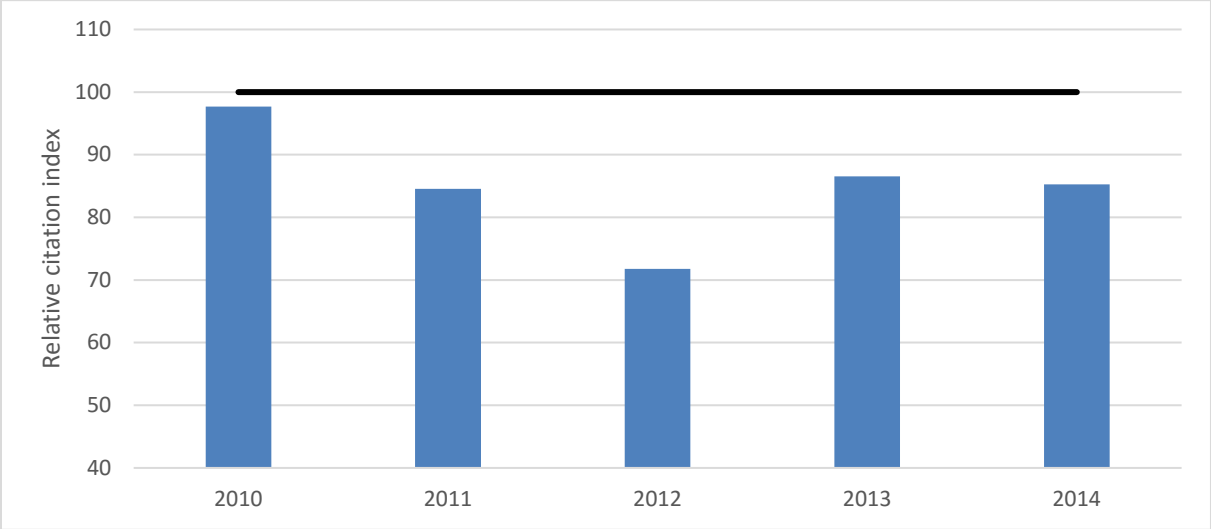

Figure 4.9 Relative citation index for Svalbard related articles, total (all countries) 2010-2014.

Source: NIFU / Web of Science.

Figure 4.10 shows the relative citation index for the main countries (in terms of number of Svalbard-articles). In correspondence with the results for polar research generally, we find that the Russian articles in particular have been little cited. The citation index is 47 for all articles and 27 for articles with Russian first author or corresponding author. Also Japan, China and Poland have low citation rates. Interestingly, all the major countries (Norway, UK, USA and Germany) have lower citation rate for their Svalbard articles than for their other polar research articles (Figure 3.8). The citation index for Norway is 95 for all the Svalbard-articles. Thus, the low citation impact of the Svalbard research seems to be a more general phenomenon that is not linked to specific countries, altough there are large differences also at the level of nations.

The figure also shows a similar indicator based on the articles with first authors/corresponding authors. For most contries, the citation index for these articles is on par with the one for all Svalbard articles. The exceptions are Denmark, Russia and Japan where the first author/corresponding author articles are less cited. The Norwegian articles with first author/corresponding author obtain a citation index of 94.

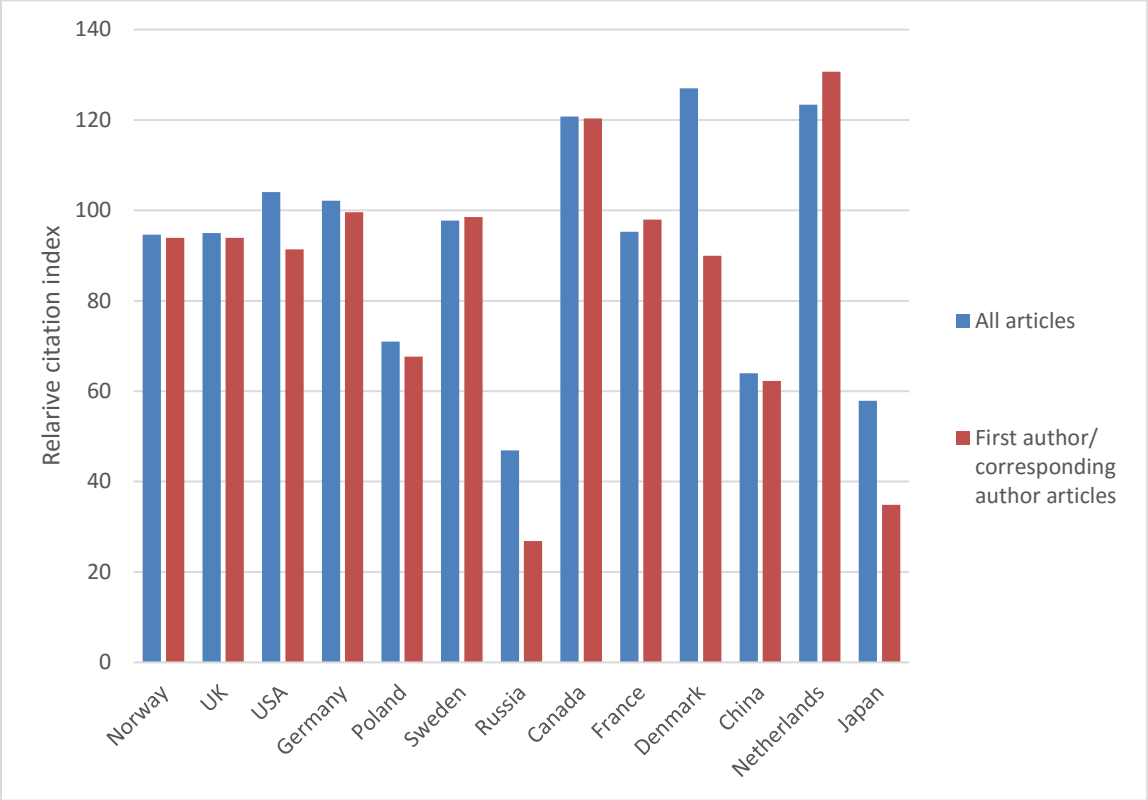

Figure 4.10 Relative citation index for Svalbard related articles, by country and authorship, 2010-2014.

Source: NIFU / Web of Science.

4.2.2 High impact publications

In Figure 4.11 we for each country have calculated the proportion of the Svalbard-articles that are among the 10 per cent most cited (10 percentile). For Norway, this ratio is 10 per cent, in other words on line with the world average, but lower than the Norwegian average for polar research articles generally (including Svalbard-articles), which is 12 per cent (Figure 3.20). There are large differences across countries, and China and Russia have proportions of 1 and 2 per cent, only.

