The Research Council of Norway

Room for increased ambitions? Governing breakthrough research in Norway 1990 – 2013

Report to the Research Council of Norway

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SUMMARY

This report analyzes the preconditions for 'breakthrough research' in Norway. It starts out from some basic assumptions about the foundations of 'breakthrough research': it is dependent on a policy system which operates with clear-cut goals and consistent expectations of scientific quality, and where the health and standing of the nation's research environments are central concerns across the political spectrum. For university governance, a key 'success factor' is a clear-cut focus on quality and a concern with the circulation of people and ideas. Successful universities are led by strong academic scholars with visions and with the legitimacy to lead. The more successful research systems have maintained a 'protected space' for faculty to pursue independent research lines under the aegis of resourceful environments, but also to foster interesting and innovative combinations of research lines. Successful institutions pursue open recruitment strategies and place a premium on mobility and circulation of people and ideas. External funding triggers and propels a quality culture as exercised in collegial, quality-conscious, arenas.

Norway performs relatively weakly when it comes to high-impact publications (as a proxy for research with the potential to transform our understanding of nature, culture and society). The international visibility of Norwegian universities is limited, and only a small share of Norwegian scholars operate at the forefront of their respective areas. The renewal of Norwegian scholars has been strong over the last decades due to the expansion of the research system, but with limited impact. This collectively portrays a research system of good average quality but with limited impact on the frontiers of knowledge.

We highlight some characteristics in Norwegian research governance that may explain this pattern. The political system lacks a consistent focus on research quality and renewal; instead, sectoral priorities are abundant, constraining the creative powers of Norwegian research and creating a culture of political expectations rather than creative energy. In addition, we see the need for a streamlining of the very broad activities of Research Council Norway, operating with fewer and more general support schemes. It is of particular importance that sectorial programs with perceived high relevance for Norway are filtered through a rigorous scientific quality control. Other weak parts of Norwegian research quality include university organization. Resources seem not to be deployed productively with large fractions of research conducted in small circumstances, primarily aiding teaching and not engaging in cutting-edge issues.

In addition, we found limited evidence of a dedicated stance towards academic quality and renewal when universities recruit and promote their faculty. International recruitments are few and sometimes poorly embedded. The Norwegian career system could therefore be transformed to enhance the focus on path-breaking qualities. If Norwegian universities and scholars are to excel internationally, a culture of quality and boldness needs to be instigated, and this can come only from the universities themselves. Such an ambitious goal should be within reach in view of the, by international standard, generous block funding to Norwegian universities. International comparisons show that a strong and legitimate academic leadership can set quality enhancing measures in motion through recruitment and priorities of resources to foster excellence.

INTRODUCTION

The Norwegian research system has grown immensely since 1990. Starting out from a position of small size and relative isolation, with only a few notable international strongholds, Norwegian research has risen to respectable international standards, boasting some areas and environments at the very highest international level. Funding as a share of GDP is still low by international leading standards, but has grown with 50 per cent in fixed prices since 1990. The number of researchers has expanded at a similar pace during the last two decades. At the same time, a revamped research council has funneled spiking resources to critical infrastructure and to focused research efforts in universities and institutes (such as centres and dedicated programmes of various kinds), which in their turn have become increasingly oriented to international publications and competitive funding. As an effect, the Norwegian system seems to have adapted reasonably well to the demands of a global and open research system, with increased international contacts and a visibility marginally above the world average.

However, Norwegian research does not excel in general and many challenges remain, impeding the production of path-breaking research in Norway. The issue figured as one of the challenges mentioned in the evaluation of RCN done by Technopolis. This notwithstanding, the issues of high impact and renewal had been discussed only *en passant*, and hence there seems to be a need to focus on this issue alone. Based on these circumstances we were commissioned by Research Council Norway (RCN) to analyze the conditions for 'breakthrough research' in Norway.

What speaks in Norway's favor is a research policy climate with limited political turmoil and a general conception that the impact of Norwegian research should be enhanced, and a genuine orientation towards improving the system in a consorted manner. The time thus seems ripe for a change. What we suggest is a range of reforms to confront some of the structural deficiencies in Norwegian research, in particular the relative misalignment between resources, research opportunities and the organization of basic research units in Norwegian universities.

To clarify our analysis and our starting points, we divide our analysis into two phases: one from 1990 until 2000, where we with some precision can state that there is a relatively clear-cut relationship between governance models and bibliometrical impact, and after 2000, where the connection is less stable but where we can make some informed predictions of the future impact of the governance model.

The 1990s can be described as a decade of modernization, in particular in rhetoric but also in terms of increases in R&D expenditure. The 2000s have been characterized by consolidation along the lines set in the preceding decade, with a more dedicated influx of resources, and the introduction of several measures to propel international visibility and the concentration of research efforts.

Our focus is on the Norwegian universities and their research environments. The significant institute sector is dealt with only marginally as it serves a multitude of purposes where scientific impact is not an overarching goal. The analysis is based on document studies (bills, evaluations, strategy documents, etc.), secondary sources (earlier studies), and around 20 interviews conducted with insightful persons working in universities, Government, and funding organizations (whose names are kept anonymous). The analysis is aligned with that of our earlier study of research systems in different European countries, where we highlighted the following dimensions in our analysis of the preconditions for breakthrough research: policy

system, funding and university governance (Öquist & Benner 2012). The bibliometrical analysis conducted by the Swedish Research Council is similarly based on that of our earlier study, and amended to include also Norwegian research. The amended bibliometrical report is annexed.

BIBLIOMETRIC ANALYSIS

This report is a freestanding and independent extension of the report "Fostering breakthrough research: A comparative study" authored by Gunnar Öquist and Mats Benner and published as an Academy Report in December 2012 by the Royal Swedish Academy of Sciences. The report compared the international standing of research with high impact in Sweden with that of Finland, Denmark, the Netherlands and Switzerland. Impact assessment was based on a bibliometrical analysis (SRC 2012) made by Docent Staffan Karlsson (at the time at the Swedish Research Council, and currently at the Royal Institute of Technology) and Professor Olle Persson of Umeå University, on behalf of the Swedish Research Council and published as an appendix to the Academy Report. Explanations to the different developments during the last 20 years were searched for in the research policy set by Governments and by the development of universities and funding systems. The relatively weak development of high impact research in Sweden in comparison with that of Denmark, the Netherlands and Switzerland was explained by, among other things, weak academic leadership unable to set priorities in terms of allocation and recruitment to foster strong and creative academic environments. Finland shared many of the characteristics of Sweden and in both countries scientific renewal was clearly hampered by very weak career opportunities for young scientists.

The present report compares the development of the research system of Norway with those of the countries studied in the Academy Report, searching for explanations to the relative weak international impact of Norwegian research. The impact of Norwegian research, as defined by the contribution to the top 10% most highly cited publications, has been done by Staffan Karlsson along the same principles as for the countries of comparison. Karlsson's report was endorsed by the Swedish Research Council and it is annexed in this report.

Based on the bibliometric analyses of scientific publications from Finland, Denmark Norway, the Netherlands, Sweden and Switzerland we can arrange the six countries into one group performing very well internationally (Denmark, the Netherlands, Switzerland) and one group performing at a lower to medium level but still above world average (Finland, Norway, Sweden). This pattern is apparent both when we consider global mean citation and global high impact citation rates defined by the top 10% index. Furthermore, in the high performing group of countries, the positive development of the high impact publications is clearly above that of mean citation rates, while in the lower performing group the two measures follow each other closely, indicating that the top performing countries foster high impact research at the expense of medium-impact research. When we look at the rate of development in the Nordic countries after 1990, Denmark and Norway stand out by having the fastest rises in citation impact. Norway, however, starts at a much lower citation rate (20% below world average) than Denmark (on world average) resulting in Denmark being 35 per cent and Norway 7% above world average in 2011. Corresponding figures for Finland and Sweden are 7 and 15 per cent. It is also noticeable that the rates of both top and mean citations peak at around 2005 in Norway. This is difficult to explain in view of the determined efforts made in Norway after 2008 to stimulate scientists to increase publishing. Of all cited papers, Norway has today the lowest percentage of publications with the highest impact as defined by the top 1% publication index.

In all countries compared, the percentage of papers never cited three years after publication range between 25 and 30%. Finland and Norway are at the upper and Denmark at the lower end of the scale. When we look at the level of international collaboration on publications, the

figures are quite similar for compared countries with the exception of Switzerland showing the highest level of collaboration. It should also be noticed that Nordic collaborations generally generate lower impact than collaborations between a Nordic country and countries outside the Nordic region.

When we break down the publication profiles into subject fields, Norway stands out by showing the largest activity spread with an exceptionally high activity in the Geosciences, 2.3 times above world average. However, high activity in this case is not linked to particularly high impact. Chemistry, Physics and Material Sciences all show relatively low activities in Norway and performing at world average in terms of impact. Taken together, Finland, Norway and Sweden have relatively few subject fields performing with high impact, while Denmark, the Netherlands and Switzerland have three to four times more subject fields performing at this level. Furthermore, the high performing countries have much fewer subject fields performing below world average than the low performing countries. When we look at the degree of interdisciplinarity there are only marginal differences between the countries but again, interdisciplinary publications from Finland, Norway and Sweden show a lower impact than interdisciplinary publications from Denmark, the Netherlands and Switzerland.

Finland, Norway and Sweden also perform less well than Denmark, the Netherlands and Switzerland when it comes to citations in high impact journals. Sweden scores at the bottom when prestigious journals like *Nature, PNAS* and *Science* are considered. Norway, on the other hand, scores lowest by volume in Medicine in these journals but it scores highest when the top 10% citation index is considered. Apparently, Norway has a small, but very competitive group of medical scientists that excel in the prestigious journals. At this level of publication analyses, individual research groups make a difference. The relatively weak publication impact performance of Finland, Norway and Sweden is also clear when we compare at the institutional level. The majority of institutions centre around the world impact average as revealed by the top 10% index, while most research institutions in Denmark, the Netherlands and Switzerland are well above world average. Finland and Norway score the lowest in this comparison.

There are no major difference in self-citation to all publications (national and international) between compared countries although Norway scores highest (10.5%) and Denmark lowest (8.8%) among the Nordic countries. Bibliometrical material also shows that self-citations to national publications have decreased in all countries after 1989.

Looking at the fraction of top scoring scientists in a country when it comes to publication impact, Finland and Norway are again at the bottom, Sweden is intermediate and Denmark, the Netherlands and Switzerland again at the top. However, when we look at recruitment of scientists to the top-performing fraction, Norway has been quite successful and well in line with Denmark and the Netherlands, while Finland and Sweden are at the bottom of this comparison. Switzerland scores highest. The reason behind this positive recruitment trend in Norway is most likely a rapid expansion of the research sector as indicated by the increased volume of publications and publishing authors. Looking at recruitments of young scientists the last years, it is clear that Finland, Norway and Sweden again have a lower recruitment rate of high performing scientists than the other three countries.

Thus, it is clear from the compiled publication performance that only Denmark among the Nordic countries ranks as highly as the Netherlands and Switzerland, all approaching the level of the United States. Finland and Norway, but also Sweden, have a long way to go before they reach the same breath of high impact publications as we see in Denmark today.

In summary, our bibliometrical analyses show a number of troubling issues remaining: the international visibility of Norwegian universities is limited. Only a small share of Norwegian scholars operates at the forefront of their respective areas. The renewal ratio has been strong over the last decades due to the expansion of the research system, but with (yet) limited impact. This collectively portrays a research system that functions well on average but that does not in any significant way lead and shape the knowledge frontiers and a country which does not host globally leading knowledge organizations and environments.

MAIN LINES IN NORWEGIAN RESEARCH POLICY 1990-2000: A GROWING FOCUS ON QUALITY

One entry-point to Norwegian research policy formation is the recurrent bills that have been presented since 1975, which review Norwegian research organization and funding (Skoie 2005). The first bills were primarily summative reports with few significant policy reforms introduced, but structural issues were gradually introduced and addressed. Some were quantitative, in particular to increase R&D investments to levels comparable to the OECD average. The issue of raising research expenditure continues to be a dominant motive in policy debates, but it primarily concerns the composition of private R&D expenditure; when it comes to public expenditure, Norway has been stable at around 0.7-0.8% of GDP in the last decades, slightly lower than that of our reference countries. Other reform impulses were qualitative, and suggested measures to modernize the Norwegian research system in parallel with the rapid increase in expenditure.

The quantitative change came first: research expenditure in the university sector grew with 70 per cent during the 1980s, conjointly with similar increases in private R&D and in the institute sector (Skoie 2005). Again, the increases were based on modest starting levels, and Norway can therefore be considered a case of 'catching-up' (similar to Finland) in contrast to the other countries in our study, which all started out at high levels of expenditure and activity already after the second world war.

A string of qualitative reforms were incepted in the late 1980s and early 1990s, intended to diagnose, confront and reform Norwegian research and its tradition of 'mediocrity' (Gudmund Hernes's characteristic, quoted in Skoie 2005: 184). At the end of the 1980s, after a decade of resource hikes primarily in the form of large sectoral programmes (hovedinnsatsområder) in areas like biotechnology and materials research, there was a general perception that the quality of Norwegian research must be addressed *as such* and more thoroughly. It was with this remit that the university and university colleges commission was appointed, producing the report 'Med viljen og viten' in 1988 (led by sociologist and later Minister for Education and Research Gudmund Hernes). A major concern for the Hernes commission was the fragmented structure of the higher education system, in particular the proliferation of district university colleges after the so-called Ottosen commission in the late 1960s. The Hernes report claimed that Norwegian universities and Norwegian research was fragmented, weakly organized and that the division of labour was poorly developed with almost 100 university colleges in addition to the universities. A national strategy ('Norgesnettet') was deemed necessary to foster research quality (and quality in education) and to bring about a productive division of labour between universities and university colleges, as well as to secure and enhance the basic research function of the universities (cf. Stensaker 2006). As an add-on and as a symbol of change, the commission proposed that Norway should create a 'protected space' for high-quality research in the form of a centre for advanced studies in Oslo, organized conjointly with the Norwegian Academy of Science and Letters.

The Hernes commission did not specifically address the large institute sector, and its articulation with research quality (or lack thereof). The commission instead focused its proposals on the structure of Norwegian research and education outside the institute sector,

and many of these were eventually effectuated. This constituted a first step towards a more concerted stance towards quality and division of labour. Quality and the structure of the university system were now on the agenda.

Reforming the career system

Academic positions were few and primarily consisted in professorships until the 1970s. Since then, the main part of tenured positions in Norwegian universities comprises both education and research, with a prescribed distribution between the two of 50/50 (Michelsen et al. 2006). The main bulk of permanent positions comprise associate (amanuensis) and full professors, even though also teaching-only positions like the Swedish university lecturers had been incepted as well as temporary positions to fill vacancies and to staff external research projects.

A major change in universities' operation was the 'promotion reform' in 1993, when any holder of a permanent position as associate professor could be promoted – after an assessment – to full professor. The proposal was first launched by the Hernes commission in 1988 (NOU 1988:28), and was preceded by a change in the Norwegian university law in 1989 in which the appointment of professors was delegated from the state to the universities themselves. In addition, the reform was a response to the creeping emergence of a *de facto* local policy of promotion that had been in place for some time, where associate professors had been promoted in various processes. The intention behind the 1993 reform was to streamline the promotion procedures and to ensure that they met similar national standards.

The ambitious goal of the Hernes commission was to introduce the North American model of 'tenure track' to modernize and 'de-localize' universities in Norway. This proved to be more difficult as the promotion system was not primarily used as a springboard for quality-based promotions. Until 2010, promotions were nationally regulated by field and assessments were made by national committees, but since then the responsibility for targets have been delegated to the universities themselves, although the large universities continue to collaborate on criteria within the natural sciences.

An evaluation concluded that the system did in fact have an initial impact on faculty motivation (NIFU 2003). However, it was also shown to have hampered mobility and has been accompanied with reductions in support funding from the universities; anecdotal evidences also suggests that it has weakened academic leadership by, in the words of one university leader, creating a very 'flat collegiate', where leadership and direction are underplayed and where new recruitments (from outside the local environment) tend to become disappointed by the lack of a 'collective will' and the scarce resources available to them as parts of their positions. We have also been informed that a remaining introspective academic culture has hampered international recruitment in some cases, and even been the reason for internationally recruited scientists to leave after just a few years. Hence, the laudable ambition of the Hernes commission to transform Norwegian universities, faculties, and departments into collective foundations of ambitious risk-taking turned out to be a somewhat more complex goal to achieve.

Merging the research councils

The funding system in Norway emerged after the World War II. First out was the technical-scientific council (NTNF), formed in 1946. The surplus from the national lottery formed the basis of the basic research council (NAVF), established in 1949. The same year saw the

inception of a council for agricultural research, later complemented by sectoral research councils for fishery and applied social science.

Reforming the research councils was another strand in the 1990s plan to modernize the Norwegian research base. In the course of the post-war period, the research council system had become increasingly diverse with some overlaps but also some cases of lacuna. In addition, some attempts had been made – along the lines of research policy trends at the time – to formulate and implement cross-organizational large-scale themes (hovedinnsatsområder, 'Main Action Areas'), but this primarily added to the organizational complexity and the lack of a committed focus on quality and renewal. In the 1970s and 1980s, several proposals had been made to reform the research council system, some of which failed, while others fared better, primarily those suggesting an augmentation of the system (such as a council for fishery research, and one for applied social science). However, the end-result seemed to be a more patchy system, with overlaps and mismatches, and tugs of war between different interests and actors.

Quality issues seems to have been discussed less in the considerations leading to the merger. The focus was instead on administrative boundaries and the balance between sectoral interests (Skoie 2005). The unified council that was proposed by the Grøholt commission as a result of the parliamentary request, suggest the inception of just one council saddled with the task of providing the government with coordinated advice, enhancing the integration of Norwegian research into European research collaboration (see Technopolis 2001 for an overview).

