Developments in Danish research performance

Scientometric mapping of developments in Danish research performance in the period 1980-2013 at macro- and meso-levels

Background-report commissioned by
The Danish Council for Research and Innovation Policy

Jesper W. Schneider & Kaare Aagaard
Danish Centre for Studies in Research and Research Policy
Department of Political Science
School of Business and Social Sciences
Aarhus University

1 Executive summary:

Danish research indexed in the Web of Science (WoS) currently performs at an absolute world class level measured by relative impact measures. This performance has high policy relevance and has received considerable attention in academic and administrative circles. In order to enhance policy learning *The Danish Council for Research and Innovation Policy* has thus commissioned an investigation of the long term development of this position covering the period 1980 to 2013.

By examining a variety of indicators and comparing the current standing of Danish research to a selected group of comparable countries (The Netherlands, Sweden, Norway and Austria) this report investigates the robustness of the overall picture and the consistency of the long term trends. Furthermore, the report examines to what extent the overall development in Danish research performance is mirrored at selected field levels. And finally, it is examined whether Denmark shows different developments in terms of collaboration, internationalization and journal impact behavior than the benchmark countries.

Overall, the report shows a very robust and consistent picture. We observe a very strong Danish performance documented by a variety of indicators including MNCS, PPtop10%, PPtop5%, PPtop1% and with regard to the share of uncited publications. Furthermore, the majority of analyses have been carried out based on both full counts and fractional counting to ensure that differences between the two methods do not distort the overall results. The strong Danish position is also documented in comparison with both the four benchmark countries and a wider set of countries.

Two main results stand out of the first part of the analysis on national performance in chapter 4: first, Denmark and the Netherlands clearly separate themselves from the remaining benchmark countries and perform at a world class level throughout the period. Secondly, Denmark has a very interesting trajectory during the 1980s and 1990s with a large drop in performance in the first decade and a fast catch-up in the second decade. From 2000 and onwards Danish research is again on par with that of the Netherlands and the two countries have very similar developments for the remaining period up until today. Overall, it is thus documented that Danish research throughout the period as a whole has been able to hold its position among the very best in spite of a strong increase in competition from a number of countries – although the gaps between the strongest research nations and the rest of the scientific world clearly are diminishing over time. In general, we also observe rather few fluctuations in the ranking between countries: Sweden is somewhat of an exception dropping from a world class level to a more mediocre standing. Also the Austrian development is interesting with a strong catching up development from a very low starting point. A major part of the explanation for the low Austrian starting point is most likely a language bias

due to limited English publication activity compared to the benchmark countries in the beginning of the period.

The following chapter 5 examines the Danish development at two different field levels: first the OECD field level classification based on the Frascati Manual with six main areas and secondly at a more detailed categorization level based on the Dutch NOWT scheme where we end up with 16 subfields. For each of the two levels we show the relative volume of the different fields in order to illustrate their weight on the overall Danish performance. We then proceed by showing the developments in performance to examine how the developments at the field levels relate to the results at the aggregated level. Due to coverage issues and challenges with regard to make comparisons across fields these results should however be interpreted with caution.

Overall, the results in this chapter show some interesting differences between fields. First of all, due to the volume it is clear that respectively the developments in performance within the *Medical Sciences* and the *Natural Sciences* play a very large role in explaining the overall Danish development. However, the two fields have very different lines of development over the time period analyzed. The *Medical field* starts out at a quite modest level but after a drop in the 1980s shows a steadily increasing trend from the early 1990s and onwards and ends up at a very high performance level. In comparison with the benchmark countries we see however, that the Danish *Medical field* performs quite well throughout the period, indicating that comparisons across fields should be carried out with caution. The performance of the *Natural Sciences*, on the other hand, starts out at a very high level and then drops (more significantly than the *Medical field*) during the 1980s. However, even at the low point the performance is still very strong. The high level for this field is then maintained for the remaining part of the period. The development of the smaller *Engineering and Technology field* resembles the development of the *Natural Sciences* – but even more marked. The performance starts out at an extremely high level and the drops drastically. But even at the low point performance is still very good. Also this field then maintains a very high level for the remaining period. Similarly for the *Agricultural Sciences* the development in performance resembles the development observed within the *Natural Sciences* – although with larger fluctuations due to a much lower overall volume. Finally, the *Social Sciences* and *the Arts and Humanities* show very large fluctuations due to low volume. This applies to the *Arts and Humanities* for the period as a whole, while the *Social Sciences* seem to show a more robust (and highly positive) trend towards the end of the period. At the NOWT sub-field level the same trends as we observe across the main fields are generally found, albeit with slight variations between individual sub-fields. In particular, it is noteworthy that *Clinical Medicine* plays a very important role for the overall development due to its size and its very positive development in the second half of the period covered in this analysis.

In continuation of this chapter 6 investigates developments in publication behavior. Overall, the trend in publication behavior for all five countries is towards publication in journals with higher

impact. To a certain extent this may be a database effect, but there are important individual variations among the countries. The combined indicator for publication behavior (MNJS) clearly shows an upward curve but also a clear rank order between the countries. The only exception is the distinct drop for Denmark during the 1980s. Due to this drop, the rank order between Denmark and Sweden is switched in this period. Denmark surpasses Sweden again during the marked rise in the 1990s. Even though this is publication behavior and not citation impact, journal publication behavior and the MNJS indicator are correlated with citation impact. Therefore it is hardly surprising that the drop in the MNJS indicator, implying more publication activity in lower impact journals, coincides with the general drop in citation impact for Denmark in these years. We also examine longitudinal changes in publication behavior, by annually assigning journals to one of five rank ordered classes from A to E, where A contain the lowest impact journals and E the highest impact journals. Over the whole period examined, all countries reduce their output in the two below average impact classes with some 10 to 12 percentage points, to shares around 28% to 35%. But the Netherlands and Denmark have the lowest relative output in these classes. All countries experience increases in all of the remaining three classes. In 1980, the generally high performing countries, the Netherlands, Denmark and Sweden, had relative outputs of 36%, 32% and 31% respectively in the two above average impact classes and in the highest impact class E, the distributions were 20% (Netherlands), 18% (Denmark) and 16% (Sweden). At the end of the examined period the discrepancy is more discernible. While all countries increase their relative output in these impact classes, Denmark stands out among the high performing countries with a 7 percentage point increase. But most noticeably, Danish publication behavior increases 4 percentage points in class E, so that the relative output in this class rises from 18% in 1980 to 22% in 2011. Correspondingly, the Netherlands rises from 20% to 23% and Sweden from 17% to 20%. The differences may seem small but it is important to remember that the journal classes are generally well correlated with aggregate citation impact of publications, hence a few more percentage points of output in higher impact classes will most likely pay off in citation impact. Indeed, in a comparison between Denmark and Sweden we show that Danish publications generally have higher impact than Swedish publications in impact classes C to E and that the difference increases with impact classes. Finally, even though most countries see a general decrease in relative publication activity in the two lowest impact classes and the trajectories resemble each other, the marked drop for Denmark (class A and B) is distinct and commences when the general citation impact was at its lowest in the late 1980s.

Finally in chapter 7 it is shown that all countries experience a significant increase in internationalization. The annual proportion of publications from the total output resulting from international collaboration/participation increases threefold from 1980 to 2013, from around 20% to around 60% of all publications. Again we see small, but still potentially important differences in the developments for the individual countries and again the Danish trajectory is very interesting. In 1980, when Danish citation impact was very high, the degree of internationalization among the five countries was also the highest at 20%. Interestingly, during the 1980s when we see a large

drop in Danish citation impact, the general rise in the annual share of international publications flattens somewhat, so that the shares resembles those of the other countries. In line with the other observations regarding citation impact (MNCS) and publication behaviour (MNJS), we observe that when Danish impact began to rise markedly again in the 1990s, and the publication behaviour began to change towards higher impact journals, we also see a period for almost 10 years where the degree of internationalization increases distinctively above the other four countries. Up until 2003, Danish shares of international publications were between 3 to 5 percentage points higher than the country with the second highest share of international publication. This development is interesting as aggregated citation impact not only is related to publication behaviour, but also to internationalization. On average publications with authors from different countries have a higher impact than publications with authors from one country only (USA is the exception). Further, there is also an interaction between publication in higher impact journals and internationalization as journals with higher impact on average also have larger shares of international publications. So changes in publication behaviour and internationalization go hand in hand and have most likely affected the development in Danish citation impact. It is, however, also interesting to contrast the development in impact for national and international publications and relate this to their annual relative volume. When it comes to international publications, those credited to Denmark and Netherlands generally have the highest average performance. However, especially in the first decade, when the proportion of international publications was relatively low (between 20% and 30% for Denmark) the impact scores are volatile with considerable annual fluctuations due the lower volume. Correspondingly, in the same period, national publications constituted around 80% in 1980 and around 70% in 1990. To begin with the impact for these national publications are above average and high compared to the benchmark countries, but during the 1980s the impact of the national Danish publications see a marked drop. Neither the Netherlands nor Sweden experience similar marked drops. Only in the late 1990s is the impact of Danish national publications again on par with Netherlands and noticeably, the impact is considerably higher than the other three benchmark countries. The marked drop in the impact of national Danish publications, given their volume in the 1980s thus influences the general Danish development in impact. It is also noticeable, that with regard to the increases in Danish impact both national and international publications contribute to this.

Finally, it should be underlined again that these developments in performance solely reflects the impact of publications indexed in the WoS. Hence, these developments are not representative of the performance of the Danish research system as a whole.

2 Introduction

Denmark today stands out as one of the strongest research nations of the world measured by relative, scientometric indicators. Several reports have documented this in recent years. In particular a report from the Noria-Net (Schneider et. al, 2010) and the bibliometric analysis (Karlsson and Persson 2012) behind the "*Fostering breakthrough research*" report (Öquist and Benner 2012) have generated debate and highlighted a remarkable Danish development since the early 1990s. In order to achieve a more nuanced picture of this performance *The Danish Council for Research and Innovation Policy* has commissioned an investigation of the long term trends of the Danish development. Subsequently, this bibliometric mapping will form the foundation of a detailed analysis of possible factors influencing the Danish development.

The mapping of the long term developments in Danish research performance in this report has two main elements: On the one hand it provides an international comparative perspective on the Danish development by comparing it to the development in four selected benchmark countries (The Netherlands, Norway, Sweden and Austria) comparable in terms of size and systemic characteristics, but with different trajectories. This part examines a variety of different indicators over a long time-span to provide a thorough and robust picture of the Danish development. On the other hand the report also looks deeper into the Danish development at selected field-levels in order to achieve a better understanding of the composition of the overall Danish performance. This part of the analysis uses the OECD field level classification with six broad areas as well as the Dutch NOWT-low classification scheme which allows for a more detailed examination of the development of selected areas and disciplines.

This report thus takes the Danish development as the explicit point of reference and examines four main questions:

1. How robust is the overall picture? The report examines a variety of indicators and compares the current standing of Danish research to a selected group of countries.

2. Is the development in Danish research performance different from the development of the benchmark countries when we apply a long-term perspective? To what extent has the relative ranking between the selected countries shifted throughout the period?

3. What does the disaggregated composition of the Danish development look like? Is the overall development in Danish research performance mirrored at different field levels? To what extent do the different fields contribute to the overall Danish development when we look at developments in both impact and volume?

4. And finally, does Denmark show different developments in terms of collaboration, internationalization and journal impact behavior than the benchmark countries? Can any of these factors contribute to explaining the differences between the countries?

In addition to addressing these specific questions this report in particular separates itself from earlier reports by applying a longer time perspective, by using more updated data, and by putting more focus at the development on selected disaggregated levels.

2.1 Caveats for the interpretation of data

In the interpretation of the data presented in this report it should be kept in mind that measuring the properties of science is a difficult exercise. Bibliometric data can contribute to this exercise with important insights, but cannot stand alone. As an example, indicators measuring citation impact capture academic impact, rather than quality, and this capture is only partially. As a consequence of this partial and one-dimensional nature of the indicators, a single indicator is often not reliable. However, when various complementary indicators suggest similar insights more convincing evidence about the property observed is offered. On the other hand, a lack of agreement between various indicators suggests that several contrasting perspectives may be relevant (Martin et al, 2014). Furthermore, the indicators have to be appropriate to the property under investigation and be applicable to the whole system under study. The limitations with regard to this are well-known within the *Humanities and Arts* and large parts of the *Social Sciences*, but also apply to certain areas of the hard sciences. Finally, bibliometric indicators are unreliable below certain levels of aggregation and need careful mathematical normalization to be used across diverse research areas. However, these normalization procedures are by no means perfect. As a consequence comparisons across fields should be treated with caution. In addition, within-field differences may also be a factor of importance which the normalization procedures fail to capture. The interpretation of the data in this report should in other words be done with care.

Despite the limitations, these types of bibliometric data do have a lot to offer in assessing aggregated, long term developments as done in this report. Large amounts of data gathered over long periods may reveal interesting trends, although potential biases still exist. While many types of statistical bias tend to level out with larger data sets, some do not. In particular, language bias and certain field biases should be taken into consideration (Moed, 2005). Similarly, the uneven growth of the Web of Science (WoS) database should also be taken into account. These issues are discussed in the following section, but will also be commented upon throughout the report where relevant.

3 Terminology, data, and methods

The present analyses are based on bibliographic data from Thompson Reuters' citation database Web of Science (WoS). We use the in-house version of WoS constructed and maintained by CWTS, Leiden University, Netherlands. This database has, amongst other things, enhanced citation and address matching algorithms compared to the standard version provided by Thompson Reuters.