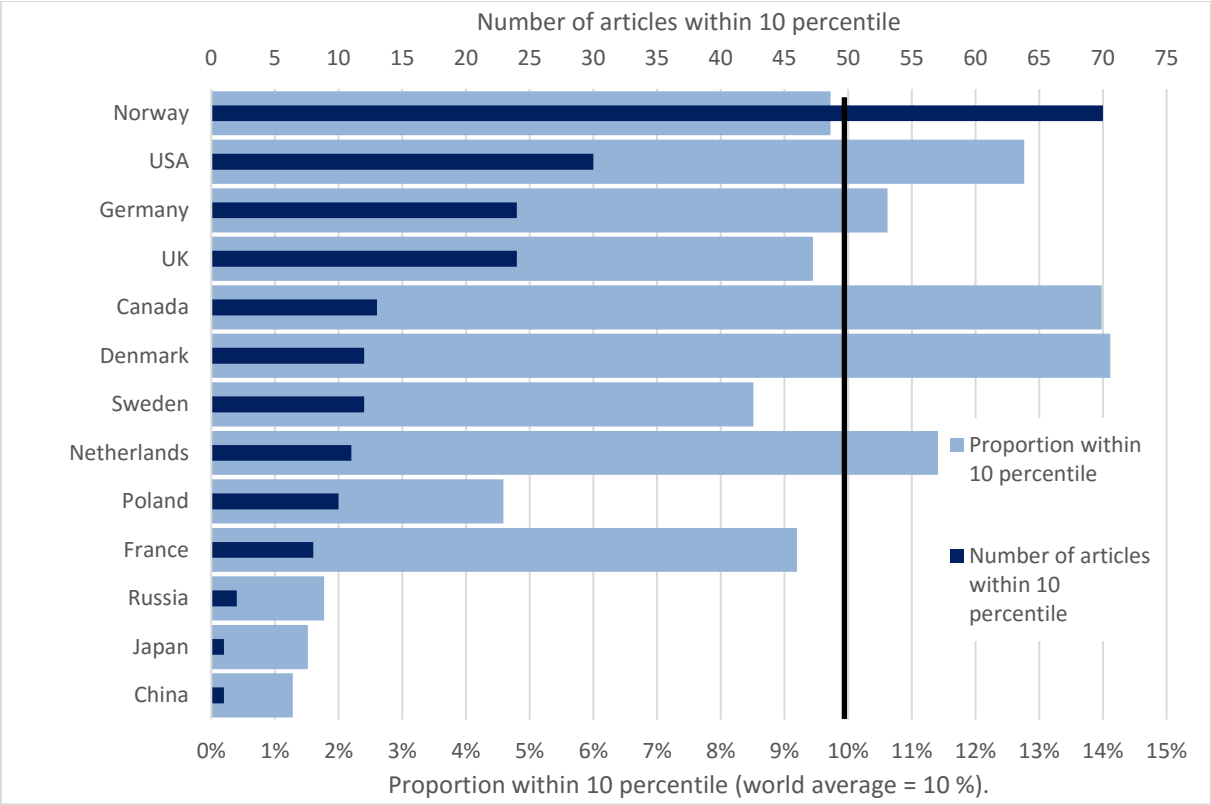

Figure 4.11 High impact publications. Number and proportion of Svalbard-articles within the 10 percentile by country, 2010-2014.

Source: NIFU / Web of Science.

The majority of the high impact Svalbard-publications have co-authors from institutions in more than one country. Table 4.2 shows how the articles are distributed at the level of country. Researchers from Norwegian institutions have contributed as co-authors in 70 of 111 high impact publications (63 per cent). Then follow USA, UK and Germany with proportions of 27-22 per cent. It should be noted that these proportions do not add up to 100, as many articles have multiple national co-authorships.

Table 4.2 Number and proportion of high impact Svalbard-articles by country, 2010-2014.

Country	Number of articles	Proportion of all high impact Svalbard publications*
Norway	70	63%
USA	30	27%
UK	24	22%
Germany	24	22%
Canada	13	12%
Sweden	12	11%
Denmark	12	11%
Netherlands	11	10%
Poland	10	9%
France	8	7%
Russia	2	2%
China	1	1%
Japan	1	1%
TOTAL	111	

*) Cumulative per cent exceeds 100 since many articles have contributions from more than one country.
Source: NIFU / Web of Science.

4.2.3 Journal profile

In Figure 4.12 we have calculated for each country a citation index for the journal set where the Svalbard articles has been published. As described previously, if this indicator exceeds 100 one can conclude that the country publishes in journals with higher than average impact. The indicator is calculated for all polar research articles and for Svalbard articles. For almost all countries shown in the figure, the journals used for publishing the Svalbard-articles have lower citation rate (impact factor) than the journals used for publishing polar research articles generally. For Norway, the index values are 121 and 103, respectively.

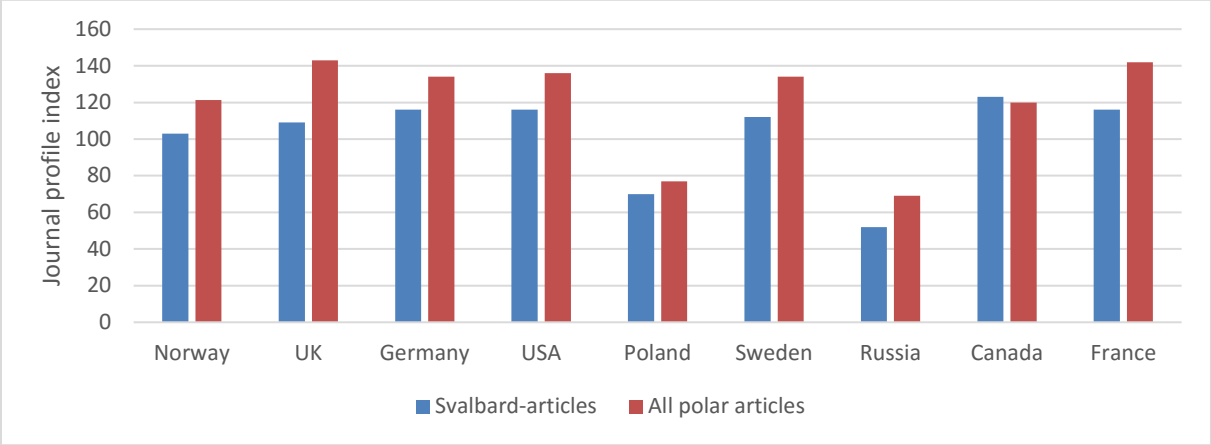

Figure 4.12 Journal profile (the relative citation index for the journals used) Svalbard-articles and all polar research articles, 2010-2013.

Source: NIFU / Web of Science.

In order to provide further insight into the publication profile of Norwegian polar research, we have listed in Table 4.3 the most frequently used journals in terms of number of publications. This table covers the entire 2010-2016 period. The journals *Polar Biology* and *Polar Research* account for the highest number of Svalbard articles, 73 and 52, respectively, followed by *Norwegian Journal of Geology* and *Journal of Geophysical Research – Space physics*. As seen in Table 3.7, these journals have a lower than average citation rate (impact factor).

Table 4.3 Journal profile of Norwegian Svalbard articles, 2010-2016. Number of articles per journal, ranked by publication frequency.

Journal	No of articles	Journal	No of articles
POLAR BIOLOGY	73	*BOREAS*	10
POLAR RESEARCH	52	*POLISH POLAR RESEARCH*	10
NORWEGIAN JOURNAL OF GEOLOGY	38	*GEOPHYSICAL RESEARCH LETTERS*	10
JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS	32	*PALAEOGEOGRAPHY PALAEOCLIMATOLOGY PALAEOECOLOGY*	10
CRYOSPHERE	27	*ENVIRONMENTAL SCIENCE & TECHNOLOGY*	9
SCIENCE OF THE TOTAL ENVIRONMENT	20	*JOURNAL OF MARINE SYSTEMS*	8
QUATERNARY SCIENCE REVIEWS	17	*POLAR RECORD*	8
JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES	16	*JOURNAL OF GEOPHYSICAL RESEARCH-EARTH SURFACE*	7
PLOS ONE	15	*MARINE BIOLOGY*	7
ANNALS OF GLACIOLOGY	15	*JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS*	7
MARINE ECOLOGY PROGRESS SERIES	14	*GEOGRAFISKA ANNALER SERIES A-PHYSICAL GEOGRAPHY*	7
BIOGEOSCIENCES	13	*ADVANCES IN METEOROLOGY*	7
ATMOSPHERIC CHEMISTRY AND PHYSICS	13	*ENVIRONMENTAL POLLUTION*	7
JOURNAL OF GLACIOLOGY	12	*EARTH-SCIENCE REVIEWS*	6
COLD REGIONS SCIENCE AND TECHNOLOGY	11	*ARCTIC ANTARCTIC AND ALPINE RESEARCH*	6
ANNALES GEOPHYSICAE	10	*PERMAFROST AND PERIGLACIAL PROCESSES*	6

Source: NIFU / Web of Science.

4.2.4 Citation rates by fields and topics

We have then analysed the citation rate of the Svalbard publications by field. The results are shown in Figure 4.13. In all fields, the Svalbard publications have been cited on par or below the world average for polar research. In cosmic geophysics and space research the citation index is 27, only. The articles in this field have received an average of 3.8 citations per publication, while this average is 7-10 citations in the other fields shown in the figure. An analysis of the referencing patterns of this field would be required in order to obtain further information on this issue.