The 1993 reform was thus guided by two overarching ambitions: to create a synergistic whole of the research councils and to create a system of advice and governance that would aid the political system. At the time, the reform was presented as the most important reform in Norwegian research policy ever (Skoie 2005). The intentions were laudable, to enhance the interplay between research fields and to strengthen science policy analysis and advice, but unfortunately the merger and the laudable ambitions were accompanied by a de facto funding reduction. This caused internal strains and hampered the ambitions to use the merged structure as a vehicle of modernization (Technopolis 2001). Hence, the first comprehensive reform of the funding system did not in itself have any significant effects on Norwegian research organization.

A string of evaluations conducted in the 1990s and around the millennium shift confirmed the view of Norwegian research as highly varied in quality with some notable strongholds but also surprisingly many weak areas and environments (cf. the evaluation of research in biology in 2000 [a] and similar evaluations in, for instance, physics, and biomedicine done at the same time [e.g. Research Council Norway 2000b]).

Partially as a response to this, Norwegian research policy changed direction after the 1990s, breaking its tradition of piecemeal reform often driven and fuelled by sectoral concerns. It did so with a hesitant start marked primarily by rhetorical changes and with relatively limited impact on research conditions. A surge of reforms began in the late 1990s, and the combination of a financial expansion and organizational change underpinned the positive development of

Norwegian research since 1995, moving rapidly from levels well below the world average (both as means and top 10 per cent citations) to reach a level just above the world average. However, a few issues remained unresolved despite a decade of reforms: one was addressed by the Hernes commission and concerned academic leadership. The other, which the Grøholt commission addressed was the autonomy of RCN and its leeway in supporting innovative lines of research beyond short- or medium-term sectoral interests. Both resurfaced in the coming decade and remain key issues today.

THE CURRENT SITUATION – ACHIEVEMENTS AND CHALLENGES

If the 1990s were a mixture of research policy priorities and of several expectations not met in practice, the picture has become more clear-cut in the last decade. The most important change was financial: the inception of the 'fund for research and renewal' in 1999, which gave Norwegian research a massive injection of funding, and in practice the reformed council (after Technopolis' evaluation in 2001) a fresh start, something the 'old' RCN never got.

The fund made several important reforms possible: it gave RCN more leeway and decreased to some extent its dependence on appropriations from the sectoral ministries. It underpinned programmes for the national priority areas for research (health and medicine, ICT, environment-energy and marine biology) that had been identified in the 1998-99 research bill. It funded infrastructural programmes for genomics and materials research. Another element in the modernization of Norwegian research system that emerged beyond the boundaries of the reformed RCN was the notion to support 'excellent environments' (SFF) for research and 'outstanding young investigators' (YFF). These first appeared in the 1999 research bill (presented by the Bondevik II Government), and after deliberations done by RCN, 13 SFF centres were incepted in 2002, and 26 young investigators were supported in 2004. The motive being that 'elite' and 'excellence' had been demoted in Norwegian funding. Enhanced international orientation and improved recruitment were key goals (Aksnes et al 2012).

The three research bills of the decade followed the same path. The ambitious bill in 2004 launched the revamped RCN in conjunction with large-scale programmes for the national priorities. In addition, the bill presented a string of proposals: national graduate schools to propel the quality of PhDs (five such schools were incepted), a hike in the number of post-doctoral positions, a tenure track position with 4-6 years before a tenure position, strengthened academic leadership with more financial clout. Several of these proposals, including the post-doctoral position and strengthened leadership, were for unclear reasons later dropped in the political process. The bill also proposed a system of monitoring publication pattern and with rewards based on the 'Norwegian model' of publication typologies. In addition, it outlined a division of labour between RCN and the universities, which gave RCN the responsibility for larger endeavors and the universities the primary responsibility for smaller operations. It, finally, set a quantitative goal: Norway should spend three per cent of GDP on research and development by 2010. It also addressed the structural imbalance between 16 ministries interacting with one national funding agency but afforded no panacea – indeed embracing the sectoral principle – although its priorities all spoke in favor of a 'protected space' for high-quality research and for a strengthened steering core within the academic system.

The 2004 bill is one of the most ambitious of Norwegian research bills, and its diagnosis of the quality deficiencies of Norwegian research, as well as suggestions for reforms to enhance the standing of Norwegian research, striking. Hence, there is no lack of political will to state the problems and suggest reforms; what is even more striking is that relatively little has happened since and that the 'veto points' of the system seem to be so manifold as to impede the reform drive.

The 2009 bill was an in-between bill with little of substance added and much more engagement and eloquence when it came to sectoral priorities. What it did embrace was a system where the RCN could actually influence the activities and quality of the research institutes, introducing a

performance based system for resource allocations, which is still in place. It also suggested, in rather general terms, that the quality of research should be strengthened, and that the research system should 'function well', that it should be international in orientation and use resources efficiently. This laid the basis for the Fagerberg commission (NOU 2011:6), appointed to investigate the economics of science but ending up pursuing a much broader discussion of the conditions for research in Norway. Its many proposals did not fit the policy climate in Norway and received criticism from many quarters. Among these was the establishment of a large pool of resources for investigator-led research within RCN (in line with a similar proposal from the Walløe commission 1999 appointed by the Royal Society of Science and Letters). The Fagerberg commission's main proposal was a massive hike in funding within the open competitive arena of RCN (the current FRIPRO programme), estimated at 2 billion NOK, to be covered by reductions in programme funding.

This line has been important in Norwegian policy debates. It has been taken up in several research evaluations (for instance in Research Council Norway 2011). The Royal Society of Science and Letters returned with inputs to the policy debate, in both 2004 and 2008, along these lines, arguing for in particular the need to increase funding of free basic research based on peer reviewed grant proposals formulated by individual researches in order to balance the present strong emphasis on more or less top-down initiated programs and networks. The Academy also argued for a stronger bottom-up influence from the scientific community on the priorities set by the RCN and that top-down initiatives should be broadly defined in order to attract different disciplinary perspectives. In addition, the Academy emphasized the need of putting a stronger emphasis on the documented performance of the applicant(s) when deciding on funding programmes and projects, and that core funding should be provided to scientists who actively publish. It identified a need to further develop the use of publication statistics ("tellekantsystemet") in setting allocation priorities. The Academy recognized the positive role of the SFF programmes but it emphasized the need to work out a model for embedment after ten year of operation in order not to jeopardize the need for disciplinary pluralism in the faculties. The academic leadership must be strengthened and made more attractive for leading scientists and a career system with tenure track must be established, which notably also is suggested in the latest research bill to the parliament.

Both the Fagerberg commission's report and the Academy reports proved difficult to absorb and transform into political action. In particular, the Fagerberg commission's analysis of the functioning of Norwegian research and research policy as being too uncompetitive, insular and driven by sectoral concerns was met with bitter resistance.

As a result of the political stalemate, the 2013 bill ended up being unsurprising, but did receive much attention for its proposal to develop 10 year plans for research and, in particular, the inception of a 4-6 year assistant professorship with tenure track in collaboration between RCN and the universities. The end-result was again a compromise and an alignment of different interests: the universities had expressed repeatedly that they had seen their action space delimited (Handlingsromsutvalget 2010), while the perception outside the universities was that money had been spread too evenly and that external funding programmes could not substitute for internal strategies and resource transfers. However, if the two goals set are actually realized – a long-term plan for research that is not the sum of the priorities of 16 sectoral ministries but rather a national plan, as well as a comprehensive career system where all positions are part of a 'tenure track', Norway will most likely be on the path towards higher international visibility. The coming years are therefore crucial for the quality of Norwegian research and the international standing of its universities.

The structure of Norwegian university system

A process had been underway all the way since 1988 (the Hernes commission) regarding the structure of the Norwegian higher education system. Its growth and proliferation had its own dynamic, driven by regional concerns and a national plan to spread educational (and indirectly, scientific) resources throughout the country. The Hernes commission laid the basis for a reduction of this complexity and opened up for discussions and debates on the governance of Norway's universities more generally.

The Ryssdal commission from 2004 took up the issue of academic leadership and paved the way for a strengthening of the leadership core, allowing universities to employ rather than elect rectors and backing the rectors with predominantly external boards to reduce internal pressures. Both the commission and the ensuing bill painted a clear picture of reform needs in academic leadership, but did not discuss issues of recruitment, power and authority in daily decisions in more detail. Rather, it signaled the need for enhanced governance mechanisms. The Stjernø commission (reported in 2008) in its turn addressed the structural composition along the lines of the Hernes commission, and functioned as a prolonged arm of the government's desire to reduce the number of higher education institutions in the country. It may have overstepped this confidence when it made the drastic suggestion to reduce the number of universities and university colleges to around 10. It also pondered on the question of whether Norway should cultivate one or a few 'elite universities' of international stature, but left the question open. Its proposals were toned down in the ensuing bill, which instead stressed that mergers and partnerships should be orchestrated by the universities and university colleges themselves rather than as parts of a master plan.

The 2013 bill devoted an entire chapter to the issue of research quality, arguing that this was a remaining weak issue and that it hampered Norwegian global networking, and the international attractiveness of Norwegian universities. It made a bold aspiration, namely to develop one or two globally leading research environments 'which can score highly in international rankings'. However, the measures to reach this goal were left largely open, for the RCN and the universities to determine.

To sum up, policy debates increasingly confront the structural problems of Norwegian research, but it has rejected radical redeployments of resources, or for that matter radical proposals to elevate a few universities to elite (international) status (Stjernø commission), or proposals to strengthen academic leadership (as in the RCN evaluations). The related issue of the basic appropriations to the Norwegian universities, its composition and connection to activity and quality, has also been discussed in several circumstances (e.g. the Stjernø Commission, NOU 2008:3). This includes studies of the basic appropriations to universities (cf. Vagstad 2007). All of this activity notwithstanding, we find few examples of a consorted stance towards enhancing quality. While much knowledge and wisdom has been afforded various investigations, we find only scant evidence of a coherent practical approach to quality and renewal in Norwegian research.

University governance – does it impede quality?

Norway's universities maintain many elements similar to those of the high-scoring countries: well-funded universities (around 70 per cent floor funding, according to the government's calculations, based on OECD statistics cited in Research bill 2013), supported by a similarly well-endowed research council and with attractive positions (comprising a minimum of 50 per cent research). However, the end result is less impressive and counters the examples of Denmark, Netherlands and Switzerland. How can we explain this?

Reforms in funding had an immense impact on the visibility of Norwegian research. Such changes were, however, largely decoupled from university governance. It began already with the reform of the career system in 1993, which emphasized conditions at the 'top' of the career (promotion to professor) but not at all the conditions at the beginning of an academic career, which was largely left untouched and relegated to short-term contracts.

Changes in the structure of education have also played in. The 'quality reform' in 2002 aligned Norwegian undergraduate education with the Bologna process and transformed it into a 3+2+3 year model. It was widely feared to hollow out the positions as associate and full professor, swamping university professor's time with educational tasks and turning research into an extra activity. While an evaluation concluded that the relationship had not been altogether altered, it also concluded that teaching is a major part of the tasks of Norwegian faculty, a situation that was not alleviated by the reform (Mathiesen 2006). This blocks the time available for research to Norwegian faculty. In fact, it appears to us as if a majority of tenured staff emphasizes education at the expense of competitive research aiming for ground-breaking results. Although the focus is on research in the present study we want to make the general comment that the relatively weak departmental governance and fragmented academic communities that we see from the perspective of research probably also affect teaching negatively. An excellent academic environment wishes to excel in both, in a productive collaboration between the two.

While the universities seem generally to acknowledge the 'quality problem', the remedy, in particular as it is exercised by the government and Research Council Norway, seemed not to address the quality breadth but rather its edge. We found a two-pronged approach: to identify and support top scientists and to aid them the competition for funding at the Research Council, the EU and the European Research Council, and secondly to raise the level of activity among 'underperformers' through publication statistics and pecuniary rewards. We find that university leadership reacts somewhat mechanically to external impetus, and does not address the wider qualities and preconditions of their departmental environments, or aim to stimulate and nurture a quality culture within and between academic environments. The research system seems to be composed of a relatively small number of 'flagships' amidst relatively weak environments, however, where the 'minimum level' has been raised. This observation is corroborated by international evaluations (e.g. Research Council Norway 2011) and by our bibliometrical analysis, which shows that Norway has the smallest fraction of 'high-performers' among the nations studied. The remedy, should one be searching for that, is probably to implement more systematic measures to enhance collaboration and interaction at the level of departments, and not delegate this to the Research Council or any other external force. With a floor funding of 70%, the universities should be able to prioritize its resources and take control of its quality development, including resource redeployments according to quality differences. We found very limited evidence of such reallocations; resources seemed more or less fixed with deans, department heads and rectors responding incrementally to the financial blockages.

In addition, the significant increase in the number of positions as associate professor and full professor has been met with a general decrease in core funding at the level of departments and faculties. Until the 1990s, when permanent positions were relatively scarce (and full professorships even more so), positions were accommodated with a modicum of extra resources. As already mentioned, the number of very small and underfunded groups seems to be quite high, and in some instances comprising the majority of faculties and departments, again with some contrasting examples of concentration of resources and staff. Hence, the relatively generous employment conditions are not translated into real opportunities of performing innovative research. There seems in particular to be a lack in support in-between the small-scale opportunities offered by the universities and the large-scale operations that are funded via Research Council programmes or by EU funding. This gap seems to have had a negative effect on a large cadre of Norwegian scholars (seen in low application rates to the Research Council), compounded by the aforementioned hollowing-out of their guaranteed research time.

In addition, the number of temporary positions has increased, assessed to be around 20 per cent of all staff employed at the universities and university colleges, despite pledges to reduce the number (Michelsen et al. 2006: 60, Rindal et al 2011). The current rules state that an employee cannot be temporary employed for more than four years after which he or she will be considered permanently employed. This figure most likely includes young scholars with insecure employment conditions, who would be better served by a stringent recruitment policy at the level of faculties and departments rather than today's reliance on external funding via project and programme grants, where considerations of future employment are not being made.

Hopeful signs are emerging, including the ongoing collaboration between the Research Council and the universities in appointing tenure track positions for six years. To be efficient, these need to be comprehensive and cover the main part of all recruitments, and be connected to other positions to create a tenure track system. While we found evidence of the awareness of open and competitive tenure track positions, we also found evidence of routine-shaped – primarily educational-driven – recruitments, and a similar lax stance towards promotions. It seemed clear that recruitment issues are not yet at the top of Norwegian universities' agenda, and the same applies for issues of internal quality assessments or strategic redeployment of resources at the level of faculties or departments. We instead found several instances of routine-based behavior and a close monitoring of Research Council announcements as the main strategic action. There are, however, some differences between the universities, where some appeared much more dedicated to strategic resource deployment and others more conservative in this respect. We interpret this as a need for external impetus for universities to better take charge of their own quality development in research.

Policy formation challenges

Norway has a highly inventive research council, which runs a large number of schemes to stimulate activities, ranging from long-term support to short-term operations, but its reach is limited and its organizational creativity may create more confusion and imitation than innovative thinking among universities. The organizational creativity is in itself an effect of the fact that the 'unified' council in reality operates almost 200 programmes, each with its own board, four divisions, also each with a board, and one main board (and 17 patrons). The top-down steering is conspicuous to an external viewer, and excellence at the highest level, which is the focus of this study, appears often to be blended with other interests.

Universities in Norway are on their side (like in Sweden) confronted with multidimensional expectations, more so than in the more successful countries in our earlier study (Öquist & Benner 2012). Permanent faculty has relatively generous conditions, including the right to promotion and the right to 50 per cent research in the positions. Both seem difficult to remold although attempts are made to enhance productivity (tellekantsystemet). Universities raise concerns over a delimited space for action, with resources locked in, ever growing educational remits, and a search for external support which is, as mentioned, flexible and constantly transformed. This perceived lack of control may seem paradoxical, given the share of resources controlled by the universities themselves (among the highest among the countries involved in the comparative study at 70 per cent), but is a reflection of the relative 'poverty' at the departmental level, where funding is tied primarily to positions and where only a fraction of university researchers receive substantial additional funding. In addition, the system of allocating floor funding is cumbersome and does not fully address the conditions for functional units.

This can be compared with Denmark, the Netherlands and in particular Switzerland, where a limited number of tenured faculty are embedded in resourceful environments and where they can be relatively secure of receiving additional support from external funders, but where they on the other hand are also embedded in a highly competitive environment where most if not all faculty are high-performers and where academic leaders take full responsibility for the academic standing of 'their' units. This could be an example for Norway to emulate, but it would take reforms at several levels: at the policy system, for the Research Council and for university governance.

One explanation of the relatively weak conditions for Norwegian research is that university growth has primarily been driven by educational expansion, circumscribing the available time for research. In addition, rising administrative burdens seems to have delimited the space for Norwegian faculty more generally (Handlingsromsutvalget 2011). Increases in research resources have primarily been earmarked and under-funded, for (very generously supported) PhD positions among other things. The expansion of PhD training seems to have increased the productivity of Norwegian research, propelled the introduction of more structured PhD programmes, and in effect doubled the number of PhD exams over a decade. It has however absorbed much resources and has not been met with a concomitant increase in funding of supervision (Thune et al. 2012). Furthermore, a PhD programme is in itself not necessarily a driver of high quality since a PhD thesis cannot take up too difficult and challenging questions without jeopardizing the exam within the stipulated timeframe.

The end result of all this is somewhat of a stalemate, where hikes in university funding have been accompanied with increasing task complexity. The political system has responded to this both by being selective and by putting a lid on public expenditure to avoid swamping what it perceives as a somewhat dysfunctional research system. The decision to close down the fund for research and renewal (Forskningsfondet) which had been run by the Research Council, and instead channel the money via the state budget, is a memento – trust in the research system and its patrons is more delimitated than, for instance, in Switzerland or in the Netherlands. We sensed a similar hesitancy of the ministry, voicing concerns of the system's efficiency but not relying on the actor's capacity for absorbing more resources. This misalignment of interests calls for a reshaping of research policy formation. The introduction of long-term research plans is one step. What may be needed in addition is a forum for advice and consultation – with international inputs – to better steer a system with many patrons but limited overall

responsibility. The commission currently addressing coordination (KUF-kommiteen) seems not to have been sufficiently strong to have any impact on the sectoral fragmentation of Norwegian research policy or the inchoate focus on quality and renewal. Furthermore, there seems to be a lack of change agents. The investigations, bills and evaluations that we have digested all show a capacity for analysis but an inability to move from diagnosis to remedy. The time should be ripe for a resurrection of the bold heritage of the Hernes commission, which marked the beginning of a renovation of Norwegian research policy.