Only journal publications indexed in WoS from 1980 to 2013 are included in the analyses. The current low quality of the Conference Proceedings Citation Index basically excludes this index (and thus this publication type) from valid citation analyses. Currently, the WoS covers approximately 12,000 journals from the sciences, social sciences and arts and humanities. Each journal is assigned to one or more subject categories (up to six). There are approximately 250 subject categories in WoS.

3.1 Categorization

For the present analyses we have aggregated these fields into 6 major OECD-fields and 16 minor NOWT-subfields. NOWT is a classification system developed for monitoring Dutch research performance: "*Nederlands Observatorium voor Wetenschap en Technologie*" (Dutch Science & Technology Observatory). Publications in multidisciplinary journals, such as Nature and Science, are reclassified based on the subject profile of cited and citing publications; however, as some of these publications mainly cite other multidisciplinary journals, not all can be reclassified. It is important to emphasize that all classification schemes to a certain extent are arbitrary. Research activity is generally practiced within specialties and publication activities are often distributed among numerous journals indexed in different WoS subject categories. Hence, research and research publications are not entirely organized along the lines of the classification schemes, which typically are constructed for other purposes. This should be kept in mind when interpreting results at the disaggregated level of major fields and especially when analyzing smaller sub-fields.

In the appendix, section 9.1, we outline the concordance between the OECD classification and the WoS subject categories. This concordance is developed and maintained by Thompson Reuters and OCED in collaboration. In the appendix, section 9.2 we outline the concordance between an adjusted NOWT classification and the WoS journal subject categories. We use a modified version of NOWT where we reduce the 35 research areas to 16. We have mainly collapsed a number of areas in engineering, social sciences and arts and humanities. This is done to ensure overview and simplicity, but also due to the small publication volumes and citation activities within a number of sub-fields. By collapsing areas we thus strive for adequate robustness.

3.2 Language

Although English by far is the most important language in written scientific communication, and even can be considered 'the' international language of science, other languages are used as well. However, the overwhelming part of the journals in WoS is English-language journals. The language of publications has a marked effect on citation-based measurements of research performance. Publications in non-English language journals indexed in the WoS count as part of a country's output, but these publications generally have a low impact as fewer scientists can read them. This effect is particularly evident in application-oriented fields such as clinical medicine. As clinical medicine represents a considerable part of the scientific output of most nations, the language of publication directly affects their performance. However, language bias is also a factor in other fields. Consequently, papers from non-English language journals have considerably lower impact than those in English-language journals. Over the period examined in the present report there has been a steady decrease of non-English language publications in WoS; from approximately 15% in 1980 to 5% today. Apart from English, German was the second largest language in 1980 at approximately 5% of the publications. This figure has dropped to just below 1% today, but it is still the second most common language in the database. Countries such as Germany, Switzerland and Austria are affected by this, but to a diminishing degree as they have decreasing numbers of publications in languages other than English (see e.g., van Leeuwen et al., 2001).

3.3 Types of indicators

We use a number of standard bibliometric indicators of output, impact, and collaboration. We use the acronyms given by CWTS to designate the indicators. The same indicators (and the same database) are used in the Leiden Ranking (www.leidenranking.com).

Most analyses are presented as time series. Output is the number of publications in a given time period, most often we apply blocks of several years, advancing one year at a time, to obtain robust and smooth time series for trend analyses. Publication types include research articles, reviews and letters, where the two former publication types have a weight of 1 and the latter a weight of 0.25.
All analyses have been done with both full and fractional counting. With fractional counting each country is credited a fraction of each publication in proportion to its share of all author addresses given in the publication. With full counting each involved country is given full credit for the publications they have contributed to. In the report we mainly present analyses based on full counts. Corresponding fractional counts are placed in the appendix except for a few country comparisons. There is an ongoing debate in the scientometric research community of whether to use full counting or fractional counting, or both counting methods. There are valid arguments for both positions. The fractional counting method is usually promoted because it has good mathematical properties. Field-normalized comparisons across countries sum up to unity in the database and provide an interpretable scale where 1 corresponds to the average citation impact in the database. Full counting may "favor" minor countries or fields with more international

publication activity. Due to multiple counts, full counting does not have same mathematical property as fractional counting, where 1 can be interpreted as the average citation rate in the database. Such a rate is higher and indicator values in general are also higher with full counting. Despite violating mathematical properties, full counting can certainly be relevant for specific analyses. Indeed, full and fractional counts can be seen as measuring different constructs, i.e. participation (full) and contribution (fractional). But for reasons of clarity and space, we do not present results based on both counting methods in the report. We focus on full counts because as an indicator of output it is easier to interpret - especially in time series. Notice, a decreasing trend in time series based on fractional counts may well be an expression of more international collaboration and not a general decline of output. On the contrary total output may well be rising. Full counts show the absolute number of publications in the database where a country has participated. Also, at the disaggregated level of fields we find that comparisons between fields is more straightforwardly done using full counts, as it gives a clearer indication of the size of the fields. Highly international fields may seem smaller when fractional counts are used, but obviously such fields may receive a full count bonus when it comes to impact. Indeed whether to use fractional or full counting is an unresolved matter in scientometrics (see e.g., Moed, 2005, Gauffriau and Larsen, 2005; Aksnes, Schneider and Gunnarsson, 2012; Waltman and van Eck, 2015). We thus provide results using both counting methods because we see these indicators as complementary rather than competing.

We define “international collaboration” as publications where there are at least two different countries mentioned in the address field of the publication. We emphasize that measuring “collaboration” using co-authorships can only be a partial indicator of “research collaboration” (see Katz and Martin, 1997).

Citation impact of publications are measured by two complimentary citation indicators: Mean Normalized Citation Score (MNCS) and the Proportion of Publications among the top *n* % of the most highly cited in the database (PPtop*n*%). All citation indicators are item-normalized according to publication type, publication year, and field-specific citation rates. This means that citation rates per publication are compared to average citation rates for the same type of publications, in the same year, for the specific research field, before they are aggregated to provide totals. This enables the comparison of so-called relative citation indicators across research fields, publication types and publication years. Such relative indicators are needed here because the typical number of citations is highly dependent on research field, publication type and the time allowed before citations are counted.

Self-citations are excluded from the calculation of citation rates and citation rates are calculated with four-year citation windows, i.e., the citations obtained during the publication year and the following years are counted. For the most recent publications, citations have only been accumulated during one or two years.

In general, citation indicators become more robust as the number of publications involved increases. At the country level, indicators are usually very robust. Also, differences in counting methods or citation windows do not seem to alter the performance rank among the selected countries in any substantial way.

The MNCS indicator is an average field normalized citation rate. When fractional counts of publications are used an index of 1 is the "database average" citation rate for the aggregated field(s). When full counting is used in combination with citation indicators, values do not sum up to unity and the "database average" of 1 does not hold. Generally, units have higher MNCS scores when full counting is applied. An important weakness of the MNCS indicator is its strong sensitivity to publications with a very large numbers of citations. Especially for smaller publication sets this can result in an overestimation of the actual impact of the publications assigned to the unit of analysis.

As the PPtop*n*% indicator is based on ranks and not averages, it is much less sensitive to publications with very large number of citations. By default we apply 10% as the threshold for the PPtop*n*% indicator (PPtop10%), where 10% means all publications cited on or above the 90th percentile in the database (notice, we do other percentile analyses as well). For each publication of a country, this indicator determines whether the publication, based on its number of citations, belongs to the top 10% of all WoS publications in the same field (i.e., the same WoS subject category) and the same publication year and of the same document type. The PPtop10% indicator equals the proportion of the publications of a country that belong to the top 10% highly cited publications. If a country has a PPtop10% indicator of 10%, this means that the actual number of top 10% publications of the country equals the statistically expected number. A PPtop10% indicator of 15% means that the country has 50% more publications than expected among the 10% most cited in the database. Notice with full counting countries have a slightly larger number, usually 1 percentage point, more publications in the top 10. A disadvantage of the PPtop*n*% indicator is the artificially dichotomy it creates between publications that are respectively above and just below the percentile threshold. Therefore we apply both MNCS and PPtop*n*% as they can be seen as complementary, though they usually also correlate strongly at aggregated levels.

Finally, we use the Mean Normalized Journal Score (MNJS) to measure the impact of the journals in which a country has published. To calculate the MNJS indicator for a country, we first calculate the normalized journal score of each publication of the country. The normalized journal score of a publication equals the ratio of on the one hand the average number of citations of all publications published in the same journal and on the other hand the average number of citations of all publications published in the same field. Only publications in the same year and of the same publication type are considered. The MNJS indicator is obtained by averaging the normalized journal scores of all publications of a country. The MNJS indicator is closely related to the MNCS indicator. The only difference is that instead of the actual number of citations of a publication the

MNJS indicator uses the average number of citations of all publications published in a particular journal. If a country has an MNJS of 1 this means that on average the country publishes in journals that are cited equally frequently as would be expected based on their field. An MNJS indicator of 1.5 means that on average the country publishes in journals that are cited 50% more than would be expected based on their field. To some extent the MNJS indicator resembles Thompson Reuters' (in)famous Journal Impact Factor (JIF) in the sense that in both cases publications are assessed based on the journal in which they have appeared. However, compared with the MNJS indicator, JIFs have the important disadvantage that they do not correct for differences in citation characteristics between research fields.

3.4 Database changes

Finally, it should be mentioned that interpreting time series based on the international citation databases can be somewhat challenging because the databases has undergone, and still undergoes, substantial changes both in structure, data format, at not least changes in scope and coverage. For several decades the WoS (essentially the Science Citation Index[1]) were stable in its coverage, where inclusion of new journals often meant exclusion of others. This has changed considerably in later decades, where commercial interests seem to be an important factor when it comes to journal inclusion. In the 2000s the database saw a huge intake of so-called regional journals especially from Asia raising the total number of journals covered by WoS markedly (Testa, 2011). While many of these journals are English language, citation traffic between them and western journals is mostly one-way. They cite western journal papers, but the opposite is rarely the case. This has consequences for the global average impact in the database; countries with many publications in western journals, where citation traffic is denser, will generally experience a rise in average impact, albeit experiences may differ between countries. Furthermore, not only has the database grown when it comes to number of journals covered, journals themselves have also grown considerable in size especially in the last two decades. In general, the annual number of issues has risen and so has the number of papers per issue.

Overall, these growth factors in the database need to be considered when examining the output of countries. Likewise, it has to be remembered that the annual output for a country is the number of journal papers with at least one author participating from the country covered by WoS in the year in question.

[1] The WoS is basically an umbrella of several citation indices with different origins. The oldest is Science Citation Index which covers journals from science, technology and medical fields. Other citation indices based on journals are Social Science Citation Index and Arts and Humanities Citation Index. Finally, in recent years, Thompson Reuters has introduced two Conference Proceedings Indices, one for science and technology and one for social science conference papers, as well as a Book Citation index.

All these factors point in the direction of using relative indicators and towards comparisons between comparable units of analysis to minimize the effects of methodological choices and database effects. Emphasis is thus placed on relative differences rather than changes in absolute numbers throughout the report.

4 Developments in performance at national level:

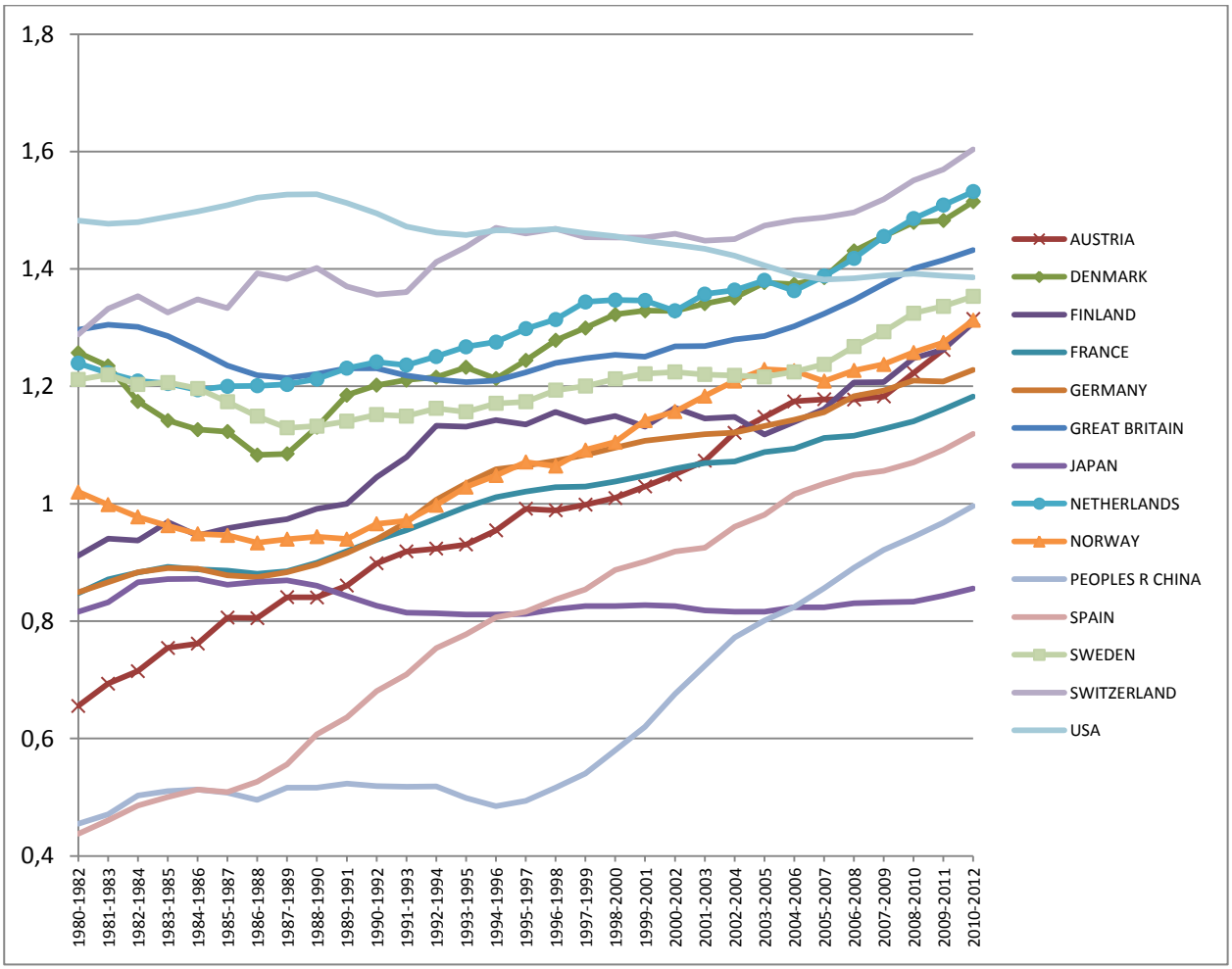
The first empirical chapter of this report examines performance at the national level among the selected benchmark countries. First, a figure showing the development in MNCS for the selected countries among a wider set of countries is shown to put the developments in performances into a broader context. Secondly, we look at the size of the systems and the production of publications of each of the benchmark countries. Finally, we move on to the actual impact of the research of these countries examining a number of performance indicators including MNCS, PPtop10%, PPtop5%, PPtop2%, PPtop1%, selected percentiles and the share of uncited publications.