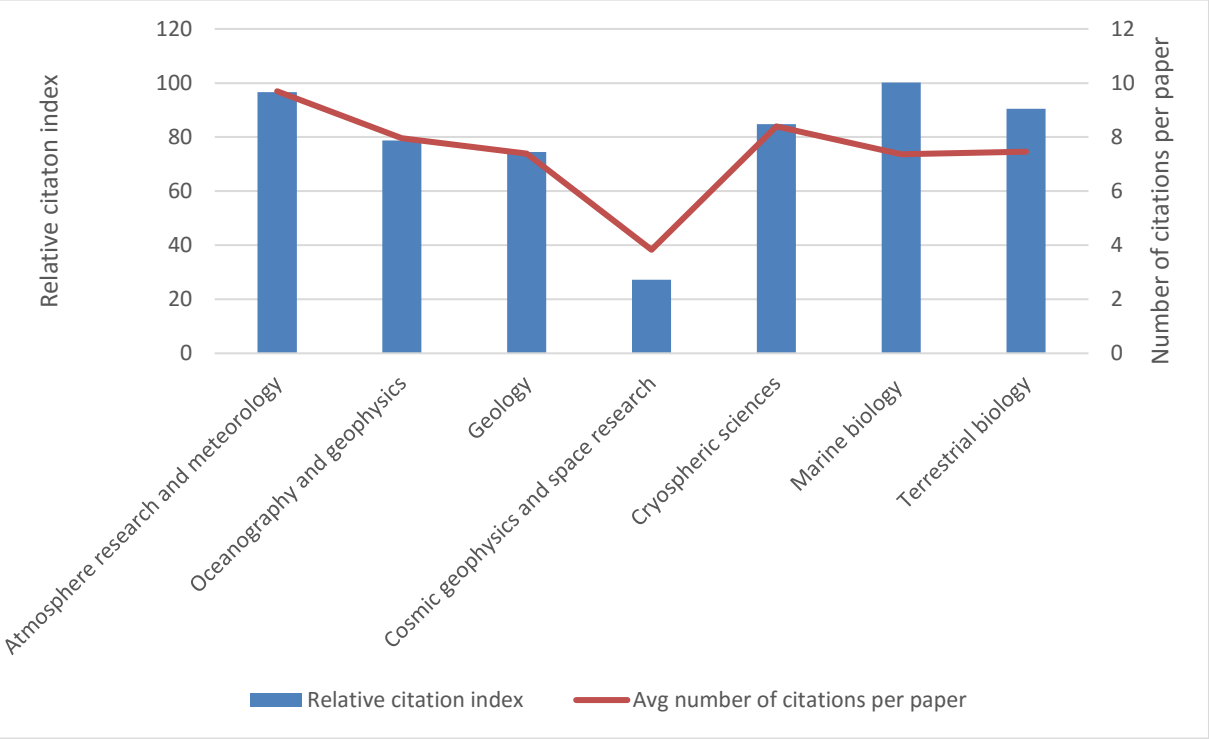

Figure 4.13 Relative citation index and average number of citations for Svalbard articles, by field (total all countries) 2010-2014.

Source: NIFU / Web of Science.

When analysing the Norwegian Svalbard articles we find that in all fields, the relative citation indexes of the Norwegian Svalbard-articles are higher than the average for all countries (Figure 4.14), however the difference is not very large. Table 4.4 provides further details on the citation index of each field at the level of countries (the largest countries by article numbers).

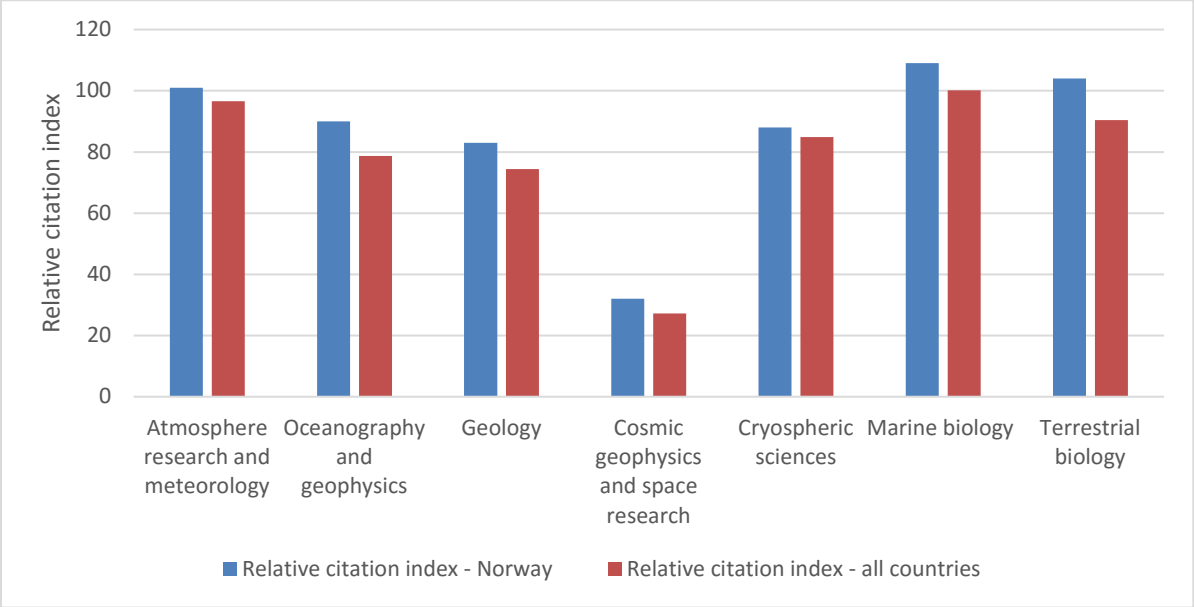

Figure 4.14 Relative citation index for Svalbard articles, by field, total all countries and Norway, 2010-2014.

Source: NIFU / Web of Science.

Table 4.4 Relative citation index for Svalbard articles, by field and country 2010-2014.*

	Atmosphere research & meteorology	Oceanography & geophysics	Geology	Cosmic geophysics and space research	Cryos-pheric sciences	Marine biology	Terres-trial biology
Austria							160
Canada							104
Czech Rep							53
Denmark							160
France							122
Germany	81		98		91	125	96
Japan				32			
Netherlands							101
Norway	101	90	83	32	88	109	104
China							64
Poland			55		59	78	87
Russia				16			
Sweden	113				110		130
UK				27	84	79	114
USA	146		93	23	108	102	120

*) Figures are shown for countries with more than 20 publications within the various fields during the time period.
Source: NIFU / Web of Science.

As shown in Figure 4.15, the articles addressing marine topics tend to be more cited than the “terrestrial” articles. This holds for all countries in total and for Norway (citation indexes (99 and 102, respectively). Moreover, the articles addressing climate or pollution issues tend to be more cited than the other articles. In particular, the Norwegian articles relating to pollution obtain a high citation index, 126.

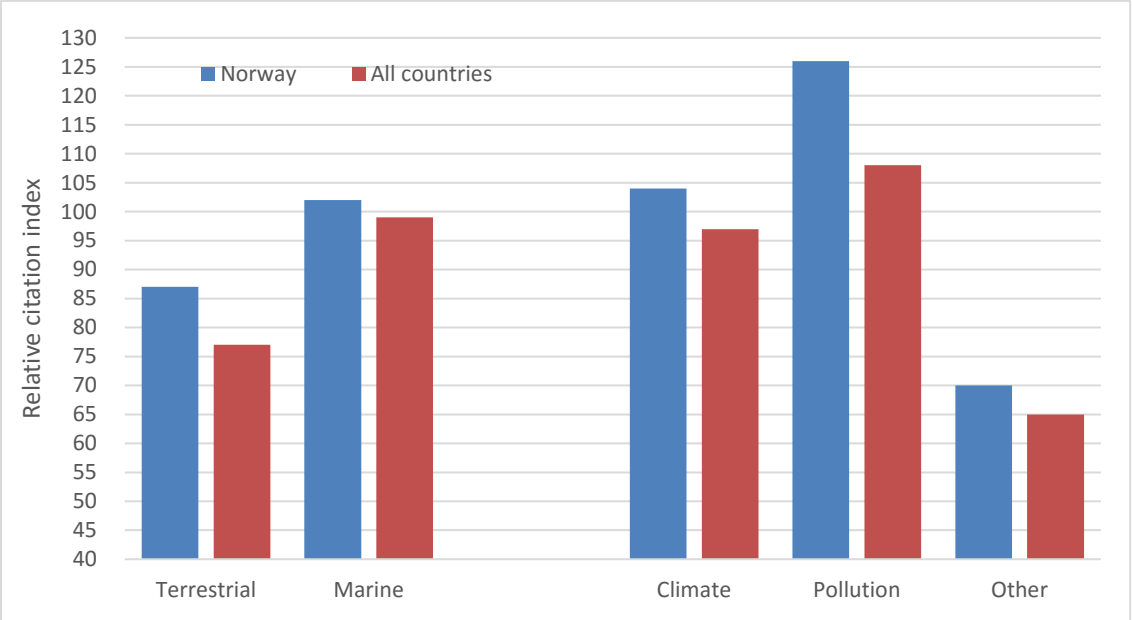

Figure 4.15 Relative citation index for Svalbard articles, Norway and all countries by type of research (terrestrial and marine; climate, pollution and other), 2010-2014.