The future of research funding

In its 'return to the deed', the most recent Technopolis evaluation argued that the basic outline and working of Research Council Norway (RCN) had been overall effective (Technopolis 2012). The evaluation – which in it self is an evaluation of the recommendations that the same organization made in 2001– is somewhat bland. In all fairness, evaluating RCN is not an easy task as it is a constantly evolving combination of tasks and assignments. RCN's resource allocation is a mixture of programme support (large-scale programmes and policy-oriented programmes) and non-thematic schemes (FRIPRO, SFF, etc.). Project support was the dominant funding model until the early 1990s, whereas the unified council has primarily operated via programme support, even though adjustments have been made in recent years. Arguably, programme support also covers investigator-led projects (Sohlberg et al 2008).

All available evidence suggests that RCN has developed into a functional 'spider in the web' of Norwegian research and indeed an agency which both universities and the political system put a lot of trust and belief in. After a tumultuous and hesitant start in 1990s, the expectations on and capacity of the council seems to have aligned with adjustments made in the most recent reorganization in 2010.

RCN has developed a pragmatic approach to a wide variety of challenges, including a renewed interest in career positions for younger scholars and measures to enhance strategic planning within the Norwegian universities (for instance by co-funding career positions, devising tenure track career paths, augmenting the FRIPRO programmes via co-funding from universities, etc.). Nonetheless, a funding agency cannot be a systemic manager but has to rely on a well-endowed and functional university system. We see a considerable risk for 'over-streching' and 'over-planning' of RCN, where programmes are too many and too complex, intended to serve too many purposes with the risk of diluting quality demands. Apart from expecting programme committees to prioritize scientific quality and operate with a large share of international experts, the RCN should focus its efforts on roles and functions that universities cannot fulfill themselves and in aligning societal demands with strict scientific goals. In these respects, lessons can be learnt from the Swiss and Dutch systems, where their funders balance between different goals in a highly efficient way, primarily by running a delimited set of programmes and by pursuing an absolute line when it comes to the scientific credibility of funded projects. Our anecdotal evidence suggests that this is not always the case, at least not consistently.

If sectoral programmes are run with more stringent demands, and if funding for investigator-led projects was more widely available, we foresee a higher degree of risk-taking in Norwegian research. This was also acknowledged as one of the lacunae of Norwegian research by the Technopolis evaluation: A 'good council' cannot supersede internal planning, quality control and risk-taking within the universities. The evaluation pointed at the lack of risk taking in Norwegian research and that RCN had failed in this respect. However, the evaluation was rather silent on the interplay between RCN and the universities in driving and promoting

innovative research. In our perception, a combination of relatively weak and constrained universities with a very active and ambitious research council does not enable bold research attempts. Universities seem to adapt rather passively to the main bulk of RCN initiatives, which in its turn reinforces the planning efforts of RCN. This is most likely detrimental for both, and measures to enhance a productive interaction between universities and the research council are urgently needed.

One aspect that lies beyond the remit of RCN is the relative lack of private funding, complementing the public purse. Norwegian private fortunes have been invested in prestigious prizes and awards rather than in developing an infrastructure for high-risk research (like the Wellcome Trust in the UK, Howard Hughes foundation in the US, Knut and Alice Wallenberg foundation in Sweden, etc.). There are exceptions to this rule (such as Bergens forskningsstiftelse), but they are too few and too limited in their scale and scope to enhance the pluralism of Norwegian research governance. Norway should welcome more private foundations like the three recently established with seats in Bergen since their strong focus on scientific quality can be a driver to enhance the competitive performance of Norwegian universities.

One aspect that the RCN could address is to streamline and re-structure its research programmes and to systematically elevate the issue of scientific quality control (compare the 'Top-sectors' in the Netherlands, where this is a basic criteria). Even though these programmes have become far fewer over time (well over 300 at the beginning of the 1990s, now around half that figure), the focus on RCN's programme initiatives, and tactical adaptations to them, seems to have a negative impact on aspirations and boldness in the Norwegian research environments. It has also been pointed at in earlier exercises that these programmes tend to cater to more 'appropriate' interests, hampering innovative lines of research as well as adventurous innovation ideas (Solberg et al. 2009 and the ensuing evaluations of FUGE and NANOMAT).

We have already mentioned the 'success stories' of SFF and YFF in addressing and highlighting top scholars of different ages. The support of investigator-initiated projects, FRIPRO, is also generally considered a 'success' in pinpointing original smaller research undertakings. However, with its low success rate it seems less adept at sustaining strong institutional settings and does not appear to have major effects on university strategies (NIFU 2012). An expansion of FRIPRO to better balance the numerous strategic programmes is most likely needed but such an adjustment may not be a panacea to the system-wide quality slack that we have identified as the key challenge to Norwegian research governance. The same holds for the other proposals that have been afforded, like establishing a new funding channel for basic research or the proposal to massively expand the funding of investigator-led research (as argued by the Fagerberg commission). Without universities taking control of their research systems based on the sufficient floor funding, there is a risk that Norway will follow the path of Sweden and Finland, where projects function as the main unit of academic activity and where universities are reduced to 'research hotels' for scientists without any overarching significant measures of leadership or quality control.

Running, on the one hand, sectoral programmes with clear-cut quality criteria defined and operated by balanced panels (with a large share of non-Norwegians), and a growing portion of investigator-led projects could streamline and propel the role of RCN as a driver of research quality and of renewal and experiments in knowledge creation. This cannot, however, occur if academic leadership of universities is not strengthened at the same time, both in terms of its

authority and its scientific legitimacy to prioritize resources to foster scientific quality of high international standard.

SUGGESTIONS FOR IMPROVEMENTS

Before we conclude and afford a few suggestions to reform Norwegian research governance, let us reiterate some of the findings of our earlier studies on the factors that support and sustain high-impact research.

A first element behind high and consistent scientific visibility is a policy system which operates with clear-cut goals and consistent expectations of scientific quality, and where the health and standing of the nation's research environments are central concerns across the political spectrum. The successful systems combine intra-scientific and sectoral goals and have developed models where sectoral concerns are filtered through demanding quality expectations. Systems of policy advice vary, from elaborate in the Netherlands to rudimentary in Switzerland, but both countries safeguard the status of internationally oriented, quality-conscious universities and pinpoints quality as their overarching goals. They never compromise on scientific quality defined by international benchmarking and expect their universities to challenge current orthodoxies and lead the knowledge frontier.

For university governance, a key 'success factor' of leading universities is leadership appointment, highlighting their academic credibility and plans for the universities, with distinct academic missions and roles, but also how they couple authority with resources. University leadership is seen as a 'chain' where leaders at the university level carefully select and entrust deans (and centre leaders), and where deans in their turn carefully select department chairs and give them adequate authority to set goals and priorities. There is a clear-cut focus on quality, with recruitment high on the agenda. University leadership is strongly concerned with the circulation of people and ideas, and with the recurrent revamping of activities to stay ahead in the competition for funding, reputation and recruitments. Successful universities are led by strong academic scholars with visions and with the legitimacy to lead (Goodall 2009).

Quality and renewal is also critically dependent on the conditions for scientific faculty. The more successful research systems have maintained, despite increasing resource competition, a 'protected space' for faculty to pursue independent research lines under the aegis of resourceful environments, but also to foster interesting and innovative combinations of research lines. Combined with ruthless quality auditing organized by the universities themselves, this has created a 'productive tension' between faculty and formal leadership and organizational structures. In parallel, the successful systems have transparent and durable models for establishing, monitoring, cultivating and – if deemed necessary – terminating activities in departments and centres.

International recruitment is another key element for successful research systems: their institutions pursue open recruitment strategies and place a premium on mobility and circulation of people and ideas. Their recruitment and promotion systems are coupled with rigorous evaluations, and mobility is therefore used as a vehicle for variation. Furthermore, an increasingly international market for top recruitments (at all levels, from assistant to full professor levels) requires the provision of competitive start-up packages.

The division of labour between funders and universities is another critical issue for the successful development of research system. Ideally, external funding complements university strategies and trigger university quality work, but does not substitute the quality control of the universities, nor does it take over the responsibility for recruiting and promoting academic staff. Funders therefore trigger and propel the quality culture as exercised in collegial, quality-conscious, arenas. This is done in a number of ways, where funding instruments are deployed to instigate new thinking, experiments, and bold behavior. This calls for a productive relationship between funders and universities, where universities are capable of setting their own priorities and where funders act as driving forces and as change agents, but not as substitute managers.

Some conclusions and issues for discussion

Here, we list some recommendations and concluding observations, based on a comparison between the 'success elements' listed above, and the characteristics of the Norwegian research system as we have understood them.

Overarching policy level: The policy system should enhance coordination and reduce the current fragmentation of governance. Goals of quality and renewal should be set centrally and imposed on both funders and universities. Once such a goal is set, it can be combined with sectoral priorities, as the Dutch case ('TOP-sectors') shows, but it is important for any nation to cultivate funders and universities that strive to true scientific excellence set by international benchmarks. This is not (yet) the case in Norway, even though it has been on the political agenda in over two decades.

RCN: we see the need for a streamlining of RCN's activities, entailing a more logical and transparent organization of its funding: fewer and more general support schemes, organized according to goals such as mobility, quality enhancement, broadened sectoral goals rather than the current jumble of aims. This would be an important step towards enhancing the top-level quality of Norwegian research. It is of particular importance that sectorial programs with perceived high relevance for Norway are filtered through a rigorous scientific quality control shaped by the highest international standards and ambitions. This seems not always to be the case, which over time undermines scientific quality and the credibility of Norwegian research.

Furthermore, the scientific community in Norway (as well as a string of research evaluations) has repeatedly argued for more resources for investigator-initiated proposals. There is definitely room for such increases, but it must be done in tandem with universities taking more and better control of their own quality enhancement. FRIPRO and similar schemes cannot substitute for this.

University: Another important bottleneck for Norwegian research quality seems to reside in university organization, academic leadership and the functioning of its basic units. Policies in the last decade have elevated a small group of eminent scholars and environments, but universities overall 'underperform'. Resources seem not to be deployed productively with large fractions of research conducted in small circumstances, primarily aiding teaching and not engaging in cutting-edge issues.

While a funding agency of the size and capacity of the RCN may address the issue of a general underperformance of Norwegian research, the daily operations of a research system should be

the responsibility of the universities. Evaluations in the early 2000s highlighted the predominance of small groups, which hampered concerted efforts and directed much – if not all – of Norwegian research into research lines with too limited ambitions. Nothing indicates that this situation has improved much the last decade, although there is evidence of departmental mergers into potentially more interactive environments. Unlike Denmark, Switzerland and the Netherlands, where basic funding function as a springboard for ambitious research plans, and where research council funding functions as a competitive add-on, many scholars and groups seem to rely solely on relatively small financial bases and do not match this with additional support from RCN or other funding sources.

Furthermore, the selection and recruitment of academic staff seems to be both routinized and unsystematic. Mobility is limited and the route to a full professorship seems to be both too short and too bound to the local environment. There is no clear evidence that there is a dedicated stance towards academic quality and renewal when universities recruit and promote their faculty. International recruitments are few and sometimes poorly embedded. The Norwegian career system could therefore be transformed to enhance the focus on path-breaking qualities.

Such a change does not seem impossible. Norway maintains fully funded academic positions, which include a guaranteed research quota and therefore has a foundation to build competitive positions for national and international mobility. However, unlike Denmark, the Netherlands and Switzerland, Norway has not invested in efficient internal mechanisms to enhance the quality of the environments in which these positions operate. It has reinforced the virtue of publications, via the system of measuring publications and (indirectly) encouraging publication activity in general and internationally renowned avenues in particular. This may have increased productivity but does according to our bibliometric analysis not influence the level of high impact publications. This does not seem to change the pattern of a stark contrast between a small group of 'high performers' and a large group of faculty with limited visibility. The estimation that only about 20 per cent of Norwegian tenured faculty apply for funding from RCN is a warning signal and an indication of a mismatch between positions on the one hand and research opportunities (including funding) on the other. This showcases the importance of the local academic culture, which sustains a focus on competitive research programmes.

Academic leadership is also rather varied. On a central university level, we found evidence of a stark variation in governance styles, from the proactive to the incremental. Many universities have schemes for monitoring research activity and rewarding productivity and visibility, most likely triggered by the "tellekant" system, but less energy is devoted to strategies to develop focused research agendas of international cutting edge. The recruitment of deans and heads of departments, as well as the mandate and financial resources delegated to them, seemed weak in most cases and we found few indications of strategic planning at these levels. To sum up: if Norwegian universities and scholars are to excel internationally, a culture of quality and boldness needs to be instigated, and this can only come from the universities themselves.

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APPENDIX

THE PRODUCTION OF HIGHLY CITED PAPERS

THE PRODUCTION OF HIGHLY CITED PAPERS

Tables and graphs from the report "The Swedish production of highly cited papers"[1] complemented with statistics for Norway

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1 Vetenskapsrådets lilla rapportserie 5:2012, Dnr 354-2012-6898.

1. CONTENTS

1. SUMMARY

Based on bibliometric analyses of scientific publications in international journals from Finland, Denmark, Norway, the Netherlands, Sweden and Switzerland, the six countries can be arranged into one group performing very well internationally (Denmark, the Netherlands, Switzerland) and one group performing at a lower level but still above world average (Finland, Norway, Sweden). This is apparent both when we consider mean citation rates and the production of highly cited papers (mainly among top 10 % in the world production). Furthermore, in the high performing group of countries, the positive development of the high impact publications is clearly above that of mean citation rates, while in the lower performing group the two measures follow each other closely. When looking at the development in the Nordic countries after 1990, Denmark and Norway stand out by having the fastest increases in citation impact. Norway, however, starts at a much lower citation rate (20 % below world average) than Denmark (on world average) resulting in Denmark being 35 % and Norway 7 % above world average in 2011. Corresponding 2011 figures for Finland and Sweden are 7 % and 15%. It is also noticeable that the rates of both highly cited and mean citations peak at around 2005 in Norway.

In all countries compared, the percentage of papers never referred to three years after publication range between 25 % and 30 %. Finland and Norway are at the upper and Denmark at the lower end of the figures. When we look at the level of international collaboration on publications, the figures are quite similar for compared countries with the exception of Switzerland showing the highest level of collaboration.

When breaking down the publication profiles into subject fields, Norway stands out by showing the largest activity spread with an exceptionally high activity in the Geosciences, 2.3 times above world average. However, this high activity is not linked to a particularly high impact. Furthermore, the subject fields Chemistry, Physics and Material Sciences show relatively low activities in Norway and performing at world average when it comes to impact. Taken together, Finland, Norway and Sweden have relatively few subject fields performing with high impact, while Denmark, the Netherlands and Switzerland have 3 to 4 times more subject fields performing at this level. Furthermore, the high performing countries have much fewer subject fields performing below world average than the low performing countries. When we look at the degree of interdisciplinarity, there are only marginal differences between the countries but again, interdisciplinary publications from Finland, Norway and Sweden show a lower impact than interdisciplinary publications from Denmark, the Netherlands and Switzerland.

Finland, Norway and Sweden also perform less well than Denmark, the Netherlands and Switzerland when it comes to being cited in high impact journals. It is interesting to notice that when it comes to citation impact, Sweden scores at the bottom when prestigious journals like Nature, PNAS and Science are considered. Norway, on the other hand, scores lowest by volume in Medicine in these journals but it scores highest when the top 10% citation index is considered. The relatively modest publication impact performance of Finland, Norway and Sweden is also clear when we compare at the institutional level. The majority of institutions centre around the world impact average as revealed by the top 10% index, while most research institution in Denmark, the Netherlands and Switzerland are well above world average. Finland and Norway score lowest in this comparison.

There are no major difference in national self-citation rate, i.e., citations from colleagues in the own country, to all publications (national and international) between compared countries although Norway scores highest (10.5%) and Denmark lowest (8.8%) among the Nordic countries. If we just consider

national citation to national publications Norway and Switzerland show the lowest values. The bibliometric statistics also show that self-citations to national publications have decreased in all countries after 1989.

If we take a look at the fraction of top scoring scientists in a country when it comes to publication impact, Finland and Norway are at the bottom, Sweden is intermediate and Denmark, the Netherlands and Switzerland at the top. However, when we look at recruitment of scientists to the top-performing fraction, Norway has been quite successful well in line with Denmark and the Netherlands while Finland and Sweden are at the bottom of this comparison. Switzerland scores highest. The reason behind this positive recruitment trend in Norway is most likely due to a rapid expansion of the research sector as indicated by the increased volume of publications and publishing authors. If we look at recruitments of young scientists for the last years it is however clear that again Finland, Norway and Sweden do have a lower recruitment rate of high performing scientists than the other three countries.

Thus, it is clear from the compiled publication performance that among the Nordic countries only Denmark rank as high as the Netherlands and Switzerland, all approaching the level of the United States. Finland and Norway, but also Sweden, are clearly behind this top group, although still performing above world average (number 12, 13 and 7, respectively, in the world ranking).

2. TERMINOLOGY AND METHODOLOGY

The analysis is restricted to articles and reviews[2] By "highly cited" or the "top 10 %"- publications we refer to those cited higher than the 90th citation percentile (P90) using a three year citation window. P90 is calculated for each year, type of publication (article or review) and subject field separately. Thus papers in subject fields with low mean citation rates have the same probability to be included as papers in more highly cited fields. Similarly, articles are as likely to be included as the more highly cited reviews. To be included in the highly cited group, a paper must receive at least one citation more than the 90th percentile. Therefore, less than 10 % of all papers are included in the group. The exact number varies between years, subject fields and type of publication, but in most cases the group consists of 8-9 % of all publications. In order to more easily compare and interpret the proportion of highly cited publications, this is taken into account by normalizing the number calculated for a country relative to the fraction of the world production (i.e. the entire database) in the same subject field, year and publication type. Thus, a country that has the same proportion highly cited papers as the world obtains the value 1 and e.g. 1.1 means that the value is 10 % higher than world average (analogous to the field normalized citation rate described below). This normalized value is called *top 10%-index*. In a few cases, corresponding statistics for papers among the top 1 % or top 0.1 % in the world are presented.