4.1 Denmark and the benchmark-countries in a wider context

Figure 4.1 shows the development in MNCS over the timespan 1980-2012 for a larger set of countries to situate the performance of the benchmark countries in a wider context. This selection of countries includes all the traditional strong research nations as well as a some of the large and very influential newcomers (in particular China and India) and thus provides a broad overview of both the development over time and the relative position of each individual country included in the analysis vis-à-vis other relevant countries. Figure 4.1 shows the development in MNCS scores based on full counts. The corresponding development based on fractional counts can be seen in Figure A.1 in the appendix.

Due to the large number of countries the figure is not easily interpretable. However, in this context it only serves the purpose of situating the selected benchmark countries among the most important parts of the rest of the scientific world. From this figure it thus becomes evident that the selected benchmark countries represent quite different standings and quite different lines of development. To put it briefly before we turn to a more thorough examination in section 4.3, it can be seen that Denmark and the Netherlands are consistently placed among the top 5 throughout the period when we include all high performing countries (the other top-performing countries being Switzerland, USA and Great Britain). However, Denmark has a remarkable drop in performance in the 1980s. With regard to Sweden we can observe a rather significant decline from the group of world class countries in the beginning of the period to a position by the end the period among the countries which could be labelled the “second league” in the national research ranking game. When we then turn to Norway we see much the same development over time as both Denmark and the Netherlands display, but consistently about 20 percent lower throughout the period. This places Norway solidly in the “second league” throughout the period as well. Finally, Austria displays a quite remarkable catch-up from a very low starting point to a position close to Norway by the end of the period. We look deeper into these developments in section 4.3.

Figure 4.1. Development in mean normalized citation scores (MNCS) based on full counts for 14 countries; three year overlapping publication blocks. A corresponding plot for fractional counts is Figure A.1 in the appendix.



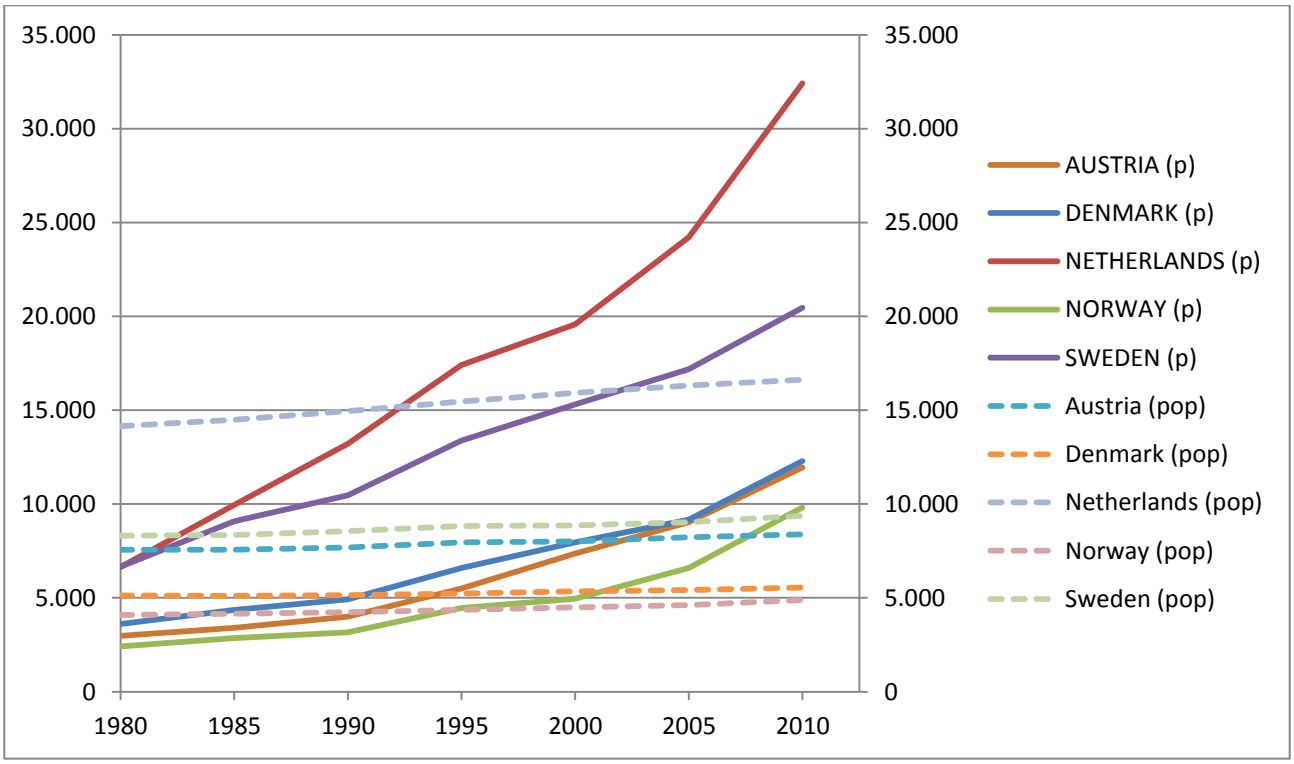
The trends are essentially the same when fractional counts are used; see Figure A.1 in the appendix. There are small differences in trajectories and ranking order, but it is the same countries that are on top: USA, Switzerland, Great Britain, Denmark, the Netherlands and Sweden. Similar to Figure 4.1, Sweden drops out of the top at the end of the period. Figure A.1 also illustrates the issues of collaboration for smaller and larger countries, but it is noticeable that the overall trends are not affected among the benchmark countries.

4.2 Size, characteristics and scientific production of Denmark and the benchmark countries

Before we turn to the more detailed examination of the developments in performance, this section compares Denmark and the four benchmark countries with regard to scientific production and population size. It is well known that countries such as USA, China, Great Britain, Germany, Japan and France lead the field in terms of absolute numbers of publications and citations. However, a ranking based on absolute numbers does not take the different features of the various

nations into account. With regard to a subsequent analysis of factors influencing the development outlined in this report it is thus more reasonable to make comparisons with countries that have similar structural features; primarily countries with comparable populations and economic performances. As mentioned in the introduction this report therefore compares a group of relatively small, fairly wealthy, non-English speaking European countries representing quite different trajectories with regard to national research performance.

Figure 4.2. Developments in population size and production of scientific papers measured in full counts.



Source: The World Bank for population sizes.

However, although the countries can be labelled as similar in a global perspective, there are still significant differences in size and research intensity. In terms of population The Netherlands as the largest country is more than three times bigger than the smallest, Norway. As can be seen in table 4.1 below the five countries also differ significantly in terms of developments in publications per 1000 inhabitants. While all countries experience a dramatic increase in numbers of publications relative to population throughout the period they do it from different starting points and at different speeds.

Denmark and Sweden have the highest ratios throughout the period, but with Denmark showing the strongest increase of the two. The Netherlands has the strongest increase of all but still ends up a bit below Denmark and Sweden due to a lower starting point. The development of Norway is quite similar to the development of Denmark, but at a slightly lower level throughout the period.

Finally, Austria has the lowest share of publications per 1000 inhabitants throughout the period quite a bit below the other four countries by the end of the period. However, combining these figures with the results shown in section 3.3 below we see that there is no straightforward relationship between the developments in research intensity relative to population size and the developments in research performance among this group of countries.

Table 4.1. Development in population size and the number of full and fractionalized publications; population size is in thousands and the calculated ratio is based on population numbers and full counts of publications. Notice, full counts can be seen as a country's participation and fractional counts is an expression of collaboration.

		1980	1985	1990	1995	2000	2005	2010
Austria	Population	7560	7570	7680	7950	8010	8230	8390
	Publications $_{full}$	2980	3410.75	3993.5	5509.25	7356	9039.5	11952.75
	Publications $_{fractional}$	2785.8	3050.7	3384.5	4288.4	5383.4	6126.0	7353.3
	Ratio	**0.39**	**0.45**	**0.52**	**0.69**	**0.92**	**1.10**	**1.42**
Denmark	Population	5120	5110	5140	5230	5340	5420	5550
	Publications $_{full}$	3603.25	4355.5	4914.75	6591	7962.75	9165.25	12289.25
	Publications $_{fractional}$	3229.4	3783.6	4087.3	5065.8	5713.0	6284.7	7863.9
	Ratio	**0.70**	**0.85**	**0.96**	**1.26**	**1.49**	**1.69**	**2.21**
Netherlands	Population	14150	14490	14950	15460	15930	16320	16620
	Publications $_{full}$	6646	9953.25	13213.75	17405.75	19575.25	24216.5	32416.75
	Publications $_{fractional}$	6110.4	8911.5	11439.2	14111.6	14713.2	17436.1	21631.2
	Ratio	**0.47**	**0.69**	**0.88**	**1.13**	**1.23**	**1.48**	**1.95**
Norway	Population	4090	4150	4240	4360	4490	4620	4890
	Publications $_{full}$	2422.25	2862.75	3167	4460.75	4949.5	6588.75	9819.75
	Publications $_{fractional}$	2216.0	2499.0	2686.4	3543.8	3720.5	4605.2	6503.9
	Ratio	**0.59**	**0.69**	**0.75**	**1.02**	**1.10**	**1.43**	**2.01**
Sweden	Population	8310	8350	8560	8830	8870	9030	9380
	Publications $_{full}$	6667.5	9082.5	10469.5	13379.75	15302.75	17187	20453.75
	Publications $_{fractional}$	6110.5	8040.0	8926.1	10677.3	11478.2	12259.2	13240.4
	Ratio	**0.80**	**1.09**	**1.22**	**1.52**	**1.73**	**1.90**	**2.18**

4.3 National development in MNCS, PPtop10, PPtop5, PPtop1, percentile classes, and in the share of uncited publications

In the following section a more thorough investigation of the patterns shown in section 4.1 is presented - but now only for Denmark and the four benchmark countries. In addition to the development in MNCS already shown in figure 4.1 this section also examines the development in performance from a variety of other angles to provide a more robust and comprehensive picture of the development in performance for the selected countries.

Figure 4.3. Developments in mean normalized citation scores (MNCS) for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks. A corresponding plot for fractional counts is found in Figure A.2 in the appendix.