Source: NIFU / Web of Science.

4.2.5 Citation rate by institutions

Table 4.5 shows the citation index of the largest Norwegian institutions and institutes within Svalbard research (i.e. those with the highest number of articles during the period 2010-2014). NILU ranks highest with an index of 143, followed by Akvaplan-niva with 129. For the other units, there are not large differences, and the citation indexes range from 95 and 114, in other words, close to the world average. The exceptions are the business sector and the "other" category (public sector, outside the HE and institute sector), with citation indexes of 61 and 56, respectively.

Table 4.5 Relative citation index for Norwegian Svalbard articles, by institution/institute/sector, 2010-2014.

	Institution/institute/sector	Number of articles	Relative citation index
HE sector	UNIS	260	98
	UiT	201	95
	UiO	178	101
	UiB	100	95
	NTNU	67	102
	NBMU	43	108
	Other HE-institutions	21	114
Institute sector	NPI	197	104
	Akvaplan-niva	38	129
	NINA	40	108
	NILU	38	143
	Other institute sector	112	106
	Other	25	56
	Business sector	39	61

Source: NIFU / Web of Science.

4.2.6 Geographical profile

In a similar way as in the analysis of Norwegian polar research generally, the articles were classified according to geographical profile. The publications that were based on research carried out in geographical locations in Svalbard, only, were termed "single location publications". This category also includes publications based on research in different locations in Svalbard. Publications based on research in Svalbard and additional external geographical areas (for example Svalbard and Greenland), are termed "multi location publications". The category of articles addressing more general subjects/articles not involving research in specific locations was not used in the case of Svalbard publications. By definition, all articles identified as Svalbard publications are related to Svalbard. Similarly, we did not use the category for unspecified locations.

Table 4.6 shows the results of the classification for the Svalbard-articles and for the publication set consisting of the Norwegian polar research publications with high and low impact. A large majority of the Svalbard articles generally and of the Norwegian Svalbard articles, were single location studies (80 and 84 per cent, respectively. Approximately one fifth of the articles were multi location studies. The multi-location Svalbard publications are however, much more frequently cited that the single location publications. This is shown in Figure 4.16. The proportion of single location Svalbard publications is higher than for the two publication sets of Norwegian polar research articles. This is one explanation of the low citation impact of the Svalbard articles.

In addition, the general studies tend to be more frequently cited overall, which is indicated by the higher fraction of these articles in the set of high impact publications. As there are no such articles in the set of Svalbard publications, this means that the low citation impact partly has a methodological explanation: The general articles which contribute positively to the overall citation index of polar research will be left out when delimiting Svalbard articles geographically. Estimations based on the sample of Norwegian high impact publications suggest that the citation index of the Svalbard publication would have been 9 points higher if including general studies. This explains about half of the difference in citation rate between the Norwegian Svalbard articles and of Norwegian polar research articles generally.

Table 4.6 Proportion of publications by geographical type for various publication sets, 2010-2014.

Type of article	All Svalbard-articles	Norwegian Svalbard-articles	Norwegian low impact polar research articles	Norwegian high impact polar research articles
Single location	80 %	84%	61 %	38 %
Multi locations	20 %	16 %	15 %	28 %
General study	0%	0 %	18 %	27 %
Unspecified location	0%	0%	7%	6 %

Source: NIFU / Web of Science.

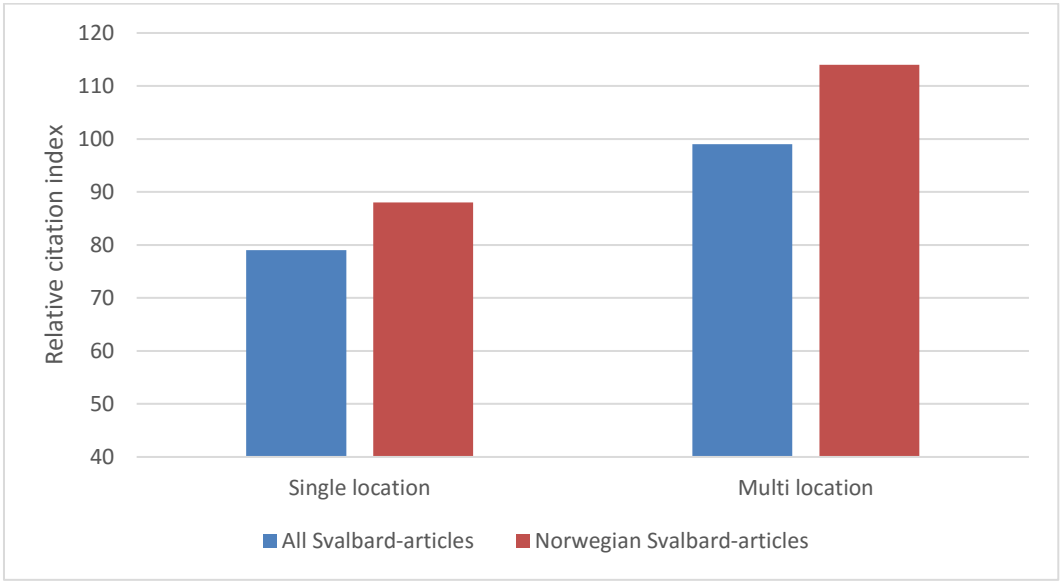

Figure 4.16 Relative citation index for Svalbard articles by geographical type, Norway and all countries, 2010-2014.

Source: NIFU / Web of Science.

4.2.7 International collaboration

As described in the previous chapter, internationally co-authored articles are generally more cited than articles which have authors from one country.[13] We have therefore investigated the importance of this issue in respect to the Svalbard articles. Overall, 43 per cent of the Svalbard articles were authored by researchers from one country, only. These articles obtained a citation index of 72 (Figure 4.17). A third of the articles had co-authors from two different countries. These articles obtained a citation index of 87. The citation index is increasing further when articles have co-authors from additional countries.

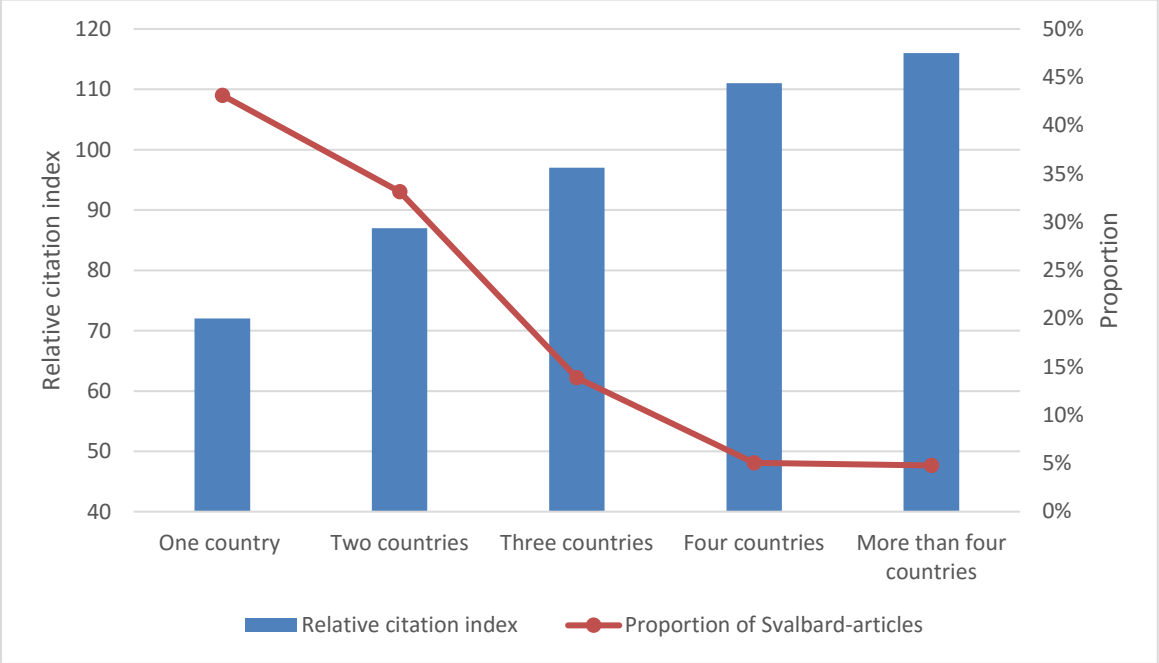

Figure 4.17 Relative citation index for Svalbard articles according to number of countries (by author affiliations), 2010-2014.