The publications not included in the top 10 % group, i.e. all publications cited at the 90th percentile or less, are called *base publications*.

All citation statistics are based on a three year citation window and self-citations[3] have been removed. Further, the citations are field normalized meaning that the world (database) average citation rate is 1 for each subject field, year and type of publication. A field normalized value of e.g. 1.2 means that the value is 20 % higher than world average. Correspondingly a value of 0.9 means 10 % lower than world average. The top-10 %-index is interpreted in the same way.

Statistics are calculated for different subject fields using two different groupings. The most detailed subject classification in the database is the journal subject fields defined by the database producer Thomson Reuters. Currently 251 subject fields are in use. Each journal issue is assigned one or several (up to 6) subject fields[4]. These fields are in most cases aggregated into 13 SPRU-fields. Publications in multidisciplinary journals, such as Nature and Science, are reclassified based on the subject profile of cited and citing publications.

[2] Here the publication types *letter* and *note* are included in the *article* type

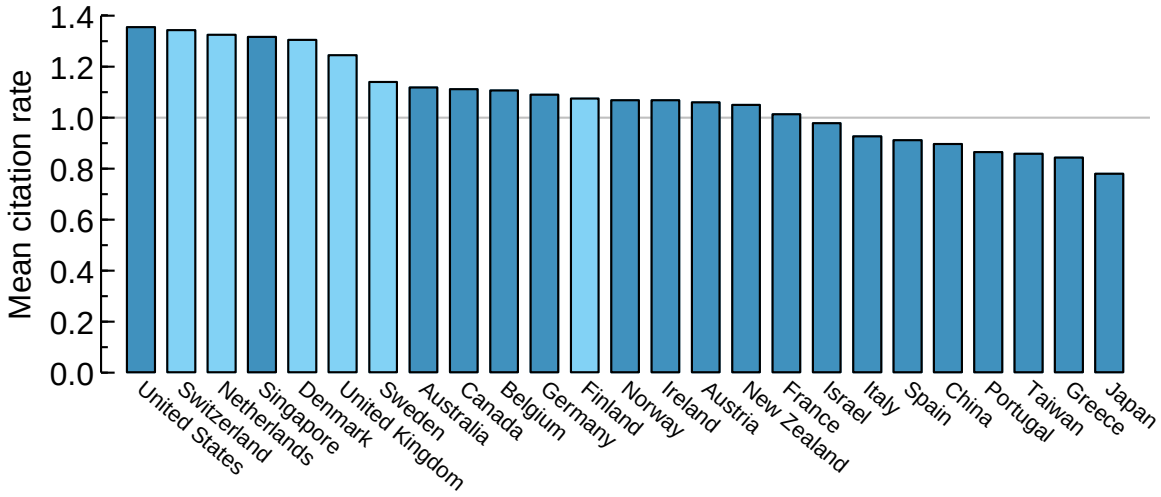
[3] Citations where the same last name and initials is found among the authors in both cited and citing paper.

[4] These groups were first defined by SPRU at University of Sussex. The SPRU classification consisted of 14 groups. Since the publications in the "other" group mainly consist of papers in multidisciplinary journals which to a large extent have been reclassified into others fields in the database at the Swedish Research council, this group has been omitted in this report.

3. GLOBAL OVERVIEW

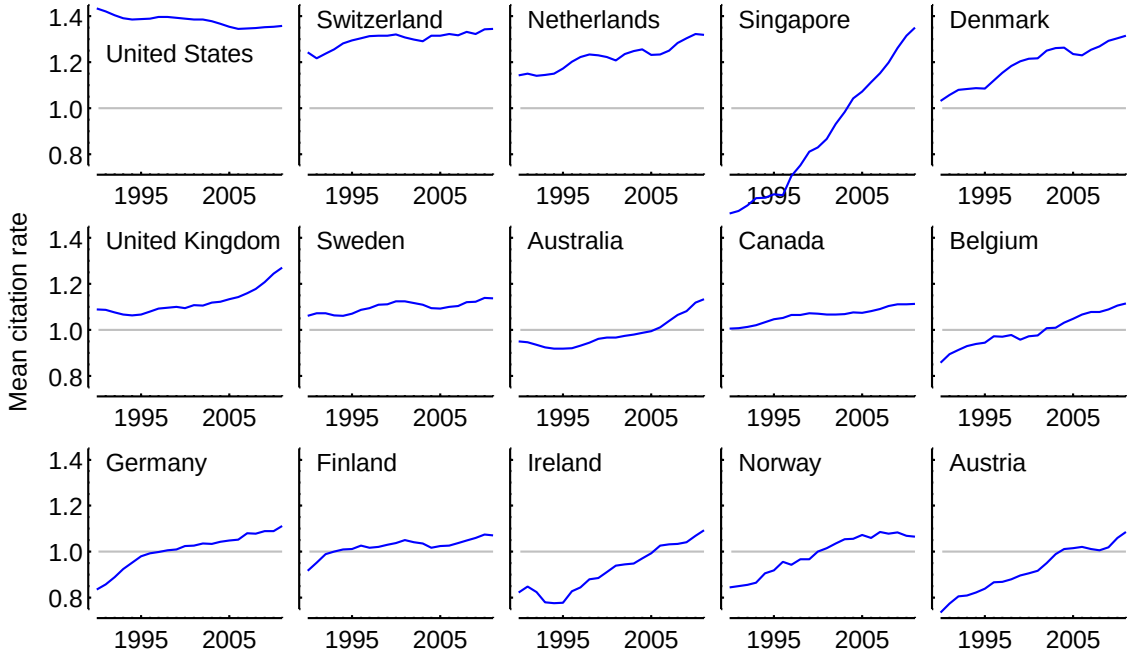
A global ranking of national mean citation rates (figure 3.2) show one quite distinct top group with five countries. This group is followed by the United Kingdom and then a large group of countries with small differences. Norway is found on the 7th posistion in this group and on rank position 13, The mean citation rate for Norway was during this period (2009-2011) 1.07, to compare with 1.35 for the United States, 1.30 for Denmark, 1.14 for Sweden and 1.07 for Finland.

Figure 3.2 The 25 countries with highest mean field normalized citation rate 2009-2011 among the 39 countries with at least 4000 publications per year. The countries in particular focus of this report are marked in a lighter shade of blue. (Data from Science Citation Index - Thomson Reuters).



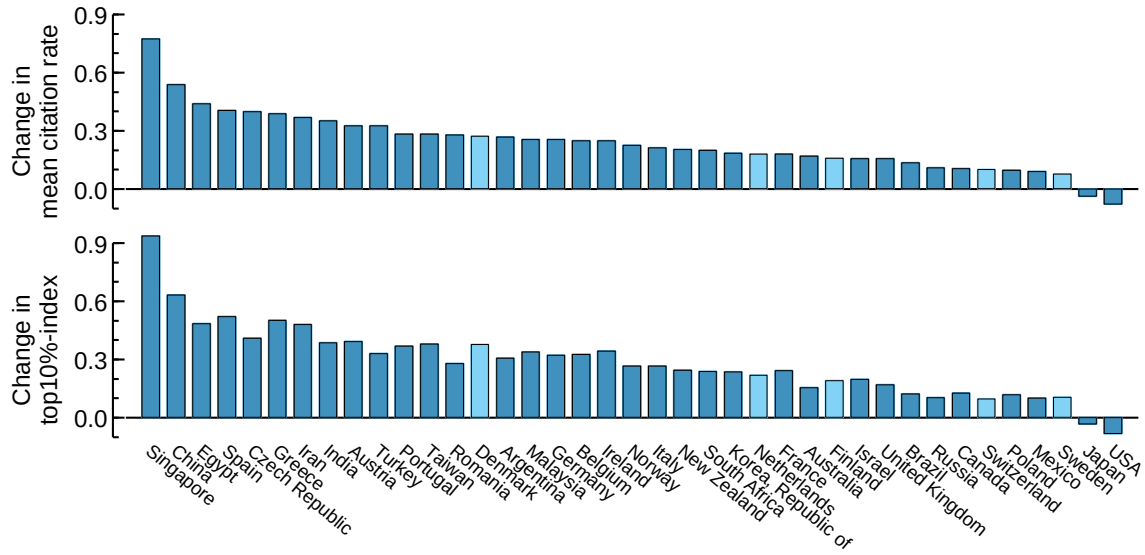
Norway shows a positive development of the national average from the early 1990's to 2005 (Figure 3.3). After that, the Norwegian curve has been relatively flat. In a Nordic comparison, Denmark shows the strongest development, but starting from a low value in 1990. The increase in mean citation rate for Norway has been larger than that of Finland or Sweden. Figure 3.4 summarises the change shown in figure 3.3.

Figure 3.3 Trend of mean citation rate between 1990 and 2011 for fifteen of the currently most highly cited countries according to figure 3.2. (Data from Science Citation Index - Thomson Reuters).



Due to the positive trend for Norway, as compared to Finland and Sweden, during the first fifteen of the twenty years studied, Norway is ranked second among the Nordic countries when presenting the statistics in terms of the total change in national mean citation rate or top 10%-index (Figure 3.4)

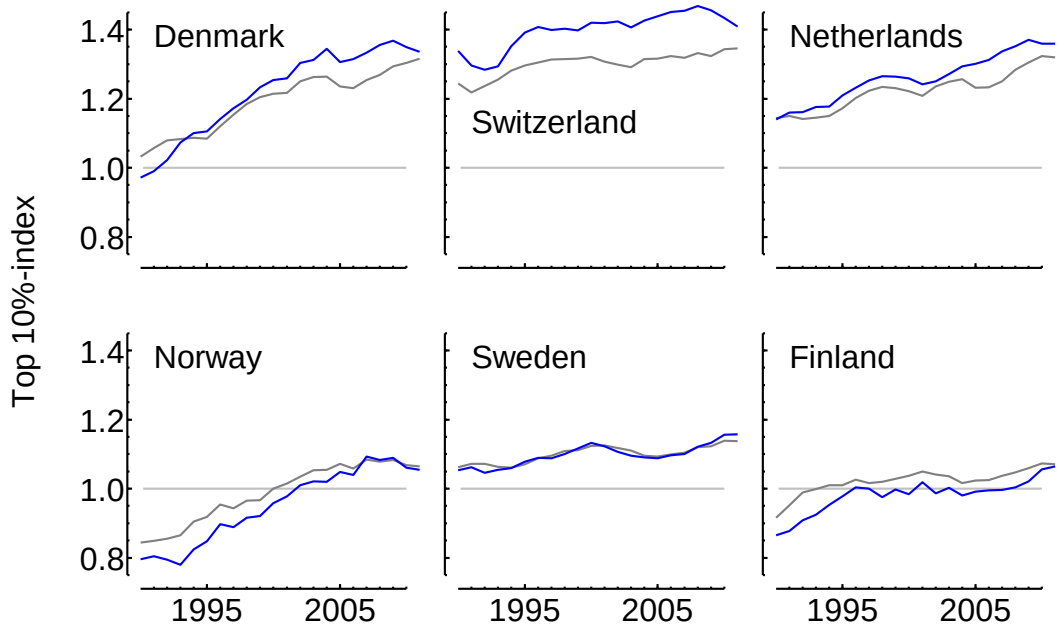
Figure 3.4 Change in mean citation rate between 1989-1991 and 2009-2011. The selection of countries is limited to the 39 countries in the world with an annual output of at least 4000 publications during the later period. (Data from Science Citation Index - Thomson Reuters).



4. THE PRODUCTION OF HIGHLY CITED AND NOT CITED PUBLICATIONS DURING THE LAST 20 YEARS

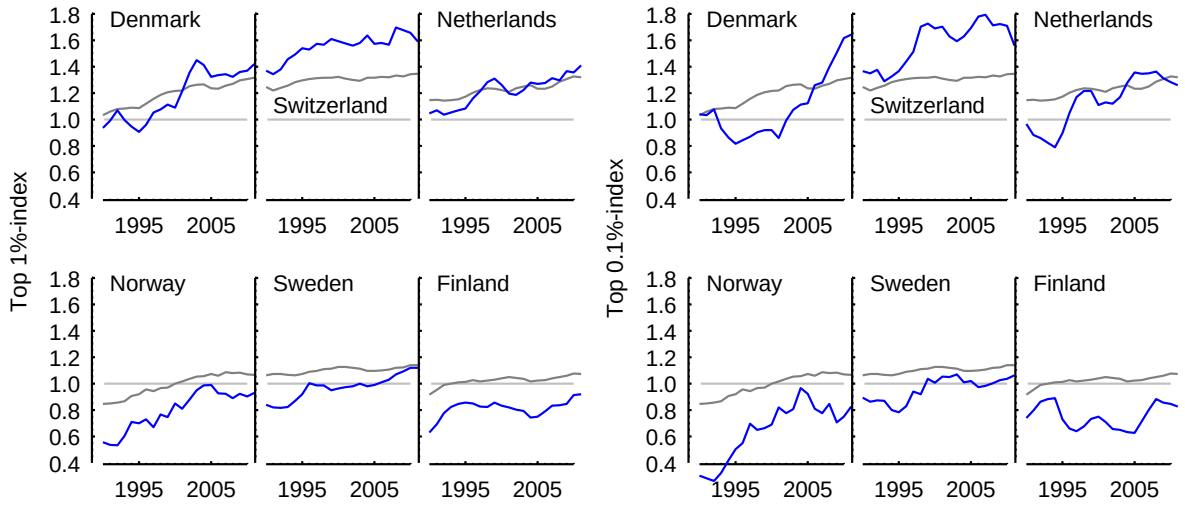
In the early 1990's, Norway had a low proportion of highly cited papers (Figure 4.1, blue line), also in comparison with the national mean citation rate (grey line). Since then the proportion highly cited papers has come up to the level of the mean citation rate. Both measures have stagnated during the last years

Figure 4.1 Development of the top 10 %-index between 1990 and 2011 for Sweden and the five reference countries. For comparison the national mean citation rate is shown as a grey curve and the grey horizontal line (with a value of one) shows the world average. The curves are based on 3-year moving averages. (Data from Science Citation Index - Thomson Reuters).



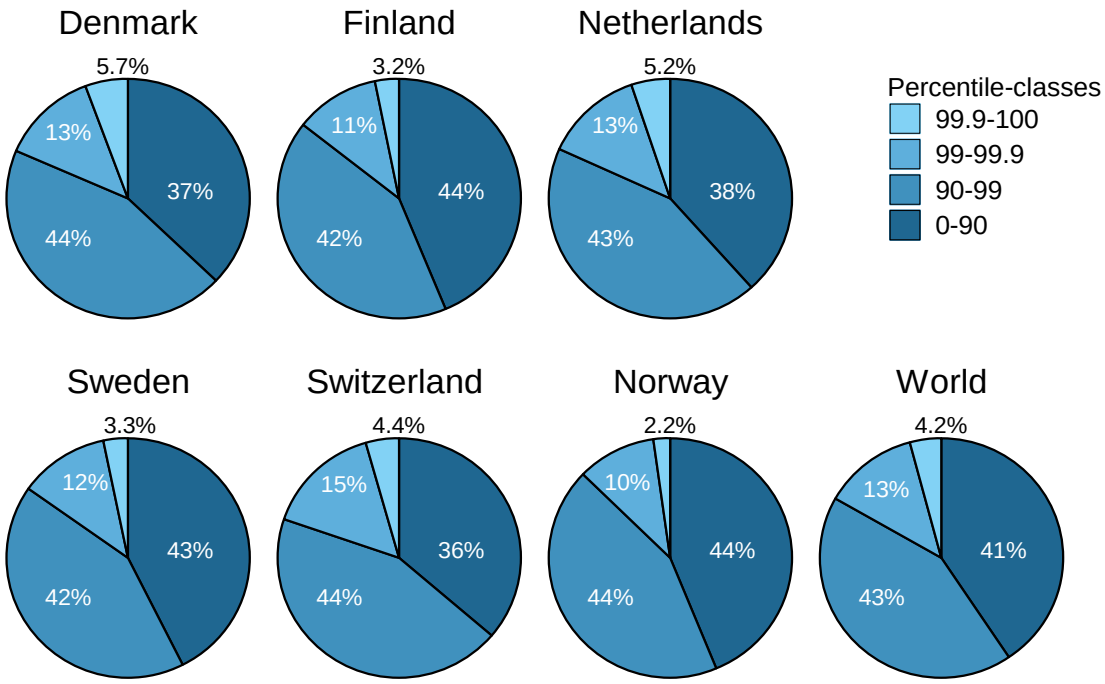
The Norwegian development of the very highly cited publications (top 1 % and top 0.1 %) is weaker than that for the top 10%-papers (Figure 4.2). Both indices are in 2011 still below the mean citation index and below world average.

Figure 4.2 Development of the top 1 %-index and 0.1 %-index between 1990 and 2011 for Sweden and the five reference countries. For comparison is the national mean citation rate shown as a grey curve and the grey horizontal line (at 1) shows the world average. The top 1 %-index curves are based on 3-year moving averages while the 0.1 %-index curves are based on 5-year moving averages. (Data from Science Citation Index - Thomson Reuters).



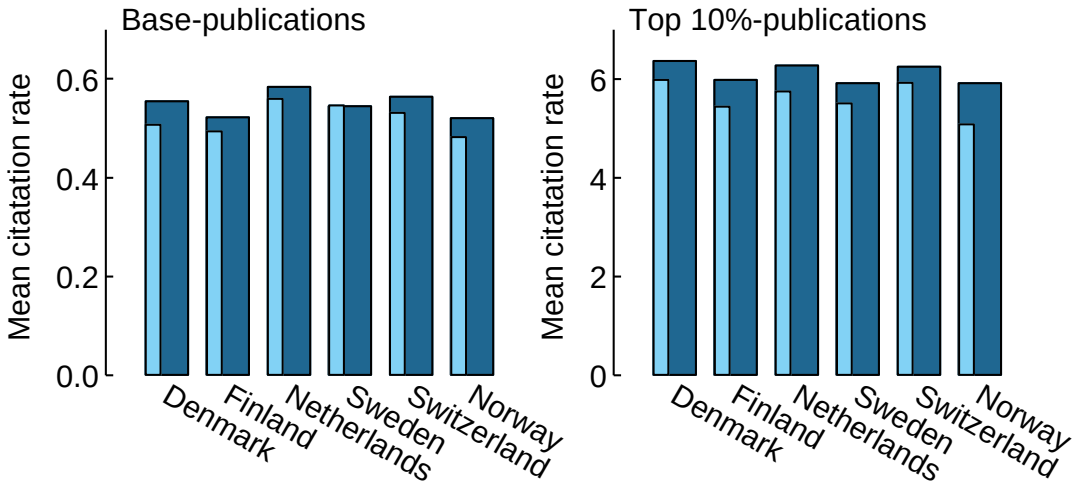
In parallel with the relatively low indices for very highly cited papers for Norway in Figure 4.2, these papers also contribute with a lower proportion of all citations received by Norway than for any of the compared countries (Figure 4.3); top 1 %-papers contribute with 12,2 % of all citations to Norwegian papers. Corresponding number for Finland is 14,2 %, for Sweden 15,3 % and for Denmark, the Netherlands and Switzerland in the range of 18-19%.