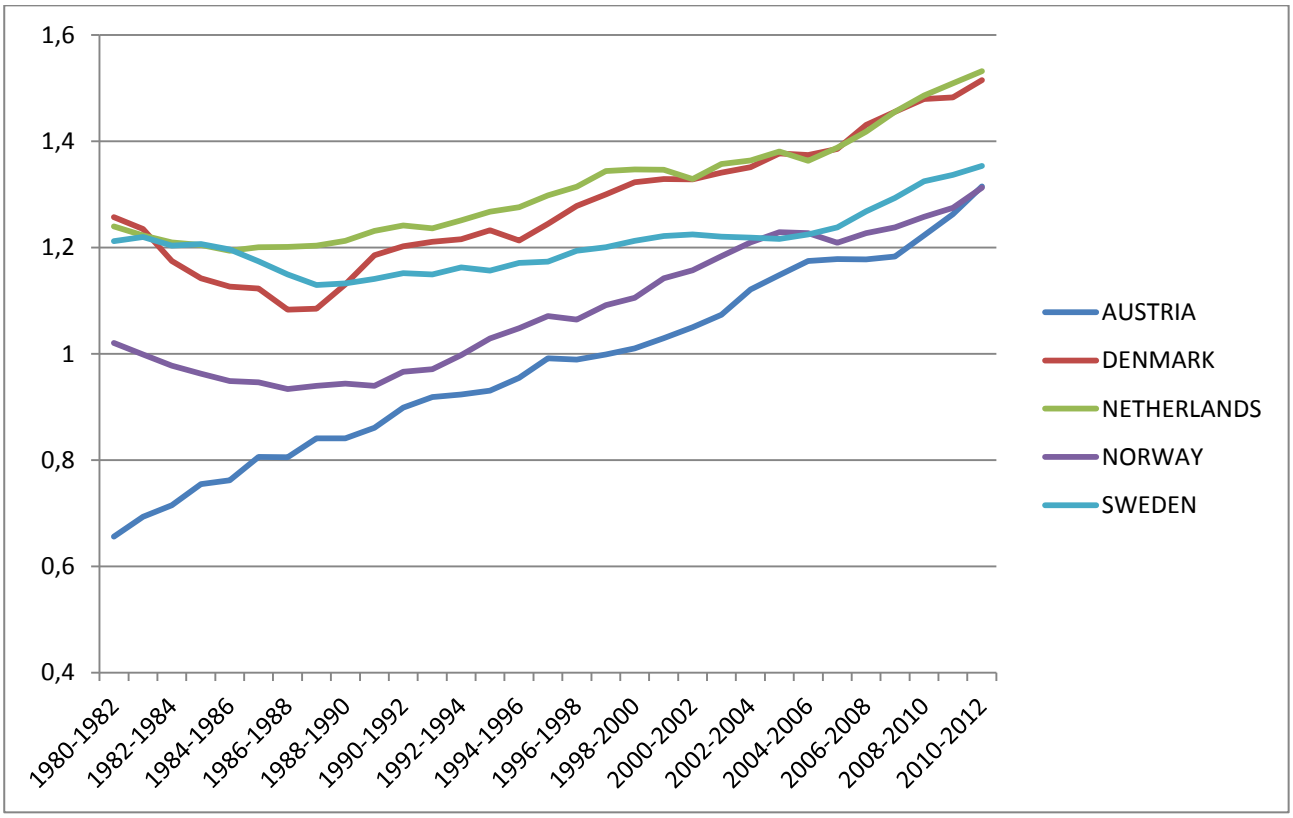
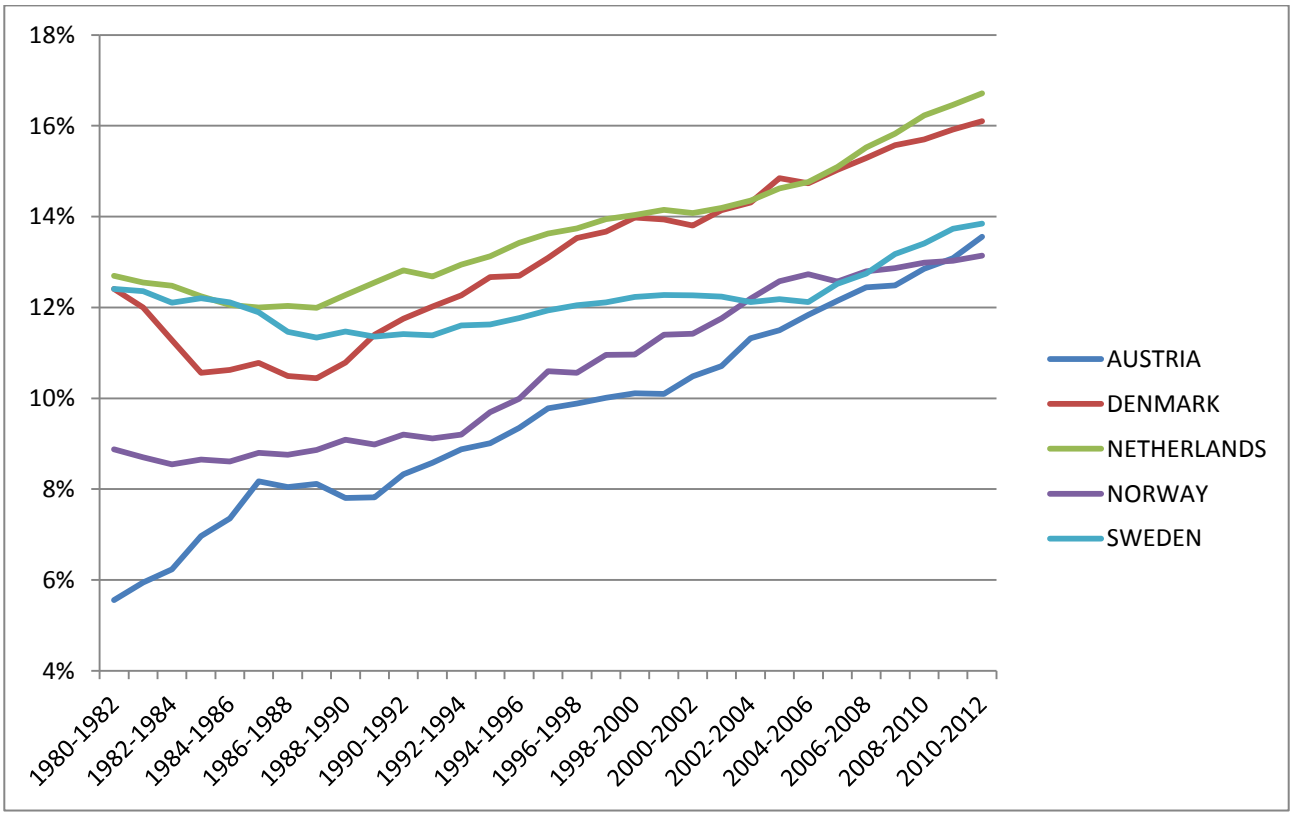


Figure 4.3 which shows the development in MNCS for Denmark and the benchmark countries gives a clearer picture of the relative development of the five selected countries than figure 4.1. Among these countries Denmark and the Netherlands clearly separate themselves from the remaining three. As mentioned in relation to figure 4.1 both Denmark and the Netherlands have performed at an absolute world-class level throughout most of period examined in this report. The main difference between the two countries can be observed during the 1980s where Danish research experience a quite large drop in performance. However, the gap to the Netherlands is closed again by the end of the 1990s. Also Sweden has a rather remarkable development, although not a very positive one. After a drop in performance during the 1980s Sweden is unable to reverse the trend for the remaining part of the period. While Denmark – in spite of a bigger drop – succeeds in returning to a world class level within a decade Sweden drops to a more mediocre standing among a large group of other countries as was shown in figure 1. Among the benchmark countries Sweden thus ends up very close to both Norway and Austria by the end of the period. In particular in comparison with Austria this development is striking. At the beginning of the period the two countries have respectively world class performance (Sweden) and very poor performance (Austria), but by the end of the period they are almost equal among a quite large group countries performing well, but still somewhat lower than the top 5 countries. Finally. Norway has a quite

steady development starting and ending in almost the same position relative to the strongest performing nations – and by the end of the period very close to both Sweden and Austria. Figure A.2 in the appendix shows the developments in the MNCS indicator for the five countries based on fractional counts. The overall trends are similar.

In figures 4.4, 4.5, and 4.6 we then turn to another type of indicator which rather than measuring the average normalized number of citations per publication counts the proportion of publications among the top *n* % of the most highly cited publications in the database (PPtop*n*%) as described in Chapter 3 of this report. As the PPtop*n*% indicator is based on ranks and not averages, it is much less sensitive to publications with very large number of citations. However, at this level of aggregation we would not expect large variations between MNCS and the PPtop*n*% percent indicators.

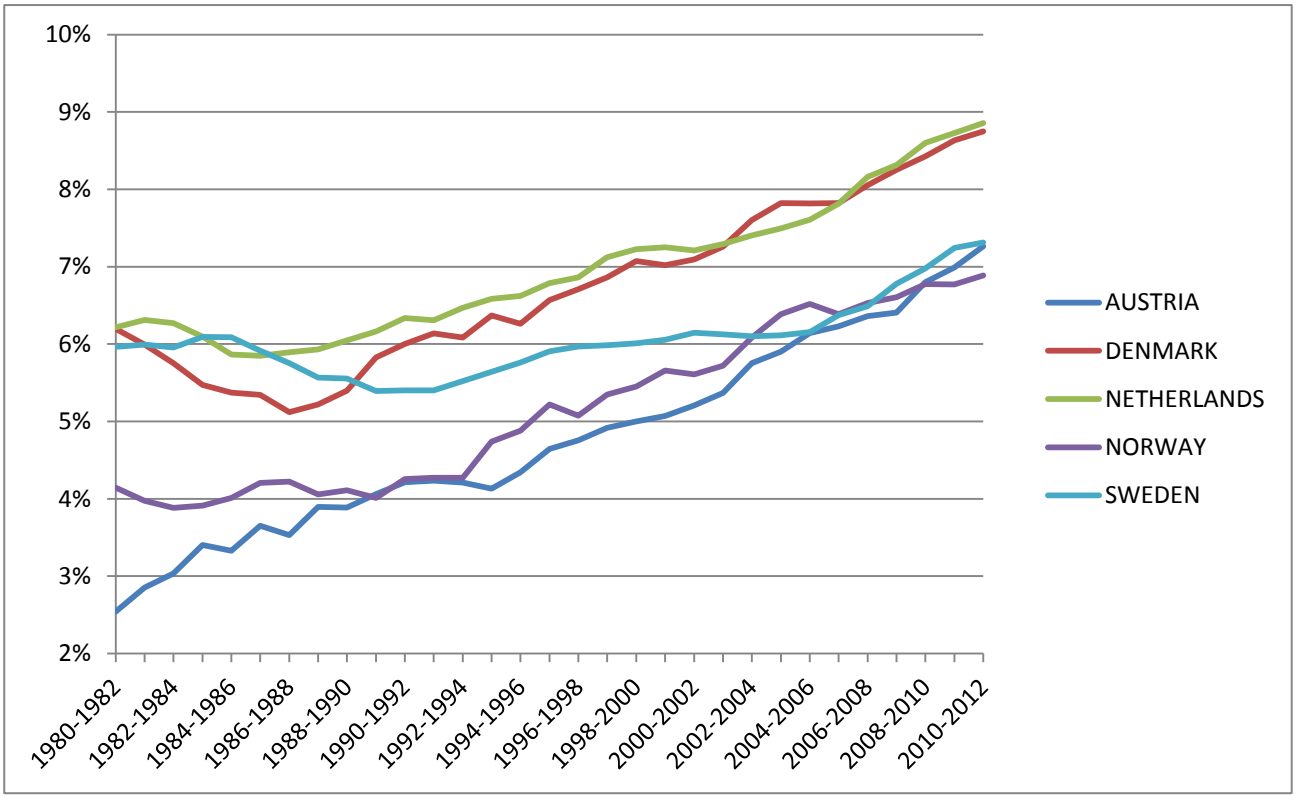
Figure 4.4. Developments in the proportion of papers among the 10% most cited in the database for the given time period (PPtop10%) for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks. A corresponding plot for fractional counts is found in Figure A.3 in the appendix.



As can be seen from figure 4.4 the development of the five countries with regard to the PPtop10% indicator is very similar to the development in MNCS. This is hardly surprising and shows the skewness in the allocation of citations to publications. As a rule of thumb, it is expected that

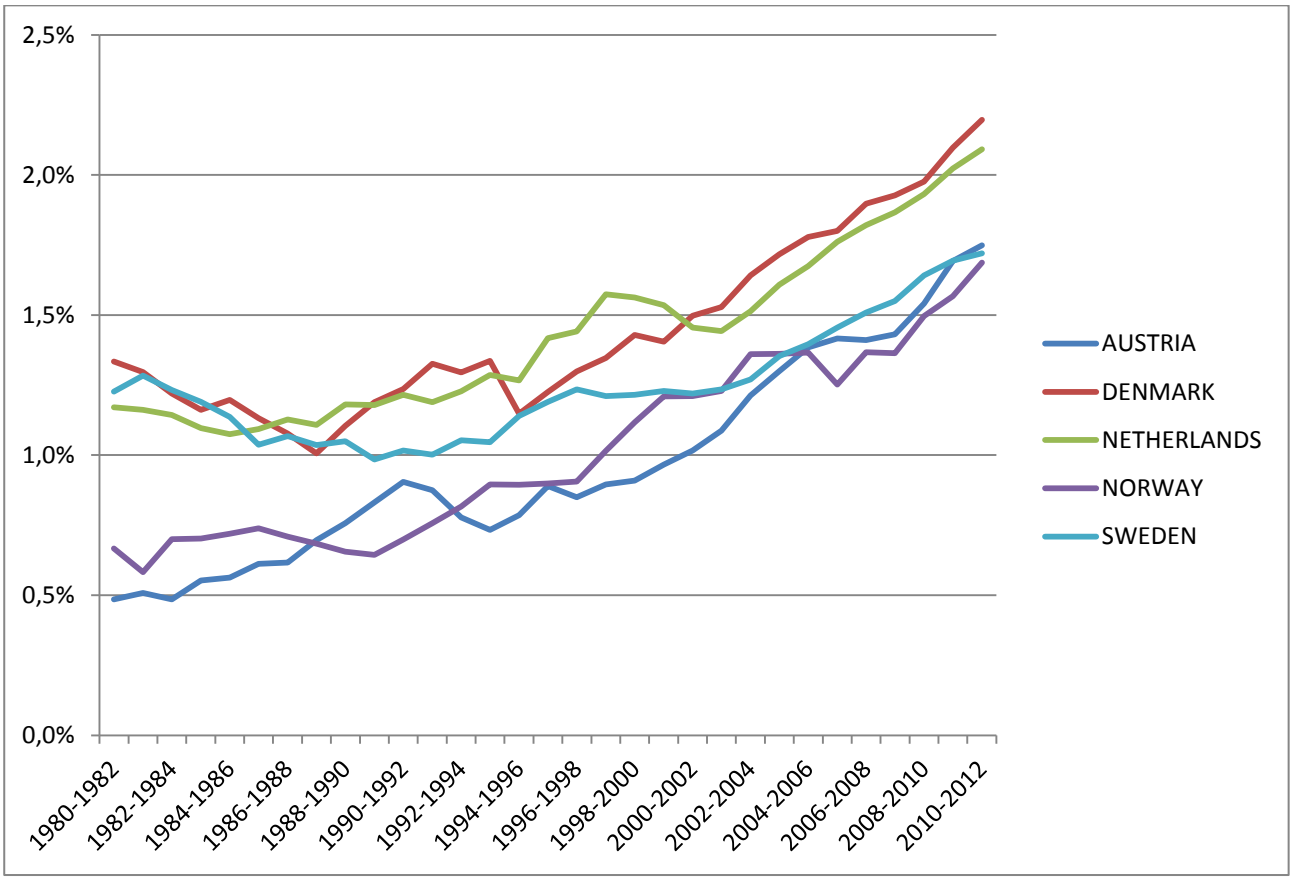
around 55-60 percent of the total number of citations within a given field are given to the highest scoring top 10 percent of all publications within this field. Thus, also this figure shows that Denmark and Netherlands are placed close together and clearly separate themselves from the other three countries.