Source: NIFU / Web of Science.

[13] In addition, multi-authored papers are generally more highly cited than single-author papers. High citation rates have been found to correlate strongly with number of authors (Aksnes, 2003).

Overall 69 per cent of the Norwegian Svalbard articles had co-authors affiliated with institutions abroad. This is on par with the average for Norwegian polar research generally (73 per cent). Thus, the Norwegian Svalbard research is also characterised by extensive international collaboration. The citation index of the latter articles was 100, compared with 83 for the articles with Norwegian author affiliations, only (Figure 4.18). However, there are large differences within the internationally co-authored publication set. Articles co-authored with researchers from Russian and Japanese institutions were cited below the Norwegian overall average.

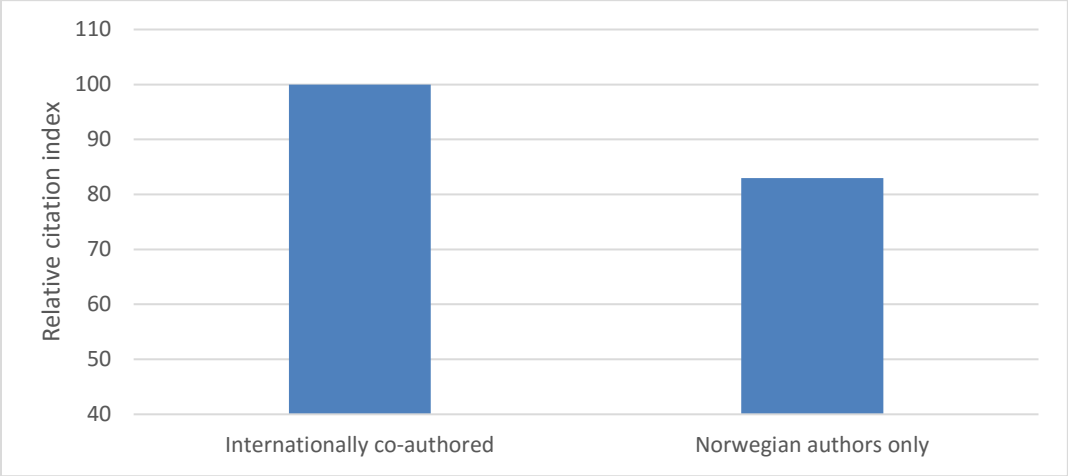

Figure 4.18 Relative citation index for Norwegian Svalbard articles, 2010-2014, internationally co-authored and "domestic" articles.

Source: NIFU/Web of Science.

4.2.8 Prolific Norwegian polar researchers

As a next step, we identified the most prolific Norwegian polar researchers and analysed the geographically profile of their articles (Svalbard and other). In total 53 researchers with more than 10 polar research articles during the period 2010-2013 where included in the analysis. Almost all the researchers had published at least a few Svalbard articles (Figure 4.19) and overall 48 per cent of the publications were related to Svalbard. This is an indication of the importance of Svalbard in Norwegian polar research.

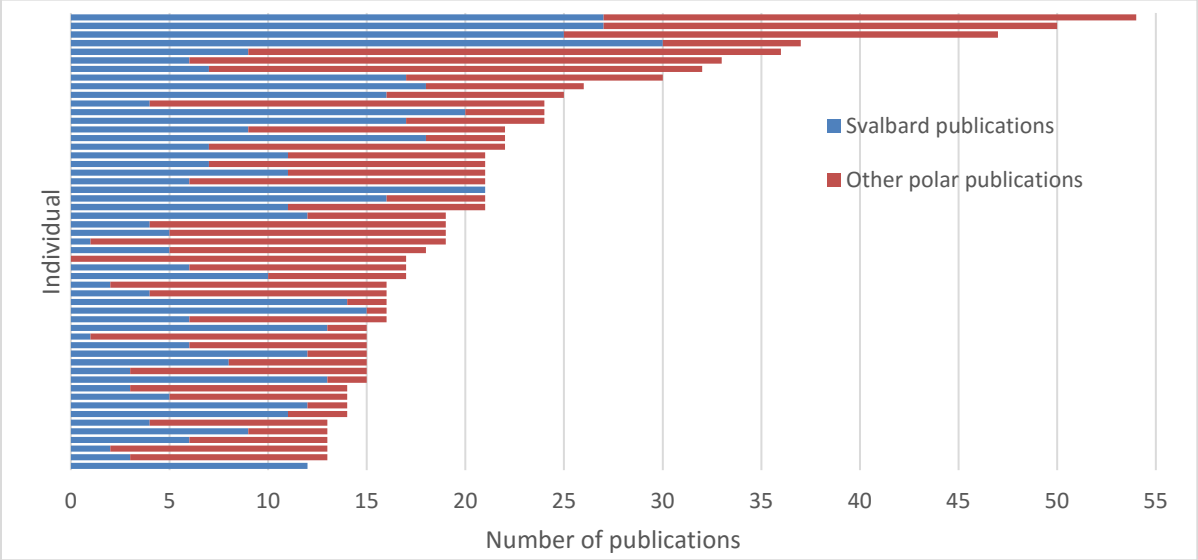

Figure 4.19 Overview of the most prolific Norwegian polar researchers (N=53), distribution of Svalbard publications and other polar publications, 2010-2013.

Source: NIFU/Web of Science.

We further analysed whether the Svalbard publications of the prolific Norwegian polar researchers were less cited than their other polar research articles. Indeed, this was also the case and the Svalbard articles obtained a citation index of 107, compared with 139 for the other articles (Table 4.7). There were also differences in the proportion of the articles within the 10 percentile, although limited to two percentage points. The results of this analysis are interesting because they suggest that the low citation impact of Svalbard research cannot be explained by characteristics of the individuals, as they are able to produce higher impact research elsewhere.

Table 4.7 Overview of the most prolific Norwegian polar researchers (N=53). Citation indicators for Svalbard publications and other polar publications, 2010-2013.

	Number of publications 2010-2013	Relative citation index	Proportion within 10 percentile	Number of articles within 10 percentile
Svalbard articles	314	107	12%	37
Other polar articles	340	139	14%	47
Total	654	124	13%	84

Source: NIFU/Web of Science.

4.2.9 Svalbard as training ground for polar research education

In the final part, we have analysed bibliometrically the role of Svalbard as training ground for polar research education. In particular, we were interested in addressing the issue in respect to the citation impact of the research.

As a first step a minor register-based survey was carried out. The survey included a few selected departments and institutes which have polar research as core activities (the UNIS departments, NPI, and biology departments at UiT). Using data from NIFU's Research Personnel Register and Doctoral register, we identified individuals with positions as PhD students during the period 2001-2011. Then, for the further analysis we included the individuals where the PhD projects partly or fully were conducted in Svalbard. Here we used available information concerning the topic of their PhD projects (title of thesis, articles, abstracts etc.). In total, we identified 71 PhD students of which almost 70 per cent having foreign citizenship (Figure 4.20). In 2015, 73 per cent of the PhD students had obtained a PhD degree. After completing their PhDs approximately half of the researchers continued with Svalbard research (partly of fully). These results show that Svalbard plays an important role in the education of polar researchers in Norway and that a large number of foreign scientists also obtain PhDs in polar research through the Norwegian higher education system.