Figure 4.3 Contribution of different percentile-classes to all citations. (Data from Science Citation Index - Thomson Reuters).



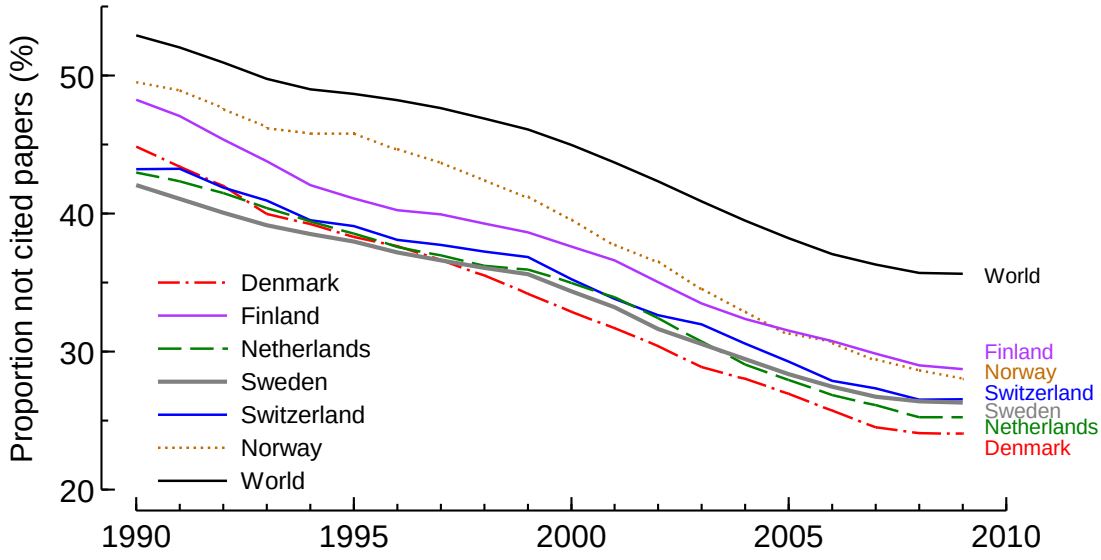
Comparing mean citation rates of the top 10% publications with the base publications (i.e. those cited less than the top 10%-papers; Figure 4.4), show that in all compared countries the mean citation rate is more than 10-fold higher for the top 10 %-papers as compared to the base publications. Furthermore, the relative differences among the countries are similar in both graphs. The relative improvement in the citation rate of the top 10% publications during the last twenty years (narrow inserted bars as compared to the wide, darker bars) was higher in Norway than in the other countries (a pattern indicated also in figure 4.1)

Figure 4.4 Mean field-normalized citation rate for the base and top 10 % publications. Wide bars show mean values for 2009-2011 and the narrow bars mean values for 1989-1991. (Data from Science Citation Index - Thomson Reuters).



In all countries, the proportion of papers never cited during the first three years after publication decreases markedly between 1990 and 2009 (Figure 4.5). For a large part of the studied period, Norway had the highest proportion of non-cited papers. During the last few years, this figure has declined more for Norway than for the other countries, and the numbers are now similar to those for Finland and approaching those for Switzerland and Sweden. During the last 10 years, Denmark shows the lowest proportion of non-cited papers.

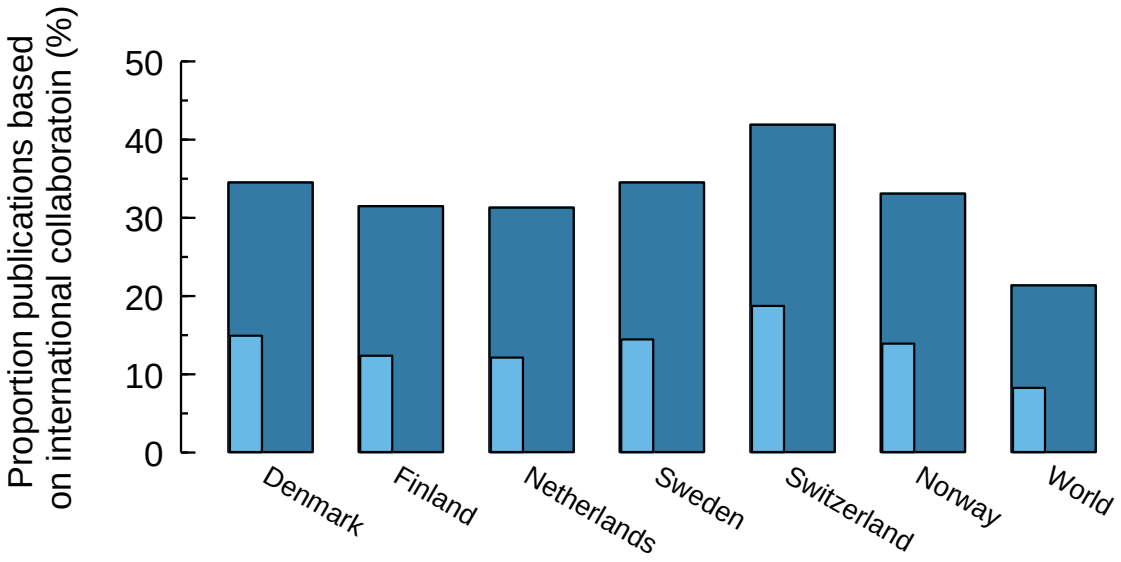
Figure 4.5 Proportion of the publications not receiving any citations during the first three years after publication. Three-year moving averages. (Data from Science Citation Index - Thomson Reuters).



5. COLLABORATION AND IMPACT

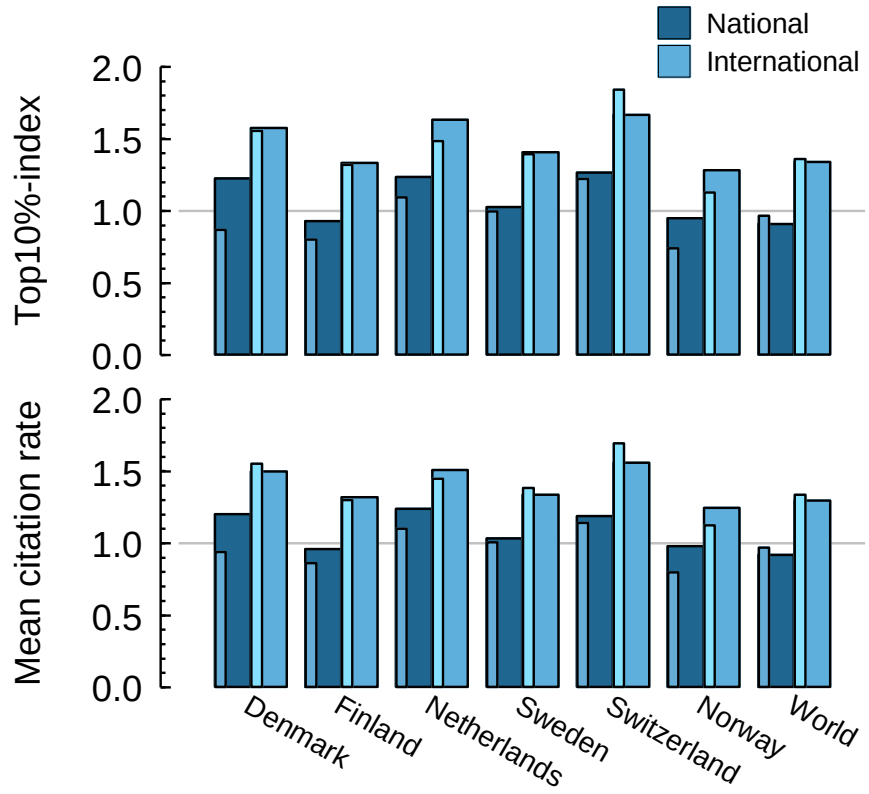
The proportion of publications based on international collaboration has increased substantially over the last twenty years (Figure 5.1). It is marginally lower for Norway (33 %) than for Sweden and Denmark (34%), while it is somewhat higher than for Finland (31%). Switzerland stands out by having the highest level of international collaboration among the six studied countries.

Figure 5.1. The proportion of publications based on international collaboration. Wide bars show mean values for 2009-2011 and the narrow bars means for 1989-1991. Based on fractionalised publications. (Data from Science Citation Index - Thomson Reuters).



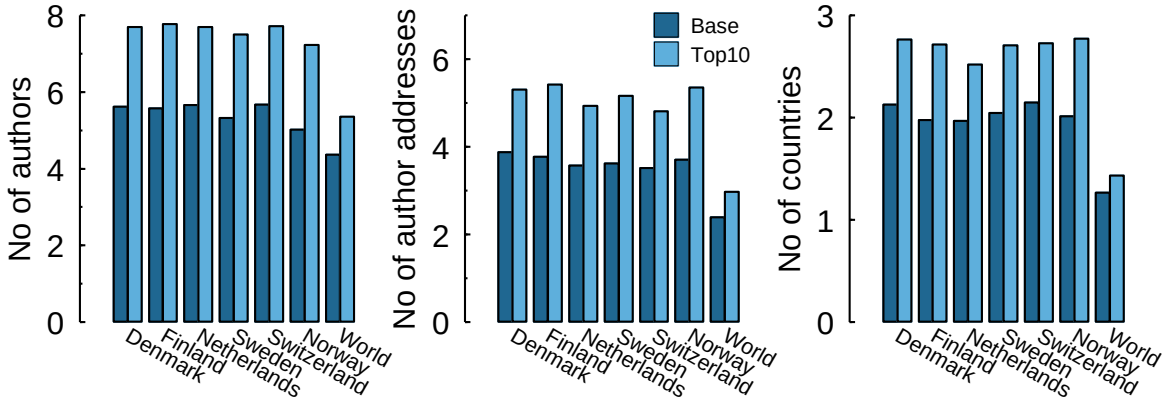
Publications based on international collaboration are in general more highly cited than publications where all authors represent the same country (Figure 5.2). For Norwegian publications, this collaboration effect is relatively small. Also Denmark and the Netherlands show relatively small differences between national and international papers, but for these countries the national publications are relatively highly cited.

Figure 5.2. Top10 %-index and mean citation rate for national and internationally co-authored publications. Wide bars show average for 2009-2011 and narrow bars 1989-1991. (Data from Science Citation Index - Thomson Reuters).



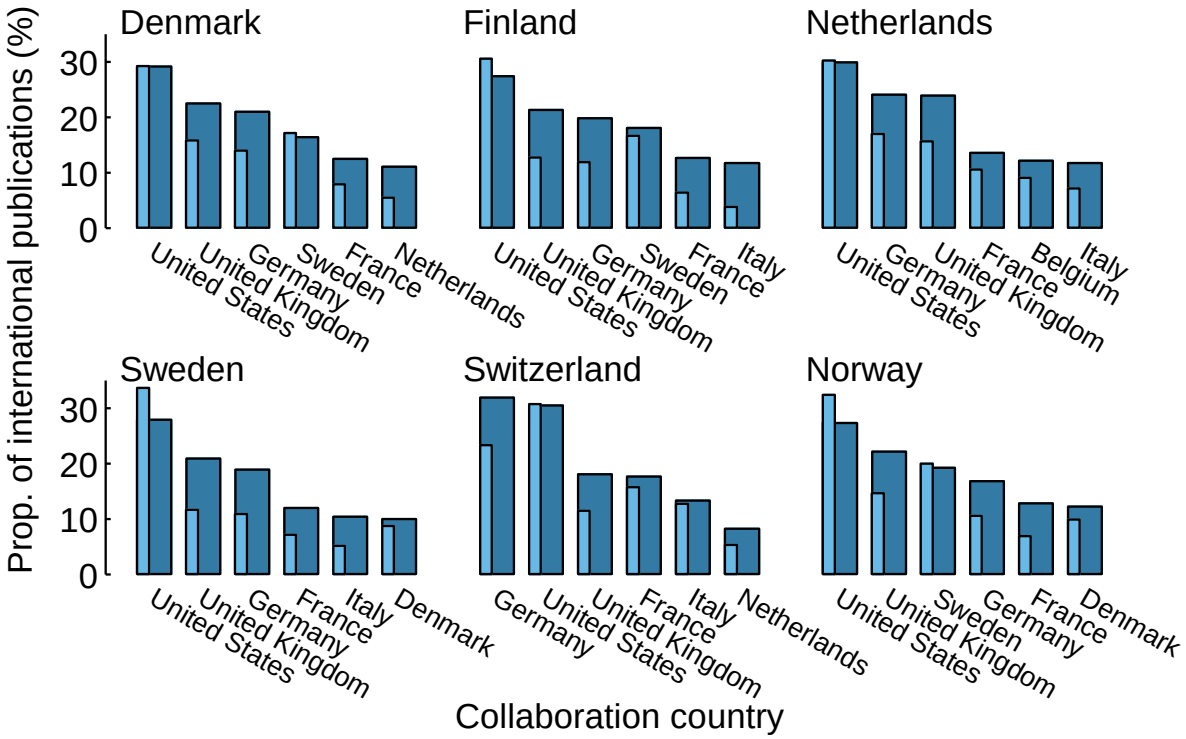
The degree of collaboration based on mean number of authors, author addresses or number of countries that the authors represent is higher for highly cited papers than for base publications (Figure 5.3). The differences among compared countries are relatively small.

Figure 5.3. Collaboration indices for base and top 10 %-publications. Base publications are those cited less than the top 10 %-publications. The statistics is based on publications with 50 authors or less. (Data from Science Citation Index - Thomson Reuters).



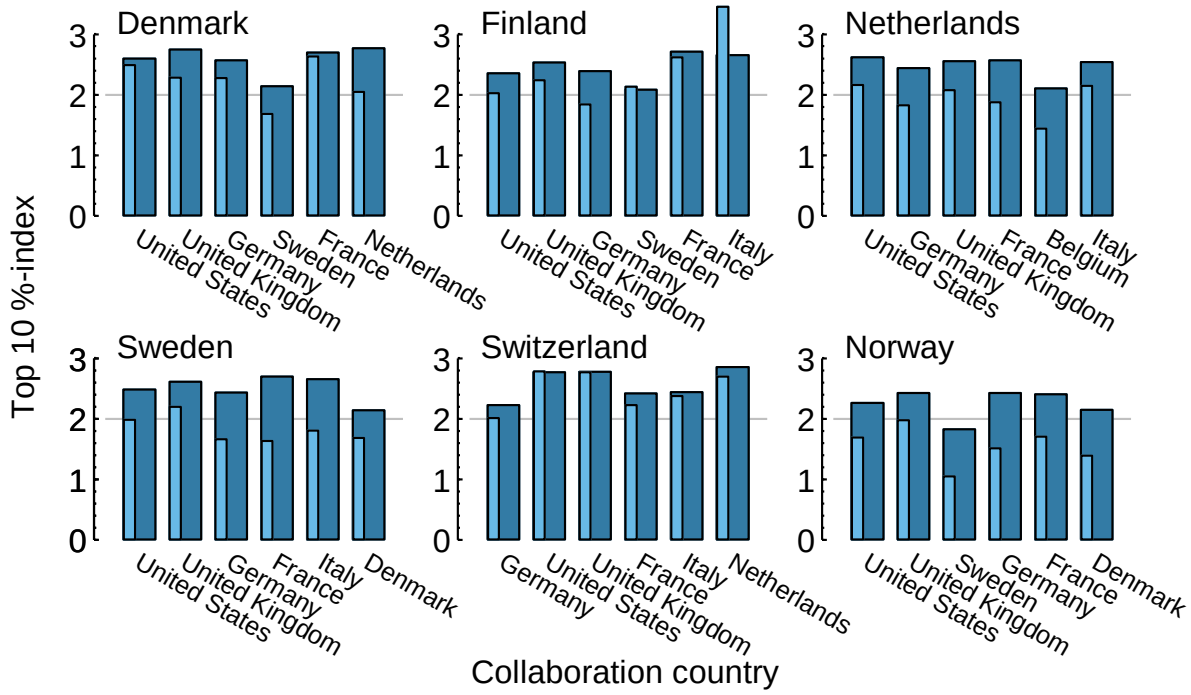
As for Sweden and Finland, Norway has increased the proportion of European collaborations after 1991 (Figure 5.4). At the same time, collaboration with the United States has decreased. Norway is the only Nordic country where two other Nordic countries are among the six most frequent collaboration partners. It is notable that both Denmark and Norway show a decreased collaboration with Sweden after 1991.

Figure 5.4. Most frequent collaboration countries. The wide, dark bars indicate mean for 2009-2011 and the narrow, lighter, bars indicate mean for 1989-1991. (Data from Science Citation Index - Thomson Reuters).



As can be seen in Figure 5.5, relatively few of the publications where Norwegian authors collaborate with Denmark, and in particular with Sweden, are highly cited. The most successful collaborations, in terms of the proportion of highly cited papers, are when Norway authors collaborate with the United Kingdom, Germany or France.

Figure 5.5. Proportion of highly cited publications among the publications produced in collaboration with the most frequent collaboration countries. The wide, dark bars indicate mean for 2009-2011 and the narrow, lighter, bars indicate mean for 1989-1991. The grey horizontal line is drawn in order to facilitate comparisons. (Data from Science Citation Index - Thomson Reuters).