Figure 4.5. Developments in proportion of papers among the 5% most cited in the database for the given time period (PPtop5%) for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.



As can be seen from figures 4.5 and 4.6 the picture is much the same when we turn to the PPtop5% and PPtop1% proportions. Not surprisingly, we see larger fluctuations in the top1% figure due to a low total number of publications in this category. However, the overall trend is not affected. We do not show corresponding figures for top 1 and 5 percent based on fractional counts as they show the same trend. Taken together these three figures add to the robustness of the trends observed in relation to the developments in MNCS and shows that the overall pattern is reproduced within the different categories. The strength in impact for the research from Denmark and The Netherlands are accordingly not just the result of a number of extremely highly cited publications but rather a general strength across all percentiles.

Figure 4.6. Developments in proportion of papers among the 1% most cited in the database for the given time period (PPtop1%) for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.



The latter point mentioned above regarding the general strength in performance of the benchmark countries is illustrated in the figures below. The five figures (figures 4.7 to 4.11) both show the performance within the different percentiles for each individual country and the share of uncited publications for four selected 3-year windows. The horizontal line at each bar facilitates the interpretation by providing a common point of reference across the countries.

As the figures show the profiles of Denmark and the Netherlands look very similar. The performance is generally high within all percentiles and the development over time is very positive. Notice however, that the Danish drop in performance during the 1980s also is visible here and can be seen within all percentiles. Both countries also have low shares of uncited publications with a clear decreasing trend. Large parts of the decreasing trend in the share of uncited publications are however database effects which can be observed for all countries. The differences in development between the individual benchmark countries are still relevant, though.
The profile of Sweden also reveals the stagnating tendency in the overall performance which we noticed in the figures above. Swedish research has a flat or slightly decreasing trend within the three first periods but shows signs of improvement in the most recent period. Also the profile of

Norway shows a positive development in all percentiles, but in this case from a lower starting point than the three countries above. This is particular visible in the higher percentiles (Top1, Top2, Top5, and Top10). We also observe that the share of uncited publications is somewhat higher than the countries above; in particular in the first two periods. Finally, with regard to Austria we again observe a very strong catching up trend, but from a very low starting point. Notice also the very high share of uncited publications during the first periods. In the period 1980-1982 more than 50 percent of all Austrian publications indexed in the WoS received no citations at all. However, language bias most likely plays a role in explaining parts of this pattern (for more details on biases and language issues see Chapter 3 and 6). In the appendix we have provided corresponding figures based on fractional counts, i.e. figures A.4 and A.8.

Figure 4.7. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Denmark. Indicators are based on full counts. A corresponding plot for fractional counts is found in Figure A.4 in the appendix.

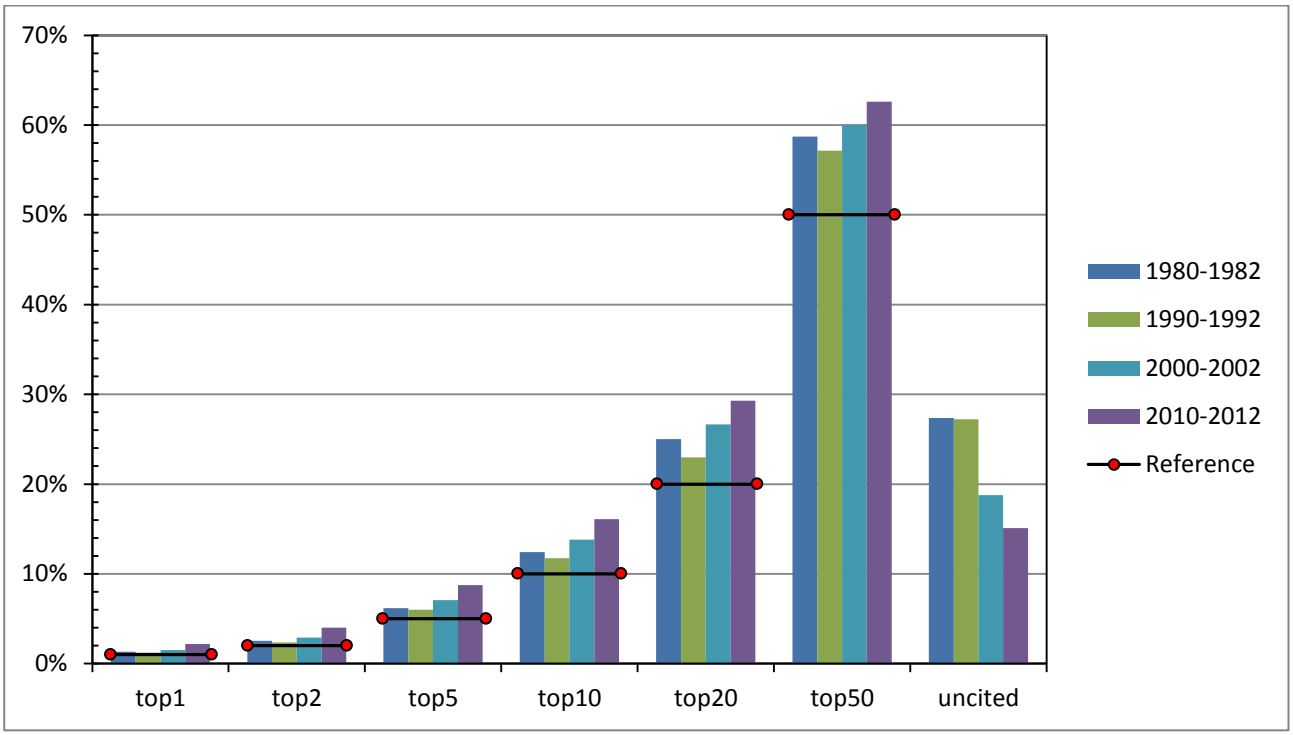


Figure 4.8. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for the Netherlands. Indicators are based on full counts. A corresponding plot for fractional counts is found in Figure A.5 in the appendix.

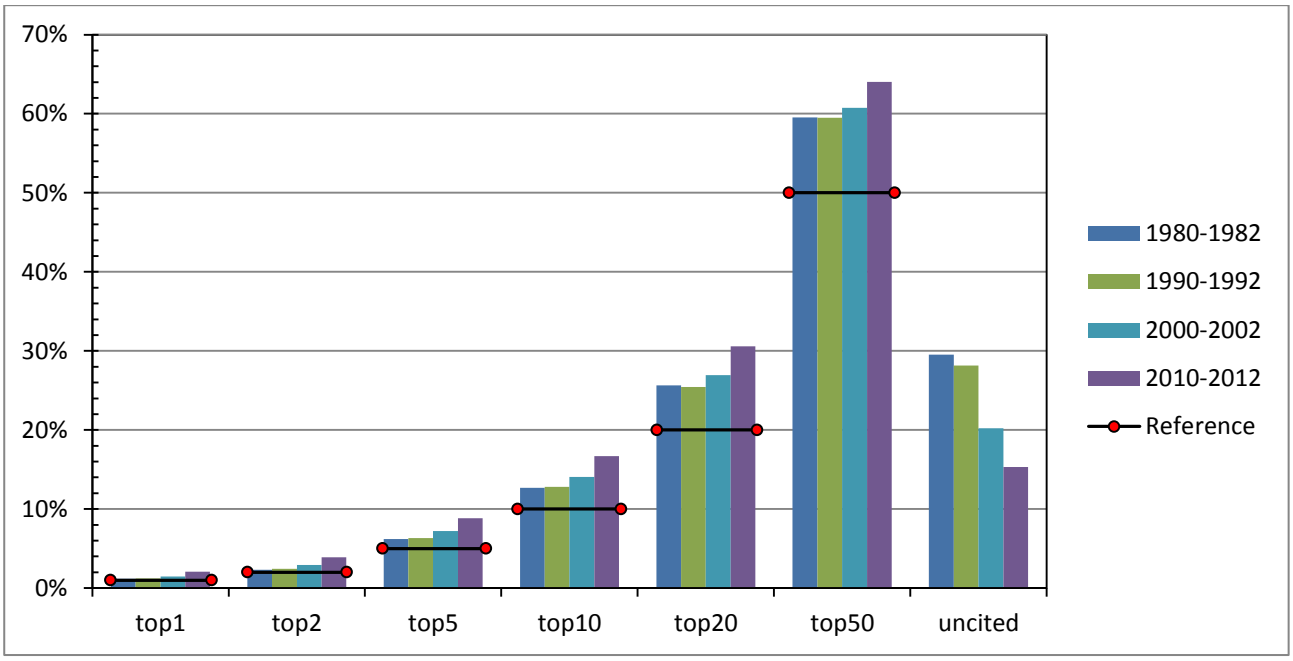


Figure 4.9. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Sweden. Indicators are based on full counts. A corresponding plot for fractional counts is found in Figure A.6 in the appendix.

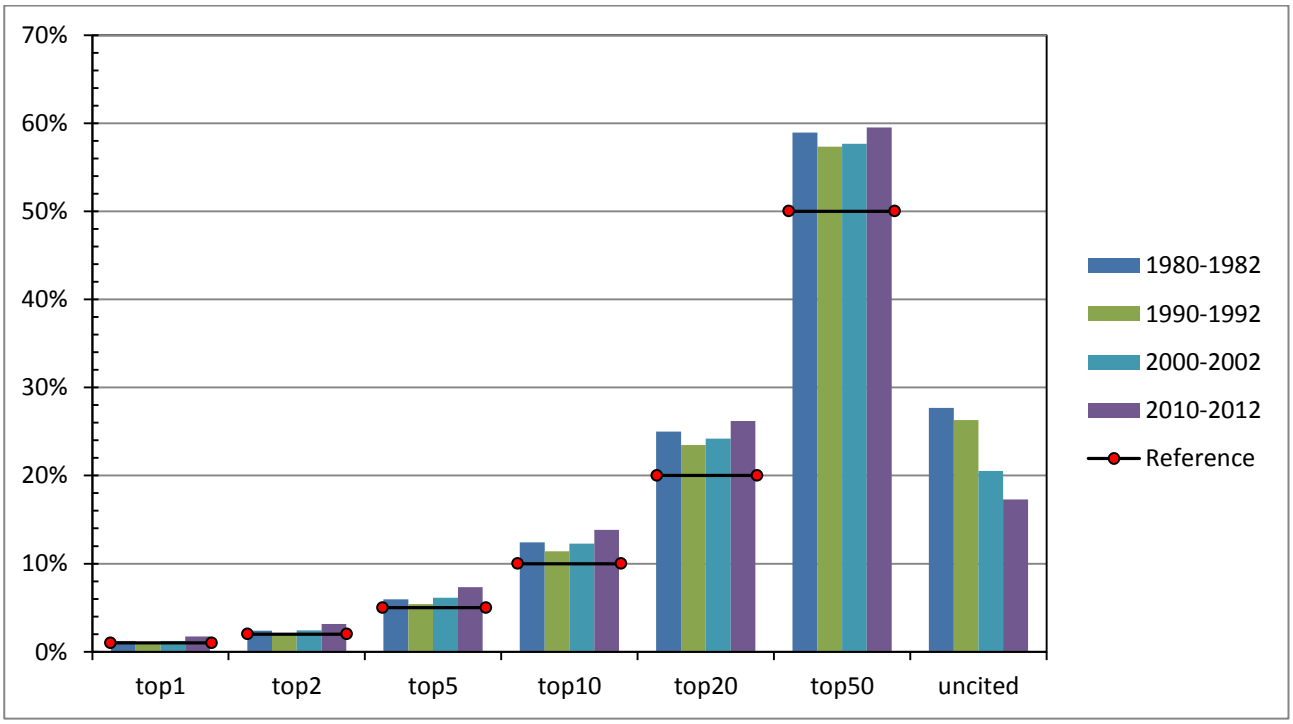


Figure 4.10. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Norway. Indicators are based on full counts. A corresponding plot for fractional counts is found in Figure A.7 in the appendix.