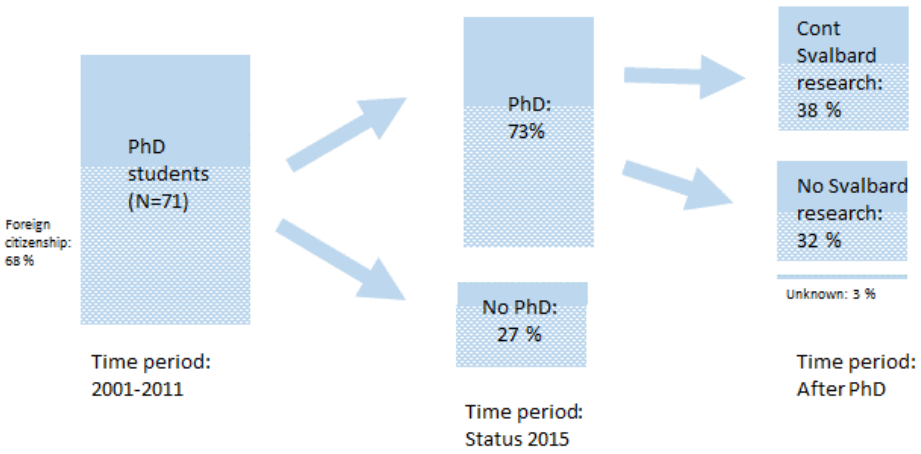

Figure 4.20 Career of individuals with PhD projects in Svalbard.

Source: NIFU.

In addition to the analysis described above, we carried out a mail survey to authors having published Svalbard articles in 2013 (one co-author per article). This survey was carried out in order to obtain information on which articles that involved PhD students.[14] In contrast to the survey above, this was not limited to UNIS, NPI and UiT, and in total 144 articles with at least one author from Norwegian institutions were included in the survey. The response rate was 85 per cent. The results show that a majority of the articles, 58 per cent, included PhD students as one co-author (Figure 4.21). Thus, the results suggest that PhD students are heavily involved in the research carried out in Svalbard.

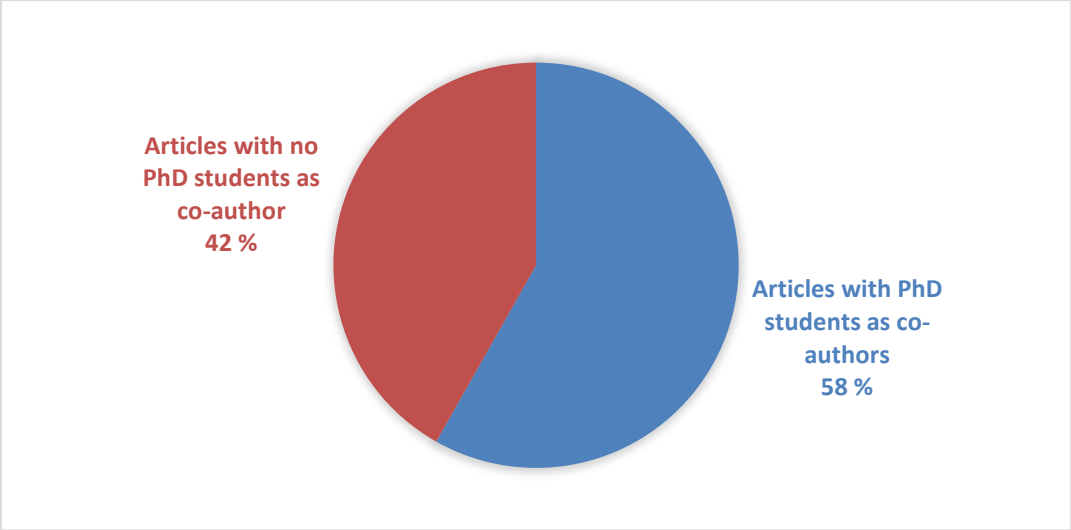

Figure 4.21 Proportion of Norwegian Svalbard articles with and without PhD students as co-authors, 2013.

Source: NIFU.

[14] The authors were asked to answer the following questions concerning the specific articles: 1. Is the article listed based on research conducted in Svalbard (field work, observations, experiments, etc.)? 2. Did the research reported in the article involve PhD students or research fellows working on a PhD? I.e., were any of the listed authors working on a PhD project at the time the research was carried out/the article written?

When analyzing the citation rate of the two set of publications, we find that the articles with PhD students as co-authors actually have been cited more frequently than the other articles. The relative citation rates of the two sets of publications are 113 and 83, respectively (Figure 4.22). However, there are relatively fewer high impact publications in the publication set involving PhD students (measured as 10 percentile), but still the proportion is 12 per cent. Although providing somewhat contradictory results, there seems to be no reason to conclude that the large extent of PhD affiliated publications, is negatively associated with the impact of the Svalbard research.

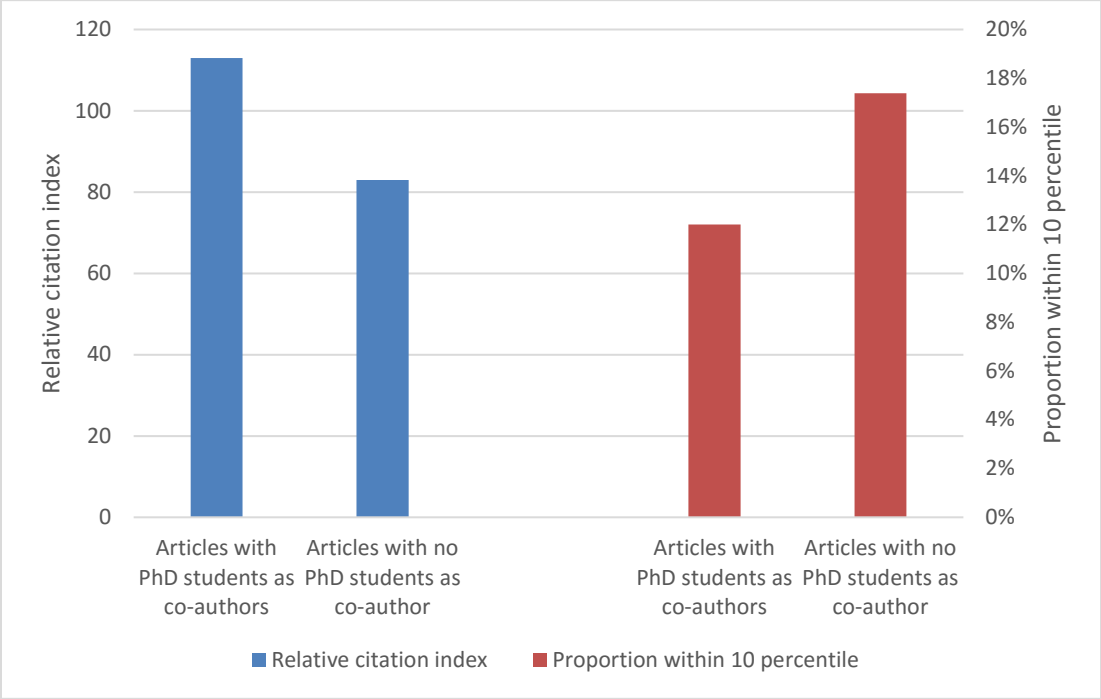

Figure 4.22 Citation indicators for Norwegian Svalbard articles, with and without PhD students as co-authors, relative citation index and proportion within 10 percentile, 2013.

Source: NIFU/Web of Science.

4.2.10 Concluding remarks

In this chapter, we have presented many different indicators and analyses of the citation impact of Svalbard publications. An important aim has been to identify the reason for the relatively low citation rate of these publications. The analysis shows that the pattern is consistent across several dimensions: time, nations and fields. In all the years analysed, the Svalbard articles have been less cited than the average for polar research generally (10-20 per cent below this average). Moreover, the major countries have lower citation rate for their Svalbard articles than for their other polar research articles. Below we have summarised some findings that may explain the low citation rate of the Svalbard articles.