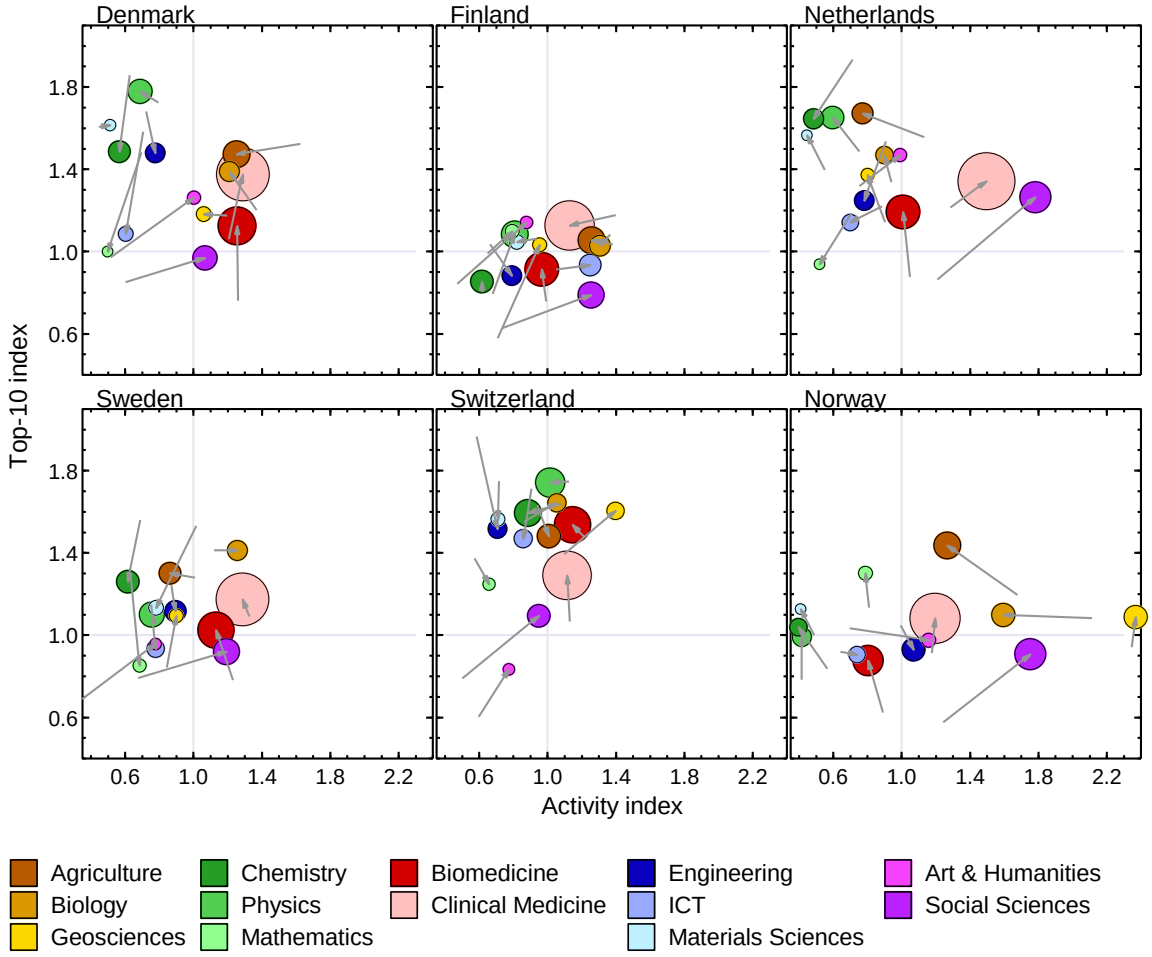
6. PERFORMANCE IN DIFFERENT SUBJECT FIELDS

All subject fields are included in this report. However, it is important to keep in mind that most of the publications for Arts and Humanities as well as for Social Sciences are **not included** in the database used for this report. In these fields other publication channels such as anthologies and books are more important than the international journals indexed in the database used. The prestige publications in these fields are often not found in the international journals. Further, in some technical fields, proceedings are an important publications channel. Proceedings are not yet included in the publication database at the Swedish Research Council.

The statistics presented here thus include publications in international scientific journals only, which is not representative for the entire output in the fields mentioned above. Further, the distribution of journal publications found in the database is skewed so that some fields are more frequently represented than others; for example, a relatively large fraction of the database publications in social sciences is in psychology and economics.

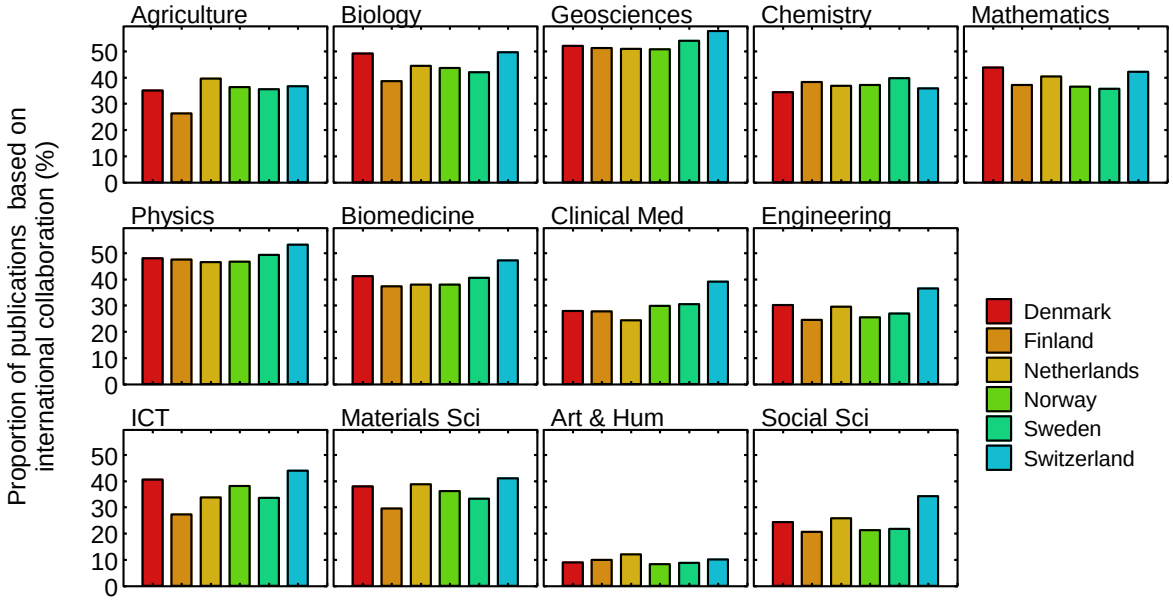
Norway shows a larger spread in Activity Index (the x-axis of Figure 6,1) than the other countries. Notable is the relatively high proportion of Geosciences, Social Sciences and Biology in Norway. The proportions of Chemistry Physics and Material Sciences are relatively low. The three largest fields have top 10-indices close to the world average of one (0.88 to 1.08). The fourth largest field according to the Activity Index, Agronomy, scores highest on the top 10-index (1.44) among the subject fields in Norway.

Figure 6.1. Activity index (the proportion of the national output of publications found in a particular field relative to the world database proportion) in relation to top 10 %-index. The colours of the circles indicate the subject field and circle size the number of publications produced. Grey arrows show the shift in position of the circles between two five year means (1997-2001 and 2007-2011). (Data from Science Citation Index - Thomson Reuters).



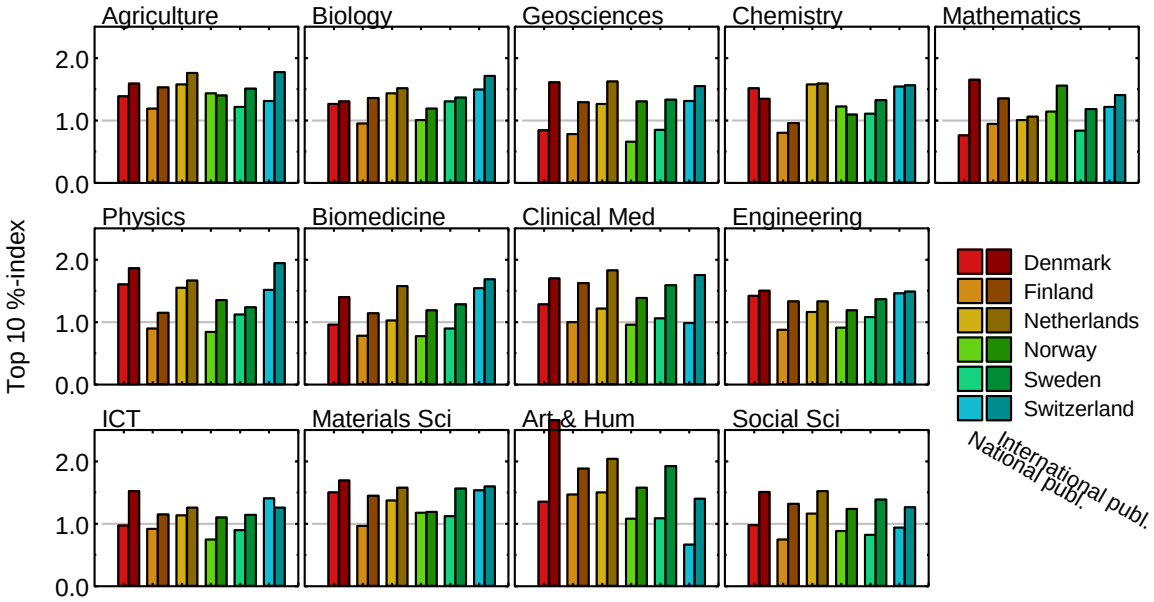
Although there are considerable differences in the proportion of papers produced in international collaboration among the different fields, there are small differences among the compared countries except for Switzerland which shows the highest international collaborations in most subject fields (Figure 6.2).

Figure 6.2. Proportion of the publications based on international collaboration in the different subject fields. Based on 2009-2011. ICT = Information and Communication Technology. (Data from Science Citation Index - Thomson Reuters).



When it comes to a comparison of the top 10% index for national and international publications in different subject fields (Figure 6.3) there is not all that much differences between countries except for Switzerland being at the top in most subject fields. Norway has a relatively high impact of national publications in Chemistry and Material Sciences and Denmark shows the strongest impact of publications with international collaborators in Arts & Humanities.

Figure 6.3. Comparison of the top 10 %-index calculated for each subject field. Left (lighter) bar is for national publications and right (darker) bar is for international publications. ICT = Information and Communication Technology. The grey horizontal line indicates world average. (Data from Science Citation Index - Thomson Reuters).



When analysing the data split into the ca 250 journal subject fields defined by Thomson Reuters (Table 6.1), the high impact statistics for Norway again is relatively similar to that of Sweden and Finland, i.e., there are few subject fields with a top 10-index above 1.5 (20 field) or above 2 (3 fields). It is also clear that Finland, Norway and Sweden sustain more low impact fields (Top 10%-index <0.8) than the Netherlands, Denmark and Switzerland.

Table 6.1. Number of subject fields where the country publishes at least 10 papers per year, the number of these fields that has low proportion top 10 %-publications. Entire table recalculated compared to the original report. (Data from Science Citation Index - Thomson Reuters).

Country	No of fields selected	No of subject fields where			Contribution to total national output of fields where	
		Top10%-index < 0.8	Top10%-index >1.5	Top10%-index > 2	Top10%-index >1.5	Top10%-index >2
Denmark	156	16	50	13	27%	6.7%
Finland	155	46	16	6	7%	2.7%
Netherlands	213	5	62	10	24%	2.7%
Norway	157	36	20	3	11%	1.1%
Sweden	190	34	30	5	11%	1.5%
Switzerland	181	17	74	13	48%	4.4%

7. INTERDISCIPLINARITY

An indication of the degree of interdisciplinarity of research (IDR) can be obtained from the spread of subject fields cited in the publications. Only marginal differences were found among the compared countries (Figures 7.1 to 7.3). However, highly cited papers have a higher IDR-index than lowly cited papers, but there is nothing indicating that research in highly cited countries is more interdisciplinary. However, in the case of interdisciplinarity publications, Finland, Norway and Sweden have a weaker impact than Denmark, the Netherlands and Switzerland (Figure 7.3).

Figure 7.1. Mean IDR-index for all publications from the compared countries. The wide, dark bars indicate mean for 2009-2011 and the narrow, lighter, bars indicate mean for 1989-1991. (Data from Science Citation Index - Thomson Reuters).

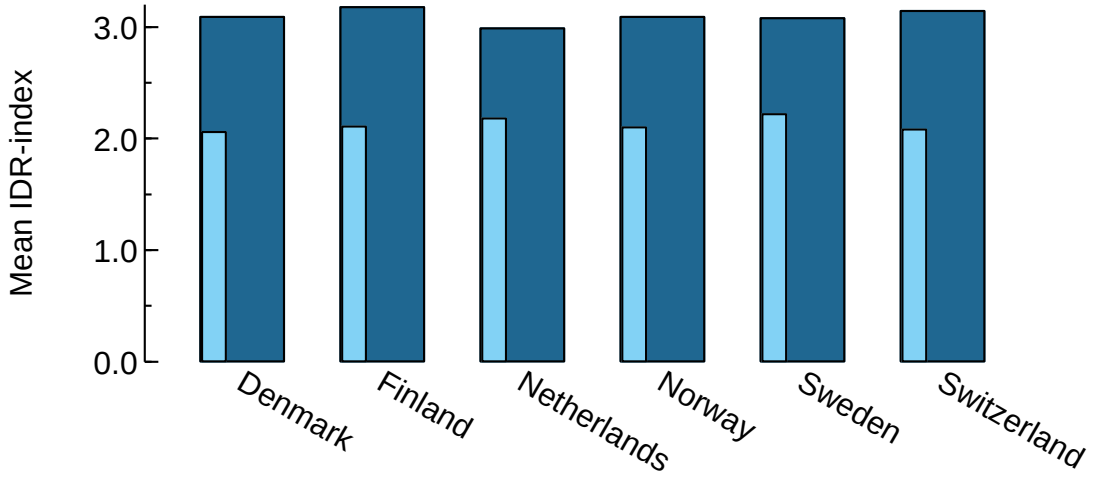


Figure 7.2. Frequency distribution of the national output on five classes of interdisciplinarity. (Data from Science Citation Index - Thomson Reuters).

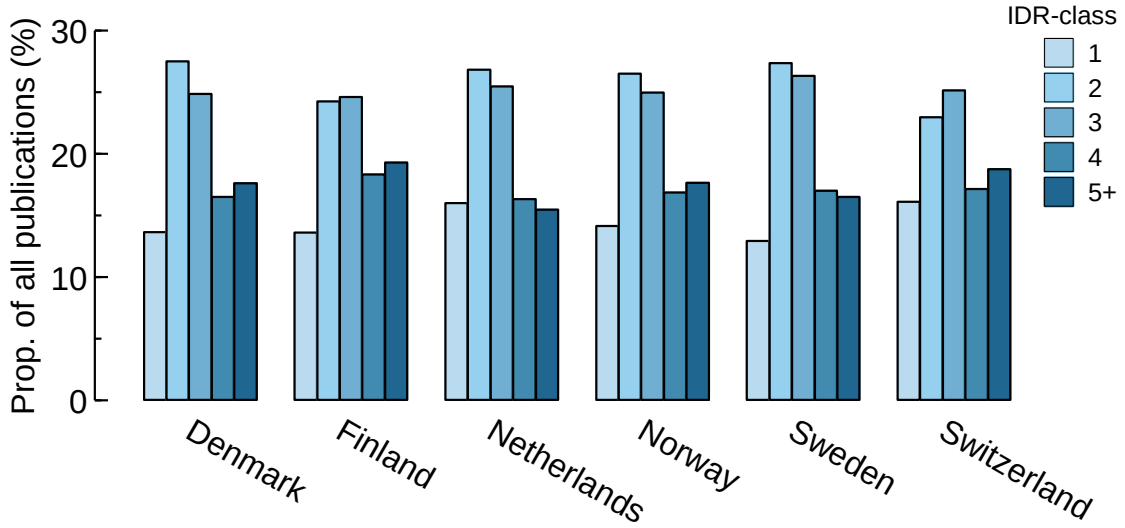
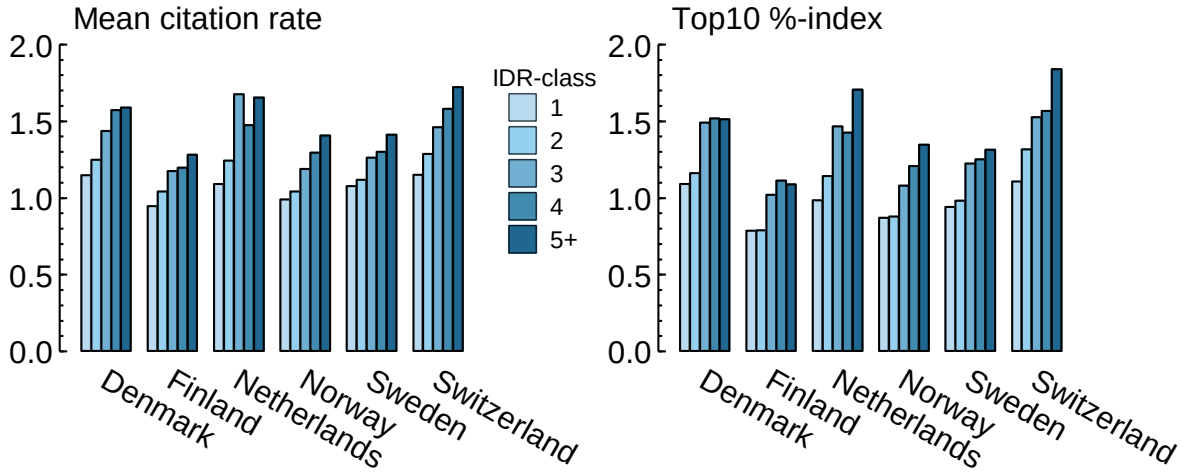


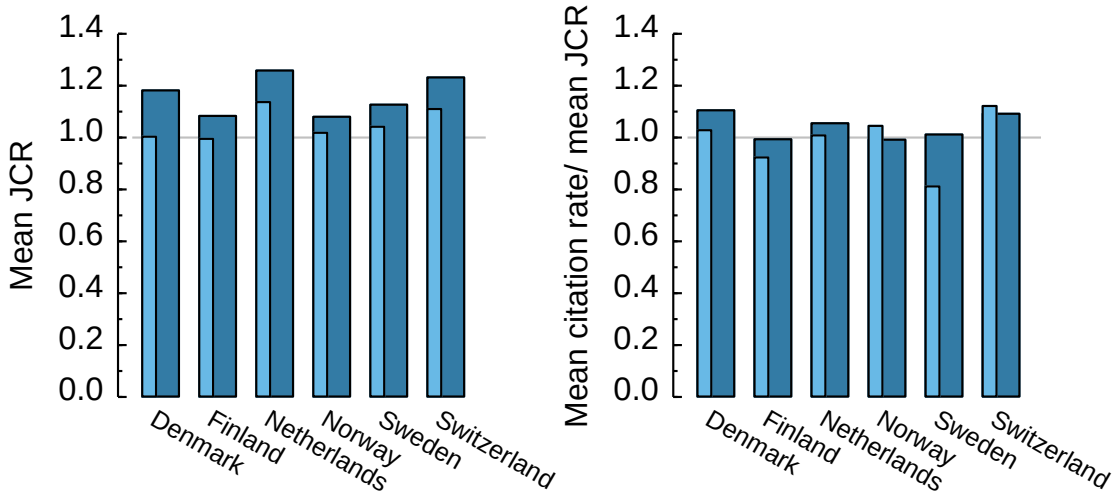
Figure 7.3. Mean field normalized citation rate and top 10 %-index for publications of different levels of interdisciplinarity. (Data from Science Citation Index - Thomson Reuters).