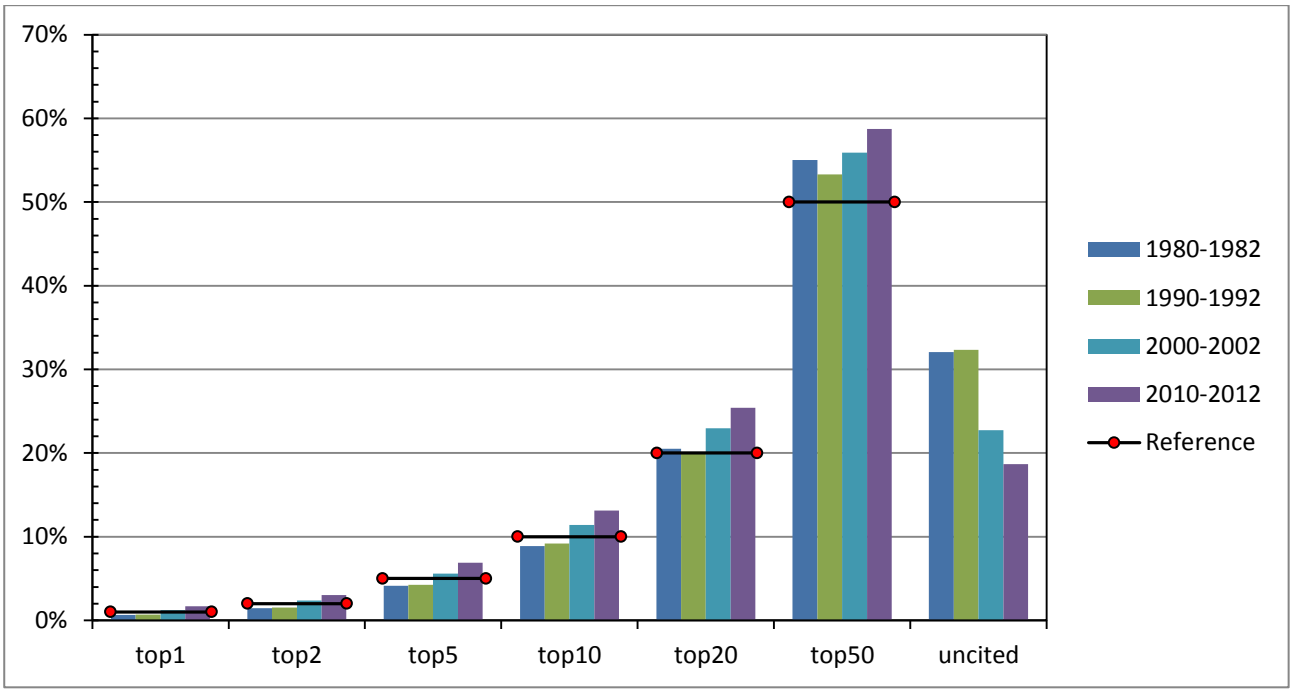
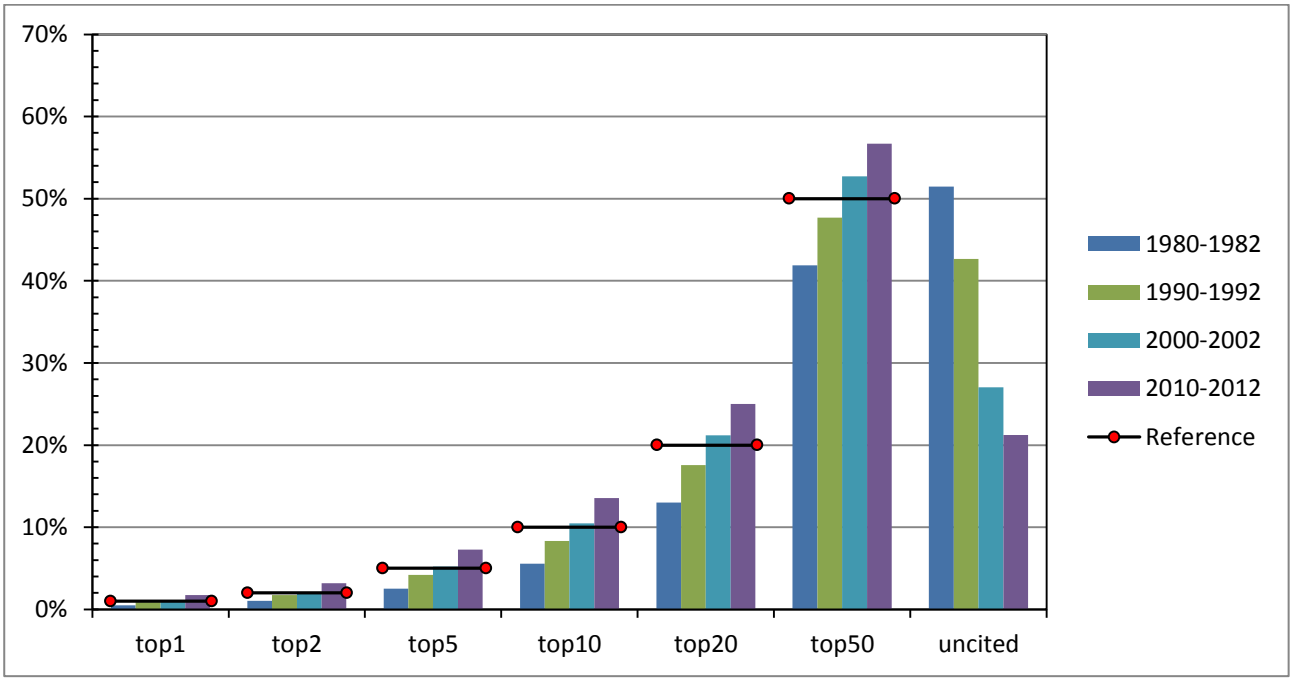


Figure 4.11. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Austria. Indicators are based on full counts. A corresponding plot for fractional counts is found in Figure A.8 in the appendix.



5 Performance at selected field levels

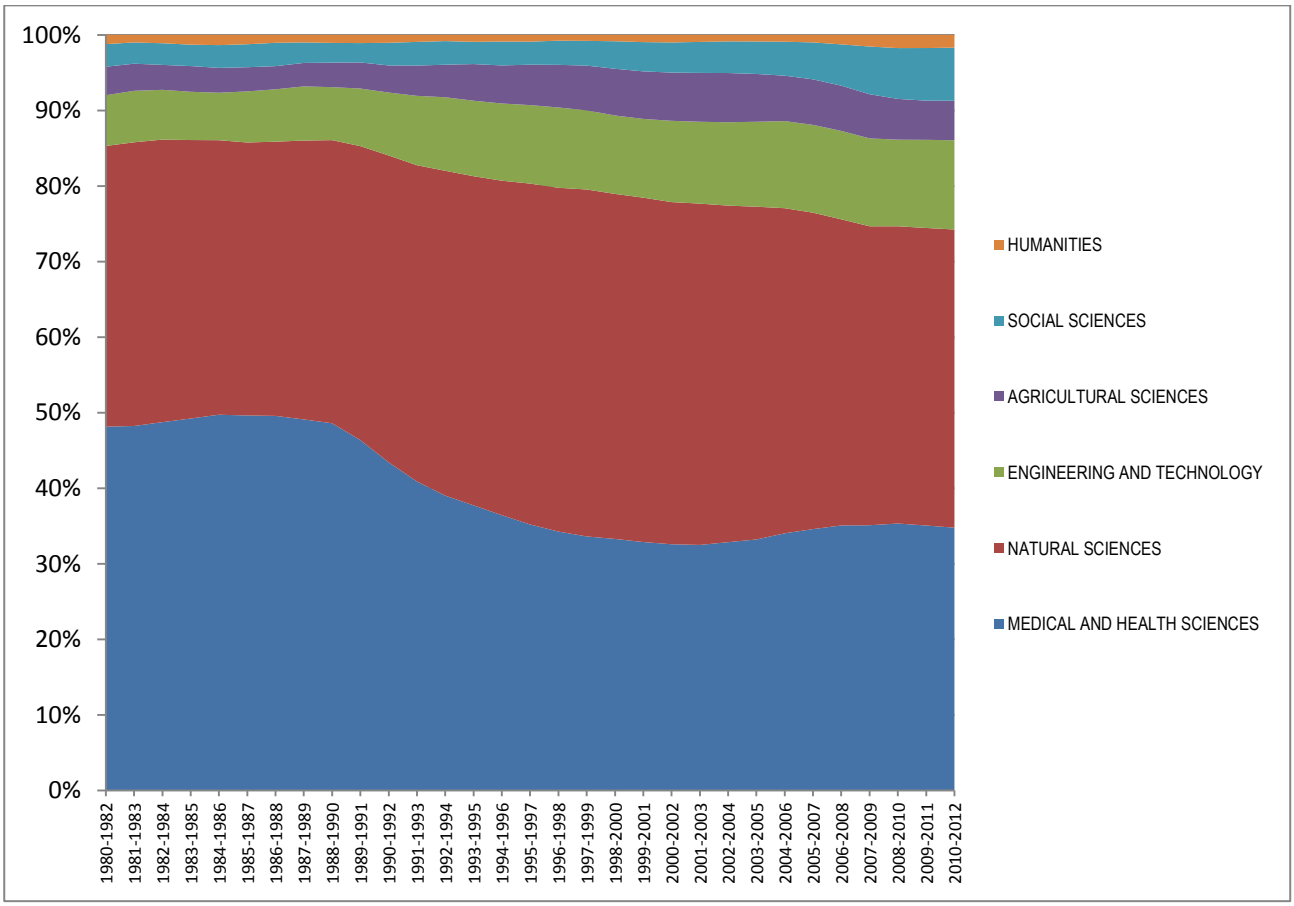
In this section we then turn to the internal composition of the Danish development. In the examination we look at two different field levels: first the OECD field level classification based on the Frascati Manual with six main areas and secondly at a more detailed categorization based on the Dutch NOWT low categorization where we end up with 16 subfields. For each of the two levels we start out by showing the relative volume of the different fields in order to illustrate their influence on the overall Danish performance. We then proceed by showing the developments in performance at the two selected levels in order to examine how the developments at the field levels relate to the overall Danish development. However, in order to address potential problems related to comparisons across fields we include the benchmark countries in the analysis at the OECD-field level to examine whether we find systematic field differences across countries which should be taken into account when we interpret the Danish results.

5.1 Performance at the OECD fields level

At the OECD field level we operate with six categories: *Natural Sciences*. *Medical and Health Sciences*. *Engineering and Technology*. *Agricultural Sciences*. *Social Sciences* and finally the *Humanities* and show the developments in performance for each individual field. However, as pointed out in the introduction and in Chapter 3 the database coverage of the research activities varies significantly across fields. In general, the coverage is good for the *Natural Sciences* and *Medical and Health Sciences*, more mixed for *Agricultural Sciences* and *Engineering and Technology* where some subfields are well-covered and others not, and finally the coverage is in general rather poor for large parts of the *Social Sciences* and especially the *Humanities*. The modest coverage of some areas furthermore means that their total number of publications becomes low which results in large fluctuations in performance and adds even further problems to the interpretation of the trends.

The latter point is illustrated in figure 5.1 below showing the relative distribution of the total number of Danish publications for each individual OECD field in the WoS. As can be seen the two fields with good general coverage are also the two fields which constitute the large majority of the total Danish production of publications in the WoS. Notice, that the field of *Natural Science* also is the one benefitting the most from the full counting method due to a higher degree of internationalization. However, the same figure based on fractional counting is shown in the appendix, Figure A.9, and shows that the difference in counting method only makes a slight difference in the overall pattern.

Figure 5.1. Developments in the relative distribution of Danish WoS publications among six main OECD fields, shares are based on full counts. A corresponding plot for fractional counts is found in Figure A.9 in the appendix.

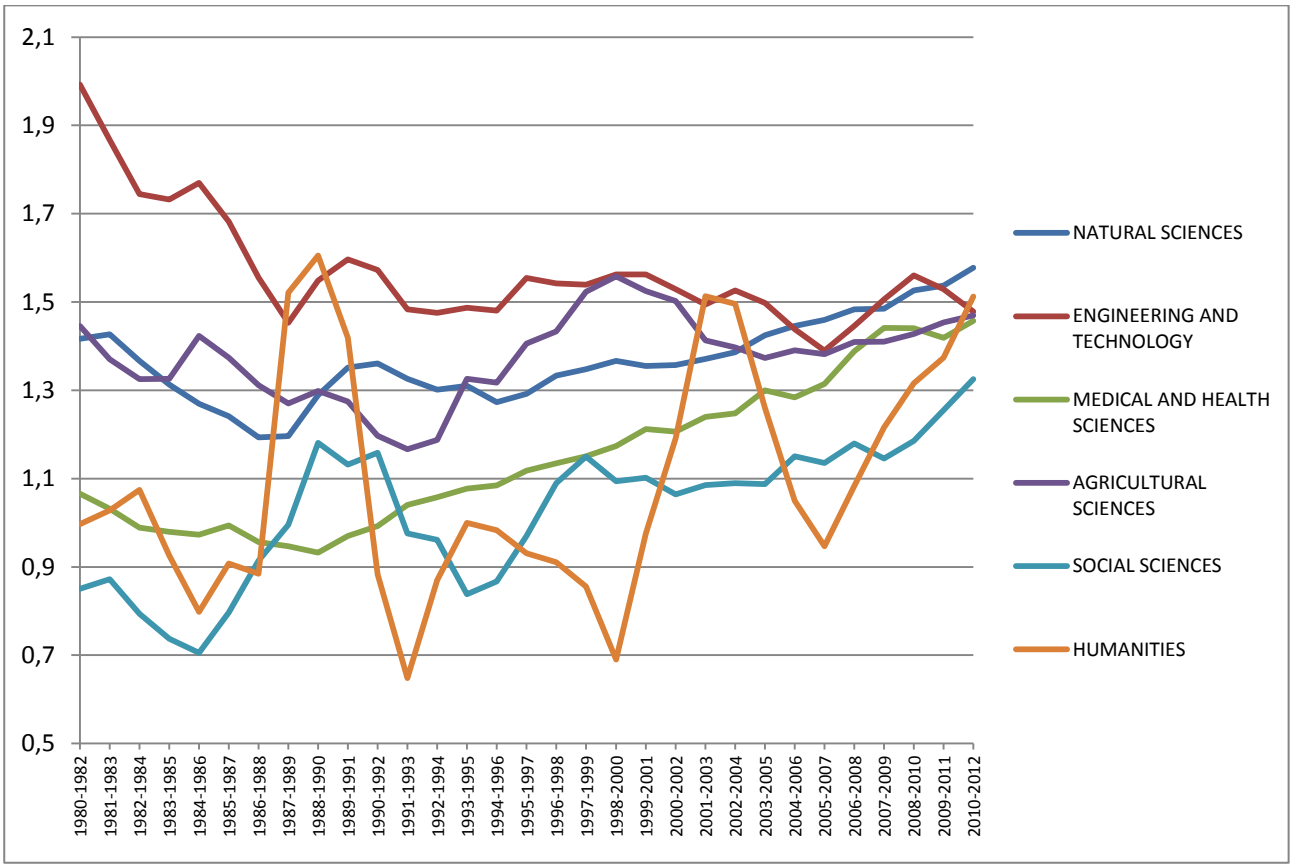


At the beginning of the period the *Medical and Health Sciences* and the *Natural Sciences* produced close to 85 percent of all Danish WoS publications. By the end of the period this figure is dropped to close to 75 percent, largely due to a relative drop in the share of publications from the *Medical and Health Sciences* and a relative increase within other fields - in particular the *Natural Sciences*. *Engineering and Technology and the Social Sciences*. But while the *Social Sciences* have increased their share from around 3 percent at the beginning of the period to close to 8 percent by the end, this field still plays a minor role in the overall picture. Similarly, the field of *Humanities* has increased its share from 1.3 percent to 2.3 percent and plays an even more marginal role due to the low coverage of this area. In between comes the *Agricultural Sciences* which are similar in size and development to the *Social Sciences*, and finally *Engineering and Technology* which shows an increase from a little more than 7 percent of the total to a little more than 12 percent. The changes in the relative shares of the different fields are to a large degree database effects resulting from a large increase in the number of journals covered as described in chapter 3. The relative drop of the *Medical and Health Sciences* is accordingly not the result of shifting Danish research policy priorities. On the contrary, this field has experienced a steady increase in the share