- For almost all countries analysed, the journals used for publishing the Svalbard-articles have lower citation rate (impact factor) than the journals used for publishing polar research articles generally. For Norway, we find that the journals most frequently used for publishing Svalbard articles have a lower than average citation rate and there are fewer publications in the leading and prestigious scientific journals measured by impact factor.

- A large majority of the Svalbard articles generally and of the Norwegian Svalbard articles are single location studies (80 and 84 per cent, respectively), i.e. based on research carried out in

geographical locations in Svalbard, only. The proportion of such papers is higher in the set of Svalbard publication than in the set of Norwegian polar articles generally. The analysis shows that such papers on average are less cited than other papers such as multi location studies. More collaborative work, involving research also beyond Svalbard would probably have been beneficial from a citation impact perspective.

- The analysis has also revealed that the low citation index partly may be explained by a methodological issue: In the overall polar research publication set there are many general studies (articles addressing more general subjects/articles not involving research in specific locations). There are no such articles in the set of Svalbard publications because these have been delimited geographically. This type of article tends to be more frequently cited generally than other articles. About half of the difference in citation rate between the Norwegian Svalbard articles and the Norwegian polar research articles may be attributed this factor.

- At the level fields and disciplines as well as institutions and institutes, there are also differences and the citation rate is particularly low in cosmic geophysics and space research. Thus, although the low citation impact of the Svalbard research is a rather general phenomenon, there are variations also at these levels.

- As for polar research generally, Svalbard research is characterised by extensive international collaboration. The internationally co-authored articles are generally more cited than articles which have authors from one country, only. This holds for Norway although the collaborative articles with some countries were cited below the Norwegian overall average. Thus, the collaboration profile plays a role. Strengthening the international collaboration pattern of Norwegian Svalbard research even further would most likely contribute to a higher citation rate.

- This analysis shows that Svalbard plays an important role in the education of polar researchers in Norway. However, the citation impact of the publications involving PhD students is not inferior compared with other Svalbard articles.

In conclusion, the analysis has revealed several factors contributing to the low citation impact of the publications. Still, the analysis is limited to bibliometric evidence and a fuller understanding of the issue would require assessment by peers investigating the content of the research. Possibly, peers would arrive at other conclusions than what is suggested by citation measures.

5 Citation as indicators

Publication and citation data have increasingly been applied as performance indicators in the context of science policy and research evaluation. The basis for the use of bibliometric indicators is that new knowledge – the principal objective of basic and applied research – is disseminated to the research community through publications. Publications can thereby be used as indirect measures of knowledge production. Data on how much the publications have been referred to or cited in the subsequent scientific literature can in turn be regarded as an indirect measure of the scientific impact of the research. In this chapter, we will provide a general introduction to bibliometric indicators, particularly focusing on analyses based on the Web of Science database.[15]

5.1 The Web of Science database

The Web of Science database covers a large number of specialised and multidisciplinary journals within the natural sciences, medicine, technology, the social sciences and the humanities. The coverage varies between the different database products. According to the website of the Thomson Reuters company, the online product Web of Science covering the three citation indexes Science Citation Expanded, Social Sciences Citation Index, and Arts & Humanities Citation Index includes more than 12,000 journals. Compared to the large volume of scientific and scholarly journals that exist today, this represents a limited part. The selection of journals is based on a careful examination procedure in which a journal must meet particular requirements in order to be included (Testa, 2012). Even if its coverage is not complete, the database will include all major journals within the natural sciences, medicine and psychology and technology and is generally regarded as constituting a satisfactory representation of international mainstream scientific research. With respect to the social sciences and humanities the coverage is more limited, and this issue will be further discussed below.

From a bibliometric perspective, a main advantage of the Web of science database is that it fully indexes the journals that are included. Moreover, all author names, author addresses and references are indexed. Through its construction it is also well adapted for bibliometric analysis. For example, country names and journal names are standardised, controlled terms. It is also an advantage that it is multidisciplinary in contrast to most other similar databases which cover just one or a few scientific disciplines.

[15] This overview is partly based on Aksnes (2005).

5.2 Citation indicators

Citations represent an important component of scientific communication. Already prior to the 19th century it was a convention that scientists referred to earlier literature relating to the theme of the study (Egghe & Rousseau, 1990). The references are intended to identify earlier contributions (concepts, methods, theory, empirical findings, etc.) upon which the present contribution was built, and against which it positions itself. Thus, it is a basic feature of the scientific article that it contains a number of such references and that these references are attached to specific points in the text.

The Web of Science database was originally developed for information retrieval purposes, to aid researchers in locating papers of interest in the vast research literature archives (Welljams-Dorof, 1997). As a subsidiary property it enabled scientific literature to be analysed quantitatively. Since the 1960s the Science Citation Index and similar bibliographic databases have been applied in a large number of studies and in a variety of fields. The possibility for citation analyses has been an important reason for this popularity. As part of the indexing process, Thomson Reuters systematically registers all the references of the indexed publications. These references are organised according to the publications they point to. On this basis each publication can be attributed a citation count showing how many times each paper has been cited by later publications indexed in the database. Citation counts can then be calculated for aggregated publications representing, for example, research units, departments, or scientific fields. Later on, additional databases have been introduced which also include citation statistics, most importantly the Scopus-database (launched in 2003) and Google Scholar (launched in 2004). The coverage of the scientific and scholarly literature varies across these databases, and the findings of citation studies are thus dependent upon the particular characteristics of the databases, their coverage, and so forth.

5.3 What is measured through citations?

Because citations may be regarded as the mirror images of the references, the use of citations as indicators of research performance needs to be justified or grounded in the referencing behaviour of the scientists. If scientists cite the work they find useful, frequently cited papers are assumed to have been more useful than publications which are hardly cited at all, and possibly be more useful and thus important in their own right. Thus, the number of citations may be regarded as a measure of the article's usefulness, impact, or influence. The same reasoning can be used for aggregated levels of articles. The more citations they draw, the greater their influence must be. Robert K. Merton has provided the original theoretical basis for this link between citations and the use and quality of scientific contribution. In Merton's traditional account of science, the norms of science oblige researchers to cite the work upon which they draw, and in this way acknowledge or credit contributions by others (Merton, 1979). Such norms are upheld through informal interaction in scientific communities and through peer review of manuscripts submitted to scientific journals.

Empirical studies have shown that the Mertonian account of the normative structure of science covers only part of the dynamics. For the citation process, this implies that other incentives occur, like the importance of creating visibility for one's work, and being selective in referencing to create a distance between oneself and others. Merton himself already pointed out the ambivalence of the norms, for example that one should not hide one's results from colleagues in one's community, but also not rush into print before one's findings are robust. Merton also identified system level phenomena like the "Matthew effect": to whom who has shall be given more. Clearly, a work may be cited for a large number of reasons including tactical ones such as citing a journal editor's work as an attempt to enhance the chances of acceptance for publication. Whether this affects the use of citations as performance indicators is a matter of debate.

The concept of quality has often been used in the interpretation of citation indicators. Today, however, other concepts – particularly that of "impact" – are usually applied. One reason is that quality is often considered as a diffuse or at least multidimensional concept. For example, the following description is

given by Martin and Irvine (1983): "'Quality' is a property of the publication and the research described in it. It describes how well the research has been done, whether it is free from obvious 'error' […] how original the conclusions are, and so on." Here, one sees reference to the craft of doing scientific research, and to the contribution that is made to the advance of science.

The impact of a publication, on the other hand, is defined as the "actual influence on surrounding research activities at a given time." According to Martin and Irvine it is the impact of a publication that is most closely linked to the notion of scientific progress – a paper creating a great impact represents a major contribution to knowledge at the time it is published. If these definitions are used as the basis it is also apparent that impact would be a more suitable interpretation of citations than quality. For example, a 'mistaken' paper can nonetheless have a significant impact by stimulating further research. Moreover, a paper by a recognised scientist may be more visible and therefore have more impact, earning more citations, even if its quality is no greater than those by lesser known authors (Martin, 1996).

5.4 Some basic citation patterns

De Solla Price showed quite early that recent papers are more cited than older ones (Price, 1965). Nevertheless, there are large individual as well as disciplinary differences. The citation counts of an article may vary from year to year. Citation distributions are extremely skewed. This skewness was also early identified by Solla Price (Price, 1965). The large majority of the scientific papers are never or seldom cited in the subsequent scientific literature. On the other hand some papers have an extremely large number of citations.