8. JOURNAL PRESTIGE

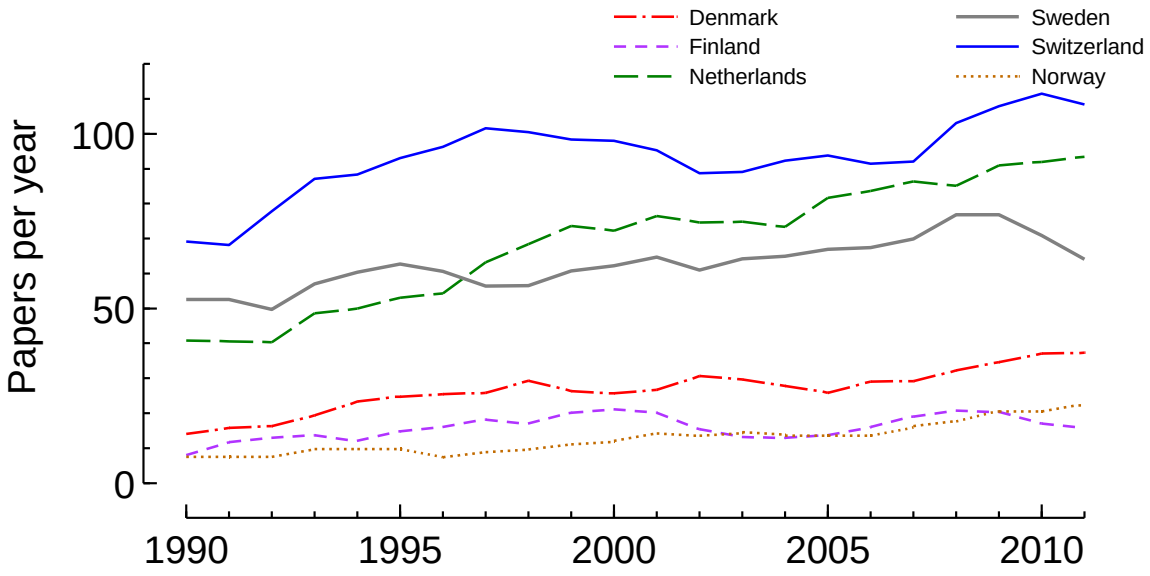
Among the compared countries, Norwegian papers are, on average, published in journals with relatively low impact (mean journal citation rate, JCR), a picture shared by Finland and also by Sweden. However, the actual citation rates of these papers are in parity with the journal average; thus the ratio between mean citation rate of the publications and the mean citation rate of the journals is close to one (0.99) for the Norwegian publications. This ratio is close to one also for Finland and Sweden, while the publications from Denmark, the Netherlands and Switzerland receive more citations than expected from the average of the journals where they appeared.

Figure 8.1. Mean journal citation rate (JCR) and the ratio between mean citation rate of respective country's publication and the mean journal citation rate. The wide, dark bars indicate mean for 2009-2011 and the narrow, lighter, bars indicate mean for 1989-1991. (Data from Science Citation Index - Thomson Reuters).



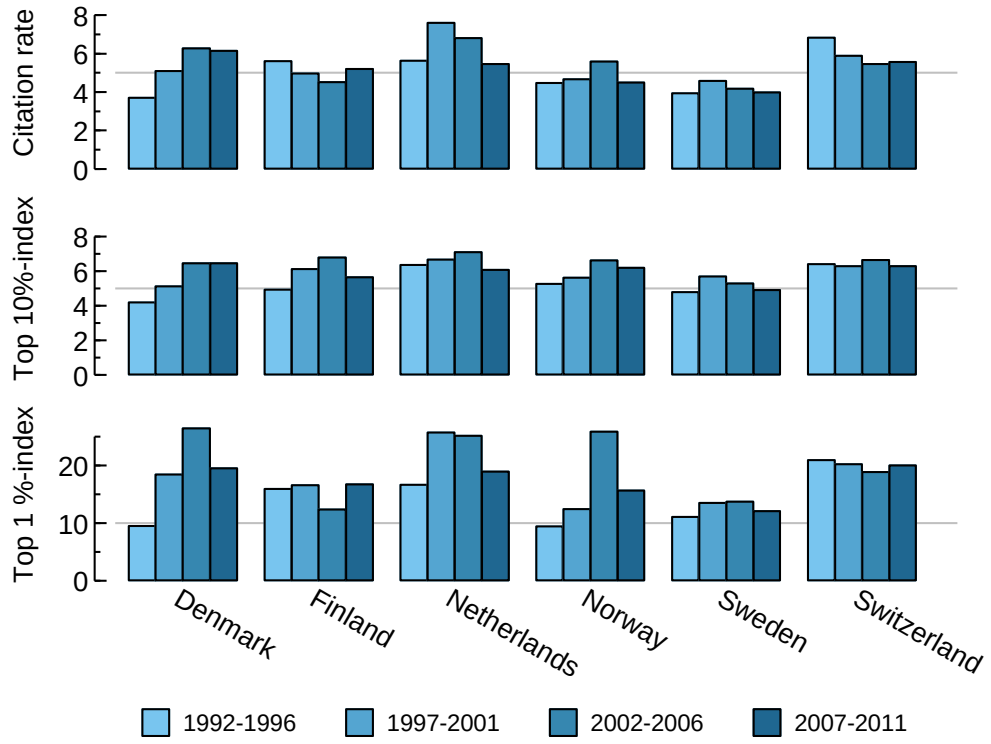
When considering the number of publications in three of the most prestigious journals, Nature, PNAS and Science, the Norwegian output has increased substantially; from about 12 papers per year 1999-2001 to slightly above 20 during 2009-2011, an increase by 67 %. This is the largest relative increase among the compared countries, the second largest increase is found for Denmark (39 %).

Figure 8.2. Number of publications per year in three prestige journals, Nature, PNAS and Science. The curves are based on three-year moving averages. (Data from Science Citation Index - Thomson Reuters).



The citation rate of the Norwegian papers in these high-prestige journals is second lowest among the compared countries; only Sweden gets a lower average citation rate of the papers in these journals. When comparing the top 10%-index or the 1%-index, the differences among countries are similar but the proportion highly cited Norwegian papers show a positive development, particularly the top 1%-index. However, the number of top 1%-papers is low and the statistics can vary markedly between years (as indicated for the 2002-2006 average for Norway, as compared to neighbouring bars)

Figure 8.3. Mean citation rate, top 10 %- and top 1 %-index for publications in the prestige journals during four 5-year periods. The grey horizontal lines are drawn to help compare countries. (Data from Science Citation Index - Thomson Reuters).



Among the compared countries, Norway has by volume the second lowest proportion of the total publication output in the high-prestige journals (Table 8.1; 0.31 %); only Finland has a lower proportion (0.27 %). The pattern is similar when comparing the contribution of these papers to the total number of citations or the number of highly cited papers (Table 8.1); Norway ranks second last in most cases.

Table 8.1. Contribution from prestige journal publications to the national output and citations received. Based on last 5-yr period (2007-2011). (Data from Science Citation Index - Thomson Reuters).

Country	Volume	Citations	Top 10% publ	Top 1% publ
Denmark	0.46%	2.2%	2.2%	6.4%
Finland	0.27%	1.3%	1.5%	5.3%
Netherlands	0.42%	1.8%	1.9%	6.1%
Norway	0.31%	1.3%	1.9%	5.4%
Sweden	0.55%	1.9%	2.4%	6.0%
Switzerland	0.80%	3.4%	3.4%	9.7%

In comparison with the other countries, the proportion of the Norwegian output in the prestige journals is low in the Medical fields (50% versus 54-71% for the other countries). A relative large fraction of the Norwegian papers in the prestige journals are instead found in the Natural Sciences and other fields.

Table 8.2. Prestige journal publications partitioned into three areas, medicine, natural sciences and other fields. Based on last 10-yr period. (Data from Science Citation Index - Thomson Reuters).

	Volume			Subject profile		
Country	Medicine	Natural Sci	Other	Medicine	Natural Sci	Other
Denmark	183.6	129.7	27.8	54%	38%	8%
Finland	112.6	58.0	10.4	62%	32%	6%
Netherlands	506.1	312.5	92.1	56%	34%	10%
Norway	89.9	69.5	20.3	50%	39%	11%
Sweden	525.0	172.4	44.9	71%	23%	6%
Switzerland	674.4	307.8	91.1	63%	29%	8%

For all countries studied, prestige journal publications in the Natural Sciences are more highly cited and have a higher top 10 %-index than those in Medicine or the "other" group (Table 8.3). For Norway the difference between Natural Sciences and Medicine is smaller. The top 10%-index for Norwegian publications in Medicine is the highest among the compared countries.

Table 8.3. Impact of prestige journal publications partitioned into three areas. Based on last 10-year period. (Data from Science Citation Index - Thomson Reuters).

	Mean citation rate			Top 10% index		
Country	Medicine	Natural Sci	Other	Medicine	Natural Sci	Other
Denmark	5.31	7.47	6.58	5.53	7.71	4.61
Finland	4.17	6.03	3.28	5.04	7.48	4.61
Netherlands	4.68	8.99	4.87	5.69	8.18	3.92
Norway	4.63	5.69	3.42	5.95	7.28	3.23
Sweden	3.32	6.26	4.43	4.42	7.06	3.37
Switzerland	4.36	8.24	5.62	5.87	7.84	4.39

9. PATTERNS AT THE ORGANISATIONAL LEVEL

Norway has the lowest number of universities and university hospitals (6) above the size threshold used (Table 9.1; more than 200 publications per year). These contribute with 59 % of the total Norwegian publications. Similar to Finland, none of these have a top 10 %-index above 1.2.

Table 9.1. Number of universities (and university hospitals) producing more than 200 publications per year during 2009-2011, and the proportion of these that produce a large proportion highly cited papers (Top 10 %-index > 1.2). The highly cited organisation's contribution to the total national output is given in the last column. (Data from Science Citation Index - Thomson Reuters).

Country	Selected universities		High performing universities	
	N	Contrib. to total national prod.	N	Contrib. to total national prod.
Denmark	7	80%	5	69%
Finland	10	68%	0	0%
Netherlands	18	70%	16	64%
Norway	6	59%	0	0%
Sweden	14	78%	5	23%
Switzerland	11	62%	9	52%

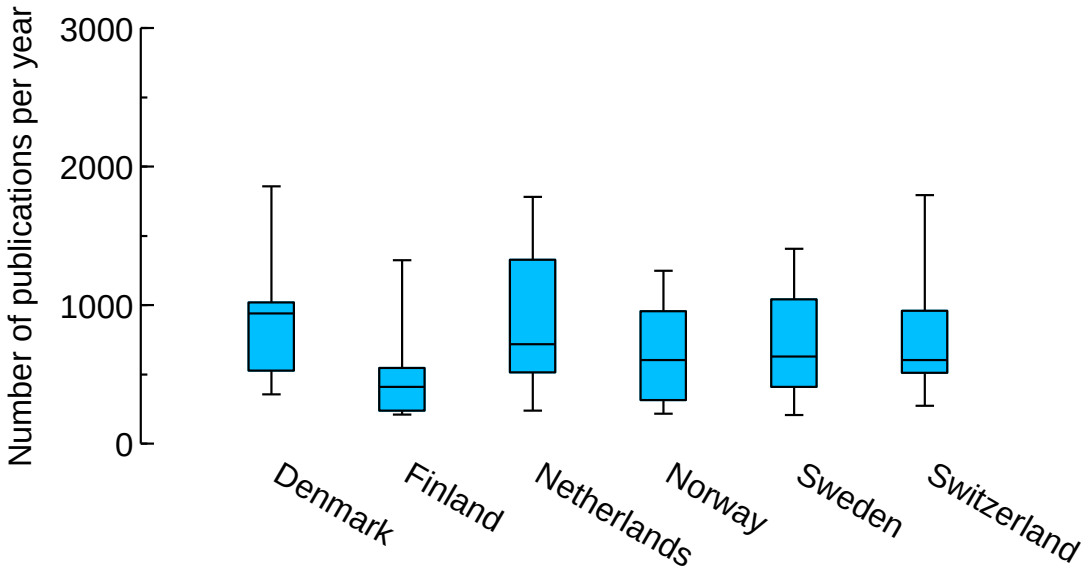
The number of universities above the size threshold relative country size (Table 9.2; measured as the number of inhabitants) is relatively low for Norway, only Netherlands has a lower number.

Table 9.2. Number of universities and high performing universities relative to country size (universities per million inhabitants). Restricted to universities and university hospital with at least 200 publications per year. (Data from Science Citation Index - Thomson Reuters).

Country	No. of universities relative to country population	No. of high performing univ. relative to country population
Denmark	1.27	0.90
Finland	1.87	0.00
Netherlands	1.09	0.97
Norway	1.19	0.00
Sweden	1.50	0.54
Switzerland	1.41	1.16

The variation in size (measured as publication output) of universities and university hospitals (again above the size threshold) is relatively similar to that of Sweden (Table 9.1).

Figure 9.1. Box plots of variation in university size. Size measured as number of publications produced per year 2009-2011. Restricted to universities and university hospitals with at least 200 publications per year. Boxes indicate the second and third quartile. The whisker endpoints indicate minimum and maximum. (Data from Science Citation Index - Thomson Reuters).



There is no relationship between university size and performance measured by the top 10 %-index, neither in the whole material nor for Norway (Figure 9.2). The only pattern revealed in the figure is that low-performing universities tend to be small, but small universities are not necessarily performing poorly as measured using this index.

Figure 9.2. Universities top 10% index versus size (number of publications per year). Restricted to universities with an annual volume of at least 200 publications. (Data from Science Citation Index - Thomson Reuters).

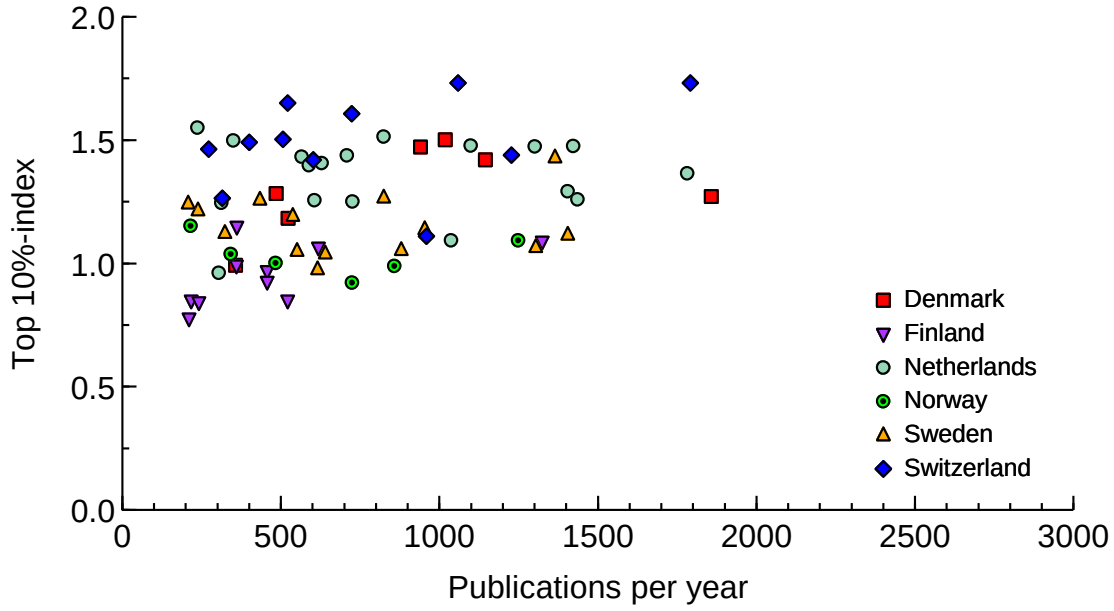
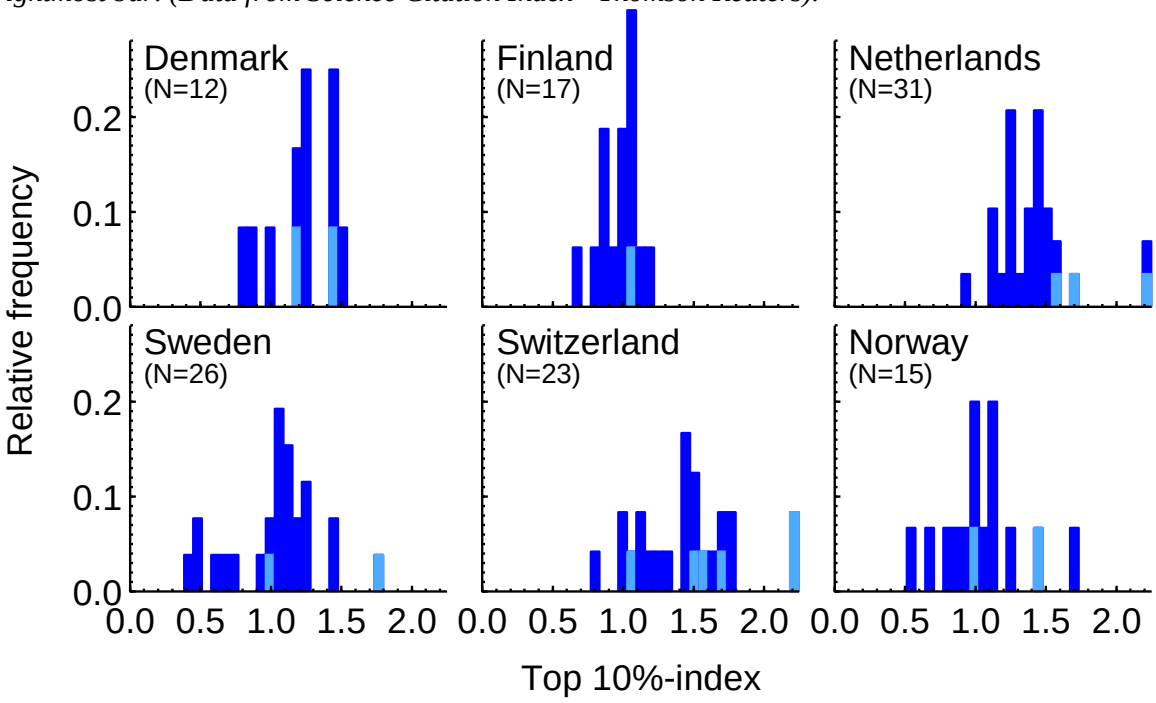


Figure 9.3 shows the size distribution frequency of a larger set of research organisations (all organisations above a size threshold of 50 publications per year). There are 15 Norwegian organisations above this size threshold with a frequency peak close to world average (1.0). Universities that have top-10% means above 1.2 are smaller than the size threshold used for the previous figures and tables in this section. Clearly, research organizations in Finland, Norway and Sweden are centred around world mean for the top 10%-index, while research organizations in Denmark, the Netherlands and Switzerland perform well above world average with few exceptions only.