of public research funding since the late 1990s and is today by far the largest Danish research field with regard to funding (Lauridsen & Graversen, 2013). While funding changes may play a minor role for the other fields, the main explanation for the shifts observed in figure 5.1 is most likely that the growth in the number of journals in WoS has been skewed in favor of specific areas; in particular the *Natural Sciences*. *Engineering and Technology* and the *Social Sciences*. Another factor of importance may be different developments across fields with regard to internationalization and collaboration. Anyhow, these shares should be kept in mind when the developments of the individual fields are interpreted. Put simply, small changes in performance within large fields may affect overall performance more than large changes within small fields.

With these caveats in mind we now turn to figure 5.2 showing the development in MNCS at the OECD field level. When we interpret the Danish development in isolation we see a number of interesting trends. First of all, it is clear that Denmark by the beginning of the period was performing extremely well within *Engineering and Technology* and very well within *Natural Science* and *Agricultural Science*. The performance of the *Medical and Health Sciences* was however more modest. Both the *Humanities* and the *Social Sciences* show large fluctuations as a result of small numbers of publications indexed in the WoS and it is accordingly impossible to interpret the performance of these areas based on this data material. This applies to the *Humanities* for the period as a whole, while the volume of the *Social Sciences* in the period after 2000 has reached a level where the development becomes more stable and thus more interpretable. The same applies to some degree to the *Agricultural Sciences*. It is noticeable that the drop in performance in the 1980s can be observed within the four fields with acceptable coverage. However, even at the low point the fields of *Natural Sciences* and *Engineering and Technology* perform strongly. When we then look at the development from the early 1990s and onwards we see that the two largest areas both show a positive development. In particular the development of the *Medical and Health Sciences* play a major role in explaining the positive overall Danish development in the latter half of the analyzed period due to the size of this field. By the end of the period this field has almost reached the level of the *Natural Sciences* and *Engineering and Technology*. Also the *Social Sciences* show a clear positive trend towards the end of the period. In the appendix figures A.11 to A.15 show the development in PPtop10%, PPtop5%, PPtop1% and the share of uncited publications for each field based on full counts. These figures confirm the findings outlined above. We only provide mean normalized citation scores based on fractional counts in support of Figure 5.2 because the trends are the same.

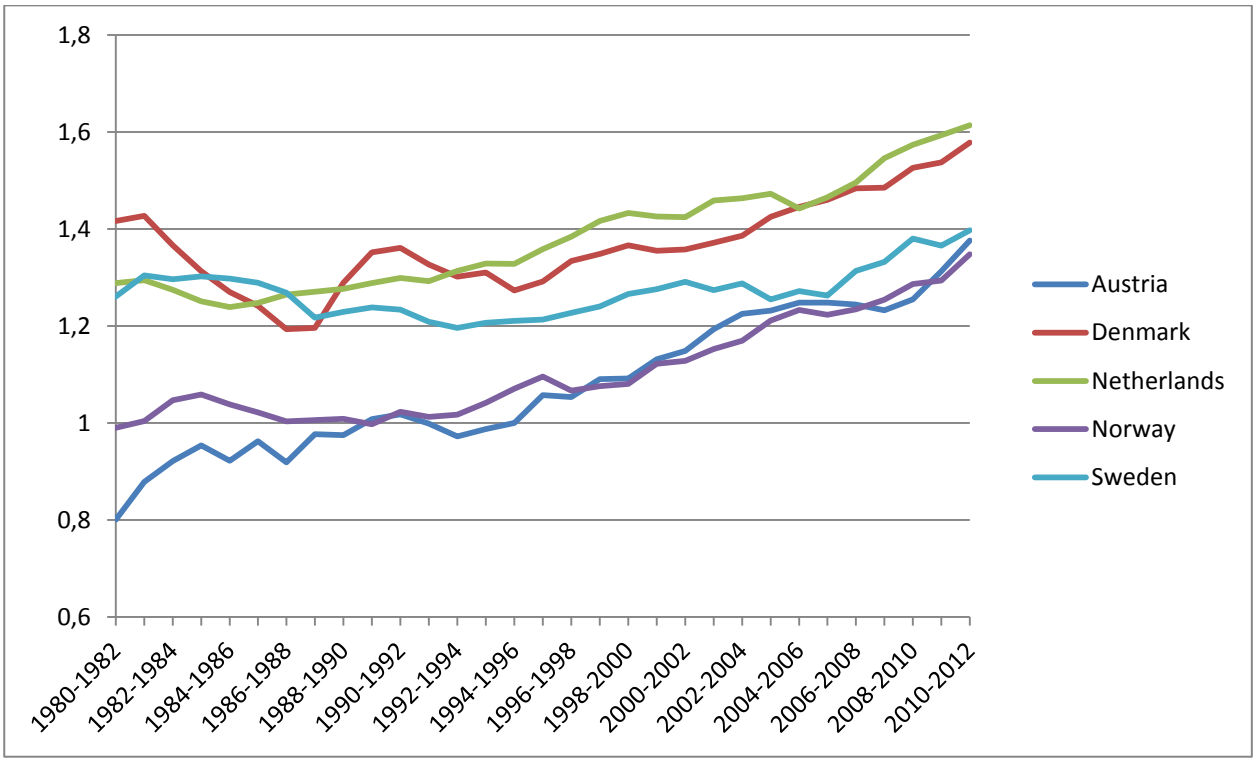
Figure 5.2. Developments in mean normalized citation scores (MNCS) at the OECD field level for Denmark. The indicator is based on full counts and calculated for three year overlapping publication blocks. A corresponding plot for fractional counts is shown in Figure A.10 in the appendix.



However, this picture could be somewhat misleading with regard to comparing performances across fields due to different types of database biases. To examine whether there are systematic differences between fields across countries the following six figures show the development per field across the five benchmark countries.

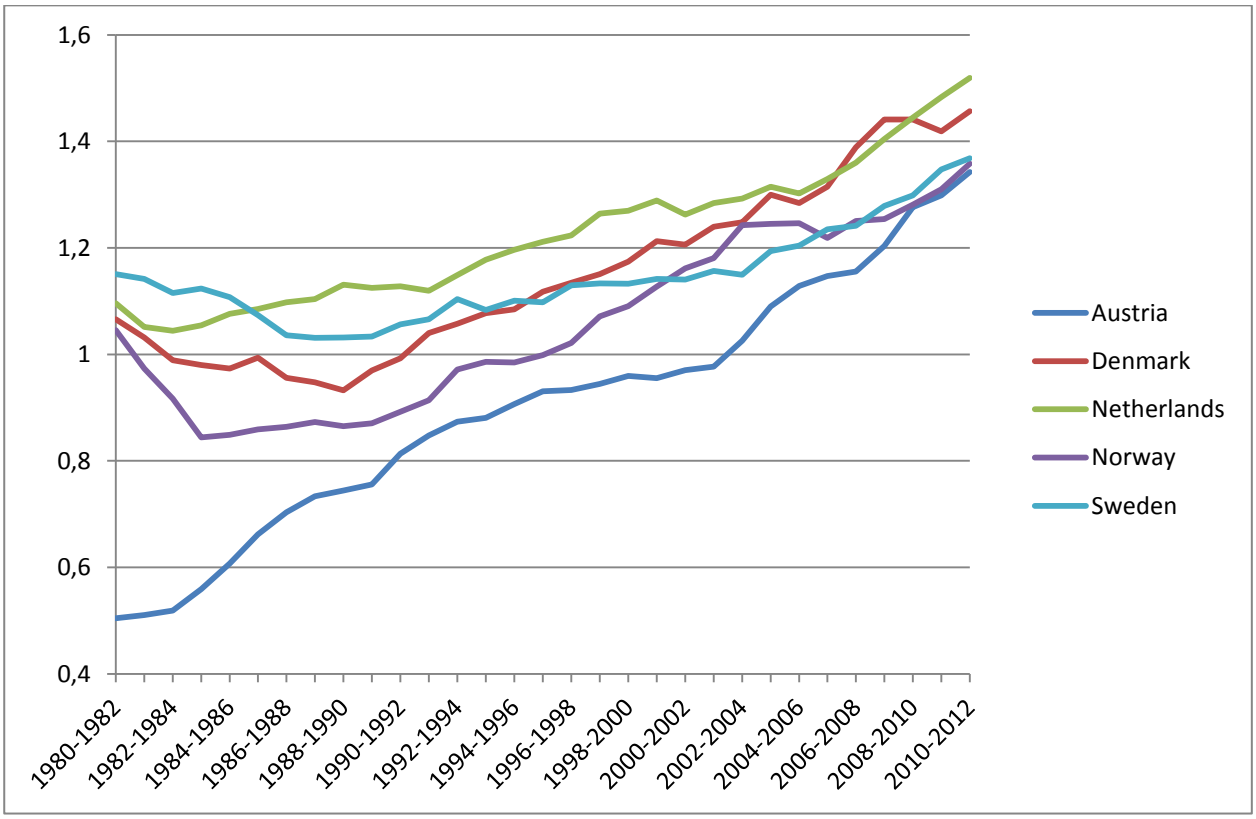
In figure 5.3 we see that the apparent Danish strength within the *Natural Sciences* also is very visible in comparison with the benchmark countries. We also see that the drop in overall national performance during the 1980s is mirrored at this field level and that the Danish drop is significant in comparison with the development within the benchmark countries. A substantial part of the explanation of the overall Danish trajectory can in other words be found within this field due to its large relative share of the total number of Danish WoS publications. Similarly, It is also noticeable that for all countries the developments of this field is very similar to the developments at the aggregated level.

Figure 5.3. Comparison of the developments in mean normalized citation scores (MNCS) in the OECD main field natural sciences for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.