Citation rates vary considerably between different subject areas. For example, on average papers in molecular biology contain many more references than mathematics papers. Accordingly, one observes a much higher citation level in molecular biology than in mathematics. Generally, the average citation rate of a scientific field is determined by different factors, most importantly the average number of references per paper. In addition, the percentage of these references that appears in Web of Science-indexed journals, the average age of the references, and the ratio between new publications in the field and the total number of publications, are relevant.

5.5 Limitations

In addition to the fundamental problems related to the multifaceted referencing behaviour of scientists, there are also more specific problems and limitations of citation indicators. Some of these are due to the way the Web of Science database is constructed. First of all, it is important to emphasise that only references in Web of Science indexed literature count as "citations". For example, when articles are cited in non-indexed literature (e.g. a trade journal) these are not counted. This has important consequences. Research of mainly national or local interest, for example, will usually not be cited in international journals. Moreover, societal relevance, such as contributions of importance for technological or industrial development, may not be reflected by such counts. Because it is references in (mainly) international journals which are indexed, it might be more appropriate to restrict the notion of impact in respect to citation indicators to impact on international or "mainstream" knowledge development.

There is also a corresponding field dimension. For example, LePair (1995) has emphasised that "In technology or practicable research bibliometrics is an insufficient means of evaluation. It may help a little, but just as often it may lead to erroneous conclusions." For similar reasons the limitations of citation indicators in the social sciences and humanities are generally more severe due to a less centralised or a different pattern of communication. For example, the role of international journals is less important, and publishing in books is more common: older literature has a more dominant role and many of the research fields have a "local" orientation. In conclusion, citation analyses are

considered to be most fair as an evaluation tool in the scientific fields where publishing in the international journal literature is the main mode of communication.

Then there are problems caused by more technical factors such as discrepancies between target articles and cited references (misspellings of author names, journal names, errors in the reference lists, etc.), and mistakes in the indexing process carried out by Thomson Reuters (see Leydesdorff et al., 2016, Moed, 2002). Such errors affect the accuracy of the citation counts to individual articles but are nevertheless usually not taken into account in bibliometric analyses (although their effect to some extent might "average out" at aggregated levels).

While some of the problems are of a fundamental nature, inherent in any use of citations as indicators, other may be handled by the construction of more advanced indicators. In particular, because of the large differences in the citation patterns between different scientific disciplines and subfields, it has long been argued by bibliometricians that relative indicators and not absolute citation counts should be used in cross-field comparisons (Schubert & Braun, 1996). For example, it was early emphasised by Garfield that: "Instead of directly comparing the citation counts of, say, a mathematician against that of a biochemist, both should be ranked with their peers, and the comparison should be made between rankings" (Garfield, 1979). Moed et al. (1985) similarly stressed that: "if one performs an impact evaluation of publications from various fields by comparing the citation counts to these publications, differences between the citation counts cannot be merely interpreted in terms of (differences between) impact, since the citation counts are partly determined by certain field-dependent citation characteristics that can vary from one field to another".

A fundamental limitation of citation indicators in the context of research assessments is that a certain time period is necessary for such indicators to be reliable, particularly when considering smaller number of publications. Frequently, in the sciences a three-year period is considered as appropriate (see e.g. Moed et al., 1985). But for the purpose of long-term assessments more years are required. At the same time, an excessively long period makes the results less usable for evaluation purposes. This is because one then only has citation data for articles published many years previously. Citation indicators are not very useful when it comes to publications published very recently, a principal limitation of such indicators being that they cannot provide an indication of present or future performance except indirectly: past performance correlates with future performance (Luukkonen, 1997). It should be added, however, that this time limitation does not apply to the bibliometric indicators based on publication counts.

5.6 Bibliometric indicators versus peer reviews

Over the years a large number of studies have been carried out to ascertain the extent to which the number of citations can be regarded as a measure of scientific quality or impact. Many studies have also found that citation indicators correspond fairly well, especially in the aggregate, with various measures of research performance or scientific recognition which are taken as reflecting quality. On the other hand, there have been several studies challenging or criticising such use of citations.

One approach to the question is represented by studies analysing how citations correlate with peer reviews. In these studies judgements by peers have been typically regarded as a kind of standard by which citation indicators can be validated. The idea is that one should find a correlation if citations legitimately can be used as indicators of scientific performance (which assumes that peer assessment can indeed identify quality and performance without bias – a dubious assumption). Generally, most of the studies seem to have found an overall positive correspondence although the correlations identified have been far from perfect and have varied among the studies (see e.g. Wilsdon et al., 2015, Aksnes, 2006).

Today most bibliometricians emphasise that a bibliometric analysis can never function as a substitute for a peer review. Thus, a bibliometric analysis should not replace an evaluation carried out by peers.

First a peer-evaluation will usually consider a much broader set of factors than those reflected through bibliometric indicators. Second, this is due to the many problems and biases attached to such analyses. As a general principle, it has been argued that the greater the variety of measures and qualitative processes used to evaluate research, the greater is the likelihood that a composite measure offers a reliable understanding of the knowledge produced (Martin, 1996).

At the same time, it is generally recognised that peer reviews also have various limitations and shortcomings (Lee, Sugimoto, Zhang, & Cronin, 2013, Chubin & Hackett, 1990). For example, van Raan (2000) argues that subjectivity is a major problem of peer reviews: The opinions of experts may be influenced by subjective elements, narrow mindedness and limited cognitive horizons. An argument for the use of citation indicators and other bibliometric indicators is that they can counteract shortcomings and mistakes in the peers' judgements. That is, they may contribute to fairness of research evaluations by representing "objective" and impartial information to judgements by peers, which would otherwise depend more on the personal views and experiences of the scientists appointed as referees. Moreover, peer assessments alone do not provide sufficient information on important aspects of research productivity and the impact of the research activities (van Raan, 1993).

Citations and other bibliometric indicators have been applied in various ways in research evaluation. For example, such indicators are used to provide information on the performance of research groups, departments, institutions or fields. According to van Raan (2000), "the application of citation analysis to the work – the oeuvre – of a group as a whole over a longer period of time, does yield in many situations a strong indicator of scientific performance, and, in particular, of scientific quality". As a qualifying premise it is emphasised, however, that the citation analysis should adopt an advanced, technically highly developed bibliometric method. In this view, a high citation index means that the assessed unit can be considered as a scientifically strong organisation with a high probability of producing very good to excellent research.

In this way a bibliometric study is usually considered as complementary to a peer evaluation (Council of Canadian Academies, 2012). Van Raan has accordingly suggested that in cases where there is significant deviation between the peers' qualitative assessments and the bibliometric performance measures, the panel should investigate the reasons for these discrepancies. They might then find that their own judgements have been mistaken or that the bibliometric indicators did not reflect the unit's performance (van Raan, 1996).[16]

In conclusion, the use of citations as performance measures have their limitations, as all bibliometric indicators have. But a citation analysis when well designed and well interpreted will still provide valuable information in the context of research evaluation. Performance, quality and excellence can also be assessed through peer review, but in spite of their widespread use, these have problems as well. A combination of methods, or better, mutual interplay on the basis of findings of each of the methods, is more likely to provide reliable evaluation results.

[16] Van Raan (1996) suggests that in cases were conflicting results appear, the conclusion may depend on the type of discrepancy. If the bibliometric indicators show a poor performance but the peer's judgement is positive, then the communication practices of the group involved may be such that bibliometric assessments do not work well. By contrast, if the bibliometric indicators show a good performance and the peers' judgement is negative, then it is more likely that the peers are wrong.

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Appendix – List of abbreviations, institutions and institutes

IMR – Institute of Marine Research

NILU – Norwegian Institute for Air Research

NINA – Norwegian Institute for Nature Research

NMBU – Norwegian University of Life Sciences

NPI – Norwegian Polar Institute

NTNU – Norwegian University of Science & Technology

RCN – Research Council of Norway

UiB - University of Bergen

UiO – University of Oslo

UiT – the Arctic University of Norway

UNI – Uni Research

UNIS – University Centre in Svalbard

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