Figure 9.3. Frequency distribution of the top10%-index for all organisations producing at least 50 publications per year. Dark blue = universities and university hospitals, light blue other organisations (mainly institutes, hospitals and businesses). All organisations with an index above 2 is shown in the rightmost bar. (Data from Science Citation Index - Thomson Reuters).



10. WHO IS CITING WHOM?

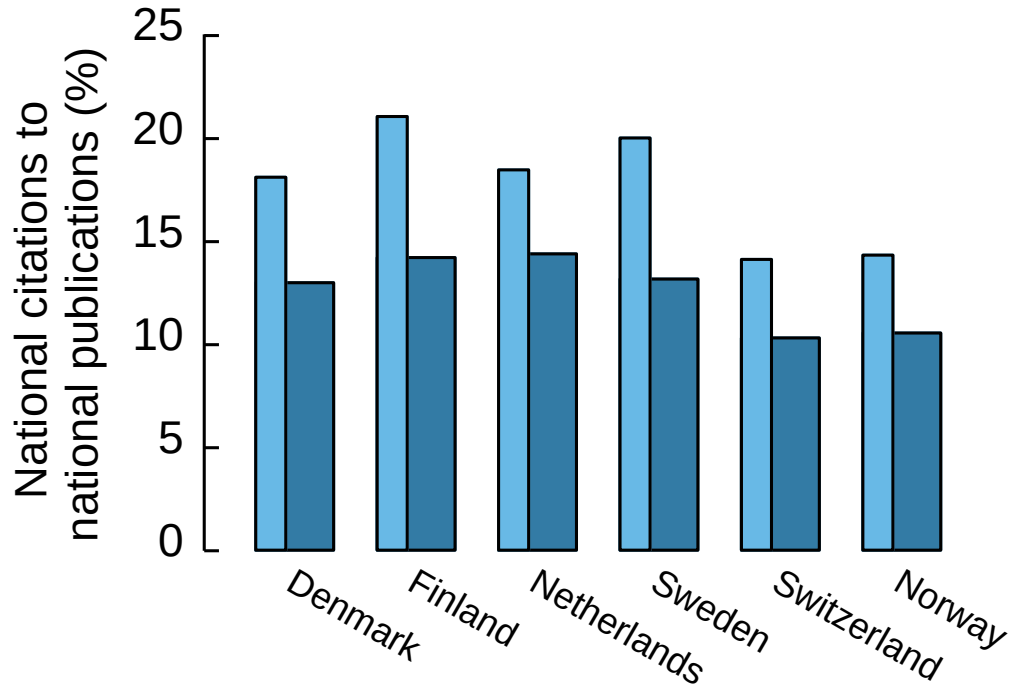
Norway has a marginally higher rate of national self-citations than the other Nordic countries (Table 10.1; 10.5% versus 8.8 to 10.0 %). Furthermore, in a Nordic comparison, Norway receives slightly fewer citations from United States, China and Germany. Instead Norway gets proportionally somewhat more citations from the United Kingdom than the other Nordic countries.

Table 10.1. Nationality of citations received by the publications of the studied countries. All the world's five largest producers of citations are included (above the thin line). Based on publications from 2009-2011. (Data from Science Citation Index - Thomson Reuters).

	Cited country							
Citing country	**Denmark**	**Finland**	**Netherlands**	**Norway**	**Sweden**	**Switzerland**	**United States**	**China**
National citations	8.8%	10.0%	10.7%	10.5%	9.3%	7.4%	39.1%	43.6%
United States	22.0%	21.2%	23.0%	20.9%	22.8%	23.9%	39.1%	12.7%
China	5.8%	5.9%	5.7%	5.2%	6.1%	6.5%	7.0%	43.6%
Germany	6.7%	6.1%	7.1%	5.8%	6.3%	8.5%	5.2%	3.0%
United Kingdom	6.7%	6.1%	6.8%	7.0%	6.3%	6.2%	5.3%	2.7%
Japan	3.7%	3.8%	3.8%	3.1%	3.9%	4.3%	4.1%	3.6%
Netherlands	2.7%	2.5%	10.7%	2.7%	2.4%	2.2%	1.9%	0.7%
Switzerland	1.6%	1.4%	1.6%	1.4%	1.5%	7.4%	1.2%	0.6%
Sweden	2.3%	2.7%	1.4%	2.7%	9.3%	1.3%	1.0%	0.5%
Denmark	8.8%	1.2%	1.0%	1.7%	1.5%	0.8%	0.6%	0.3%
Finland	1.0%	10.0%	0.7%	1.3%	1.5%	0.6%	0.5%	0.3%
Norway	1.2%	1.1%	0.7%	10.5%	1.3%	0.5%	0.5%	0.2%

Clearly the proportion of self-citation of national publications (i.e. publications with no international collaboration) has decreased in all countries since 1989. Norway and Switzerland have the lowest ratio of citations to national publications.

Figure 10.1. Citations to national publications from the own country. Wide darker bars means for 2009-2011 and lighter narrow bars means for 1989-1991. (Data from Science Citation Index - Thomson Reuters).



11. PROPORTION OF TOP SCIENTISTS

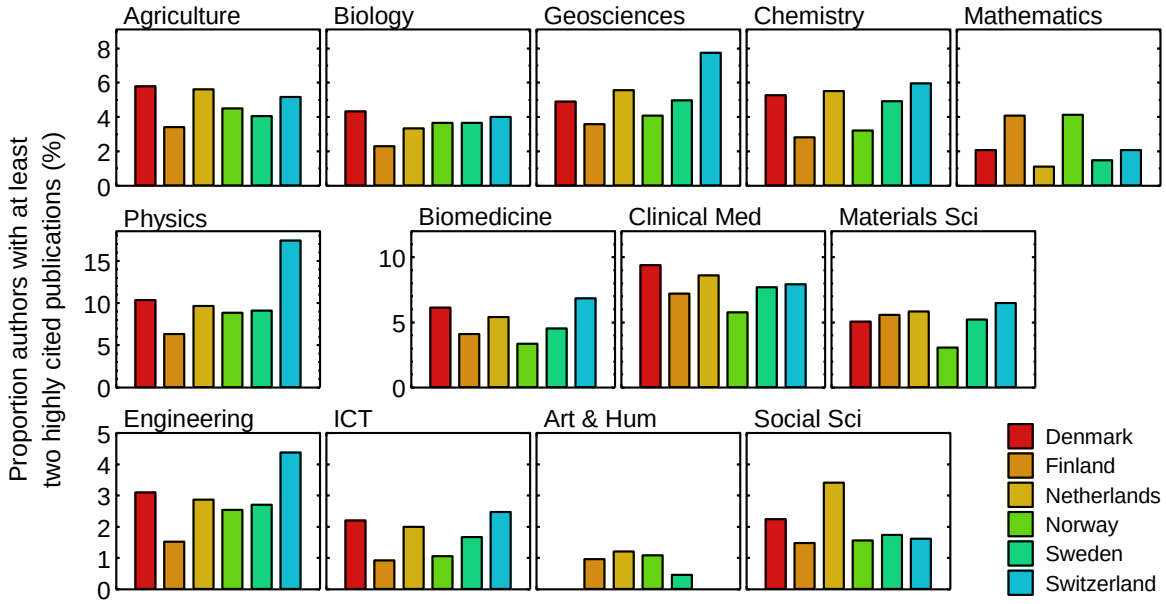
Norway has together with Finland the lowest proportion of authors who have produced highly cited papers during 2009-2011 (Table 11.1; before 2009 the Thomson Reuters database did not have a link between author name and address). The productivity of these authors varies marginally between countries. The low figure for the proportion of authors with at least one highly cited publication between 2009-2011 holds up for all subject fields (Figure 11.1) excepts for Mathematics where Norway and Finland score better than the other countries. Switzerland stands out as having the highest proportion of scientists performing at the high impact level in most subject fields.

Table 11.1. Proportion highly cited authors and number of publications per highly cited authors during a three year period (2009-2011). Calculated slightly differently as compared to the original report. (Data from Science Citation Index - Thomson Reuters).

	Authors with at least one top 10%-paper			**Authors with at least two top 10%-paper**		
Country	**Proportion of all authors**	**Total number of publications**	**Number of top 10%-publications**	**Proportion of all authors**	**Total number of publications**	**Number of top 10%-publications**
Denmark	22.1%	4.6	1.52	6.3%	9.5	3.11
Finland	16.8%	5.3	1.55	4.2%	11.3	3.20
Netherlands	22.1%	4.7	1.53	6.0%	10.1	3.16
Norway	16.8%	4.9	1.57	4.1%	10.1	3.10
Sweden	19.5%	4.8	1.50	5.2%	9.5	3.02
Switzerland	24.1%	5.0	1.70	7.1%	10.7	3.48

There are substantial differences among subject fields in the proportion authors with at least two highly cited papers during 2009-2011. In most cases the rank order among countries within a field is the same. The main exceptions from a Norwegian perspective are, as indicated above, that Norway perform well in Agriculture and Mathematics.

Figure 11.1. Proportion (%) of all author names that have at least two highly cited (top 10 %) publication during a three year period (2009-2011). Note the different Y-axis scales. Calculated slightly differently as compared to the original report. *(Data from Science Citation Index - Thomson Reuters).*



12. RECRUITMENT OF TOP SCIENTISTS

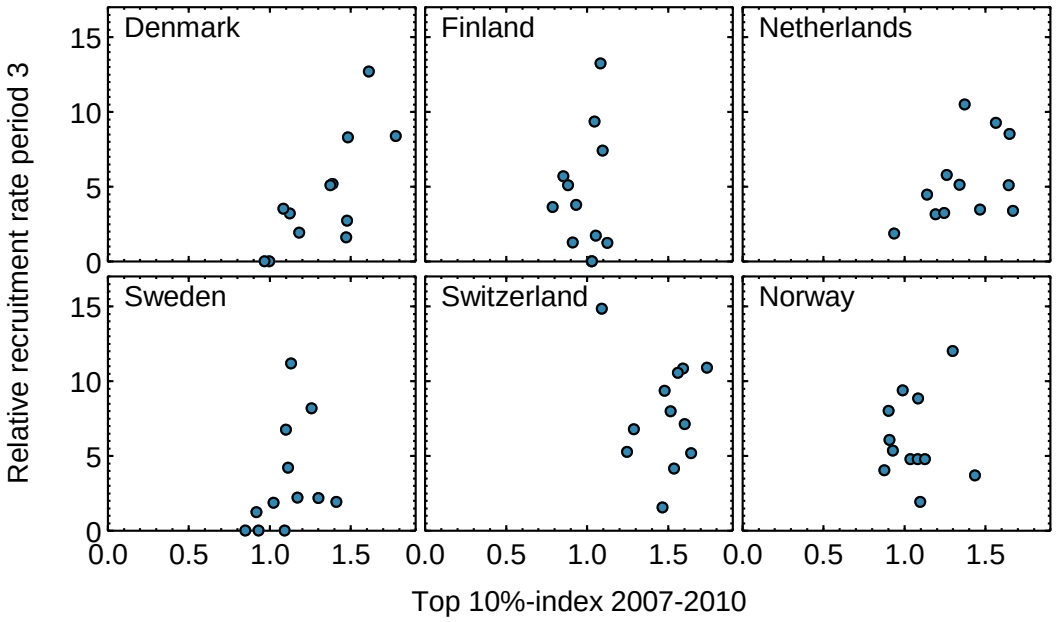
In this section, an attempt is made to measure the recruitment rate of scientists, the proportion emerging in the top 10% impact category during the last 25 years (Table 12.1; divided into three 15 year overlapping periods). The numbers are relatively high for Norway, particularly during the last two periods, while Finland and Sweden have had the slowest recruitment rate. Norway has shown the largest growth rate among the compared countries both in terms of volume growth and number of authors. The relatively high values for Norway are likely to be due to the relative high growth rates in terms of publication volume and number of authors.

Table 12.1. Recruitment rate: Per cent of elite authors emerging during the last five years of a 15-year period. For comparison the mean annual growth rate of the publication volume and the number of author names are shown in the two last columns. (The restrictions mentioned above for the calculation of the recruitment rate apply.) (Data from Science Citation Index - Thomson Reuters).

Country	Period			Mean growth of publication volume 1986-2010	Mean growth of no. of authors 1986-2010
	1986-2000	1991-2005	1996-2010		
Denmark	8.1%	5.3%	5.0%	2.8%	5.9%
Finland	7.7%	4.0%	3.1%	3.2%	6.2%
Netherlands	9.5%	6.5%	5.2%	3.5%	6.1%
Norway	6.0%	5.5%	5.0%	3.8%	7.0%
Sweden	5.4%	4.4%	3.7%	1.9%	5.2%
Switzerland	10.6%	6.3%	7.7%	3.0%	6.3%

When comparing the relative recruitment rate versus the top10%-index for 12 SPRU-fields, it is clear that Finland, Norway and Sweden centre around world average, while Denmark, the Netherlands and Switzerland have had a much better recruitment of scientists performing in the top10% publication category (Figure 12.1).

Figure 12.1 Recruitment rate versus the top 10 %-index for 12 Sussex University defined subject fields (SPRU-fields) between 2007 and 2010. The field Art and Humanities is excluded due to the low number of publications and authors found in this field. (The restrictions mentioned above for the calculation of the recruitment rate apply.) (Data from Science Citation Index - Thomson Reuters)



13. CONSIDERATIONS ON STATISTICAL SIGNIFICANCE

The statistics presented in this report are based on an entire dataset rather than on random sampling. Further the data quality is high with very few random errors. Therefore the statistics presented are an accurate representation of the situation within the limits of the coverage of the database as described below. When comparing universities or countries, there is a degree of randomness in which year a particular publication is printed and thus in annual means. However, all statistics presented in this report are based on three- or five-year means. These means should show very small random components.

There are, however, some cases where the "measuring error" could be larger. (1) For the organisation statistics in section 9 the university names for Nordic countries are unified and corrected (see Piro 2011). For the other countries the unification is more superficial; the number of organisations above the size threshold and university size could therefore be underestimated for the non-Nordic countries. (2) In sections 11 and 12 when using last name and initials to identify individual researchers.

Nevertheless, statistical significance test were performed in some cases. For one of the smallest datasets presented, publications in the prestige journals in section 8.2, some statistical tests were performed using annual averages as "replicates". For example, the top 10 %-index for the last period (leftmost bars in each group, middle row, in Figure 8.2), the Swedish value is not significantly different from the Finnish (P=0.17) but significantly lower than that for all other countries (P=0.013 or less; tested by a generalized linear model in SAS). For the top 1%-index in the same graph the Swedish mean is not significantly different from that for Finland or United Kingdom (P= 0.12 and P=0.14, respectively) but significantly lower than the means for Denmark, Netherlands and Switzerland (P=0.01 or less). With respect to this dataset it should be kept in mind that the number of fractionalized top 1%-publications from each country each year is extremely small in the prestige journals (in the order of 1- 20, except for the United Kingdom with 40-70, c.f., Figure 8.1). Most other statistics presented in the report are based on considerably larger data sets. It is therefore safe to assume that the differences between Finland or Sweden and the other countries are statistically significant (in the above sense) in most cases.

An important restriction to all statistics presented is, however, that the report is based on a commercial database covering a fraction of all scientific publications only; those in ca 12 000 international journals. As stated above (section 6) this restriction is most important for *Arts and Humanities* but significant also for *Social Sciences*. Further, for some technical fields, 'proceedings' is an important type of publication not included in the database at the Swedish Research Council. All statistics should be interpreted in this context; the statistics describe the performance of publications in the journal set indexed by Thomson Reuters. In some fields there are important publications in other publication channels.

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