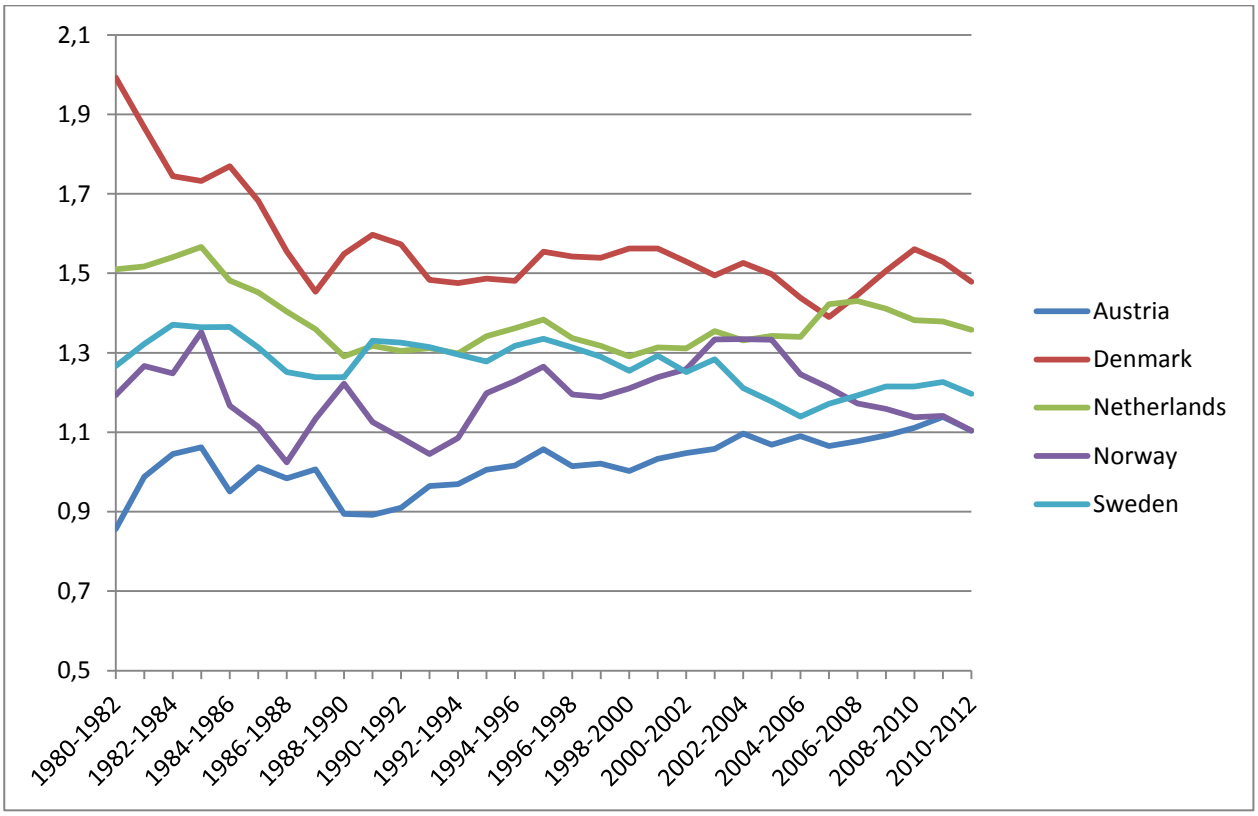
In figure 5.3 we then turn to the development within the *Medical and Health Sciences*. Here we see that this field consistently performs at a lower level than the field of the *Natural Sciences* in all countries. The explanation is most likely that the journals of this field indexed in the WoS are more of a mixed bag than the journals indexed for the *Natural Sciences* as described in chapter 3. Among the medical journals we find a substantial part which is more local and not purely oriented towards academia resulting in lower citation activity, while the journals within the *Natural Sciences* are more "purely" academic. This affects the overall performance of the fields and may explain (parts) of the field differences. Besides this relative lower performance of the field as a whole across all countries we see that the *Medical and Health Science* field of Denmark performs very well in comparison with the benchmark countries. In comparison with the Netherlands the Danish performance within this field has been more positive since the early 1990s and has closed a substantial gap. However, also here we see the drop in performance during the 1980s which also can be noticed for both Sweden and Norway. Again it should be kept in mind that we are dealing with a very large field and the developments here thus play a very large role in the overall Danish performance. To understand the overall Danish development the two fields analyzed in figure 5.2 and 5.3 are accordingly by far the most important ones from a system level perspective.

Figure 5.4. Comparison of the developments in mean normalized citation scores (MNCS) in the OECD main field medical sciences for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.



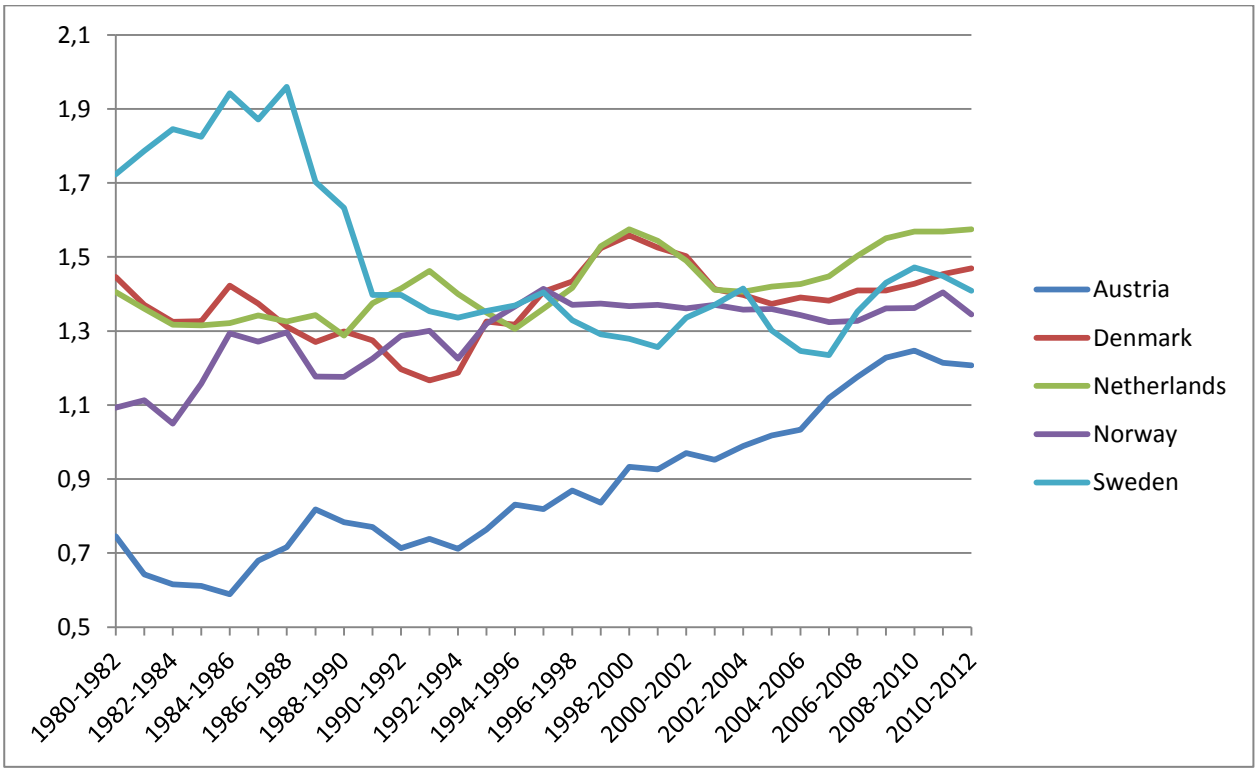
While the development within *Engineering and Technology* plays a more marginal role in explaining the overall Danish performance due to its volume, the trajectory is still highly interesting. We see that the Danish performance within this field was exceptional by the beginning of the period – not only relative to the other Danish fields but also relative to the benchmark countries. Despite a substantial drop during the 1980s the field remains very high performing throughout the period. The field as a whole is however much smaller than the two fields analyzed above and thus plays a lesser role in the overall development – although the very high performance clearly has contributed positively throughout the period. We also remind that this field in general has a substantial part of its publication output in conference proceedings. The development shown in the figure is thus not representative for the performance of the field as a whole.

Figure 5.5. Comparison of the developments in mean normalized citation scores (MNCS) in the OECD main field engineering and technology for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.



Also the field of *Agricultural Science* has performed well throughout the period at a level similar to the other benchmark countries (except Austria). However, the total volume of the field is low and the development should thus be interpreted with caution. Similarly, due to the size of the field it has limited impact on the overall Danish development.

Figure 5.6. Comparison of the developments in mean normalized citation scores (MNCS) in the OECD main field agricultural sciences for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.



Finally, the problem observed above with regard to the problems associated with low volume is even more pronounced when we turn to the two last figures in this section. As figure 5.7 and in particular figure 5.8 show we have very large fluctuations in performance within these fields. Coupled with the low coverage in WoS of the total research activities within large parts of these fields, we find performance assessments inappropriate in this context. However, we see by the end of the period a more stable development within the *Social Sciences* as a result of an increasing volume. As mentioned above, the trend appears to be very positive from 2000 and onwards but we need a longer time-perspective to assess whether this is a fluctuation or a more stable trend. The figure also shows that the larger size of the Dutch and Swedish systems leads to more stable developments for these countries in the latter half of the figure.

Finally, figure 5.8 is only included to illustrate the problems associated with using these types of indicators within the *Humanities*.

Figure 5.7. Comparison of the developments in mean normalized citation scores (MNCS) in the OECD main field social sciences for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.

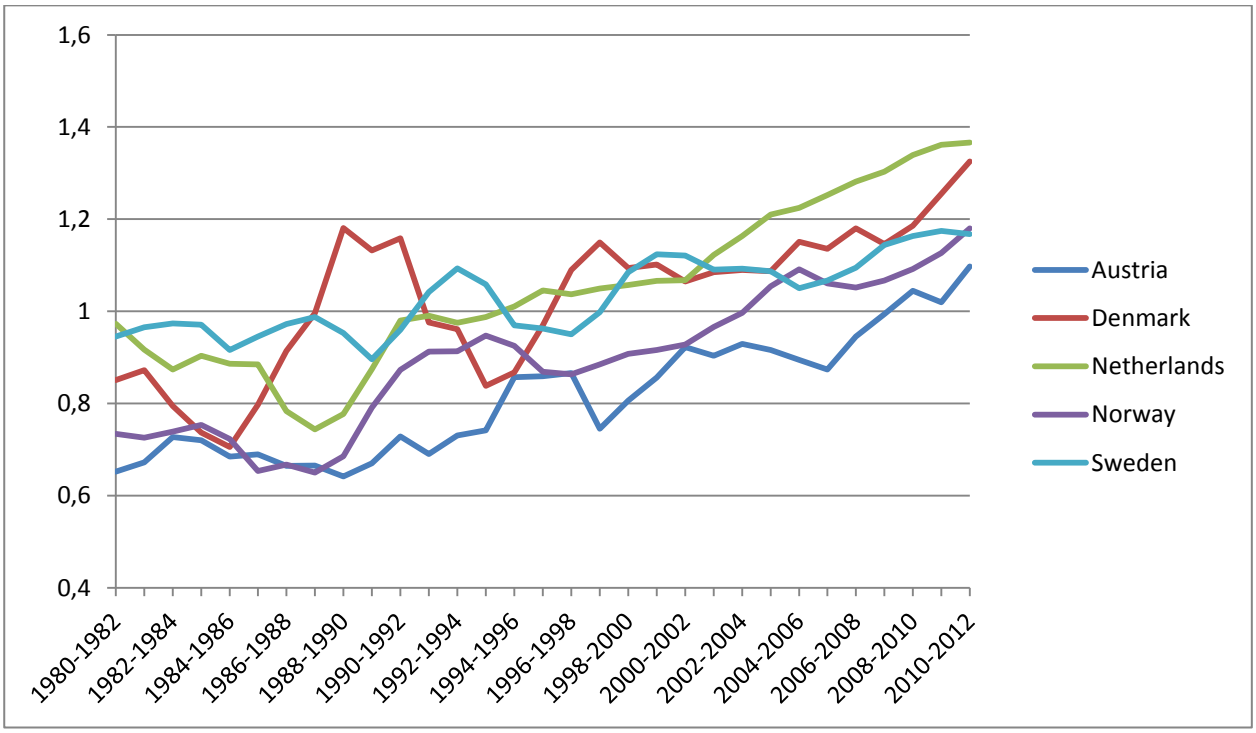
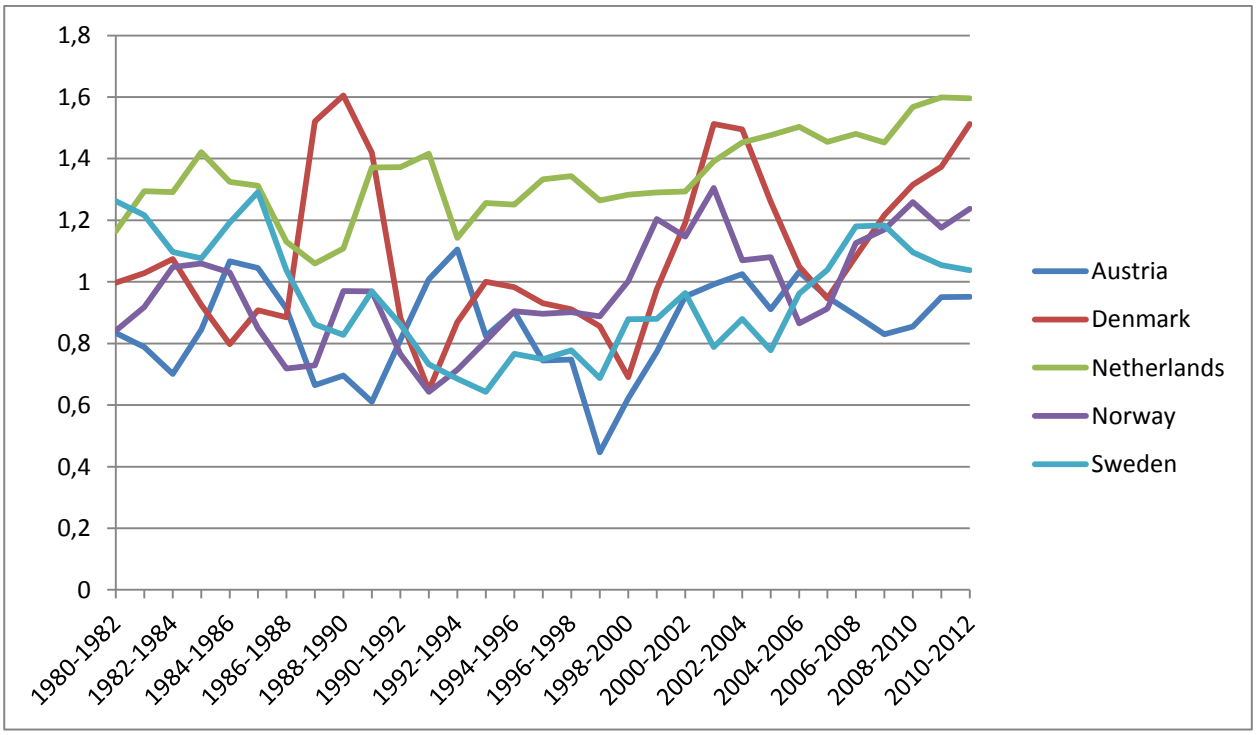


Figure 5.8. Comparison of the developments in mean normalized citation scores (MNCS) in the OECD main field humanities for Denmark and the four benchmark countries. The indicator is based on full counts and calculated for three year overlapping publication blocks.

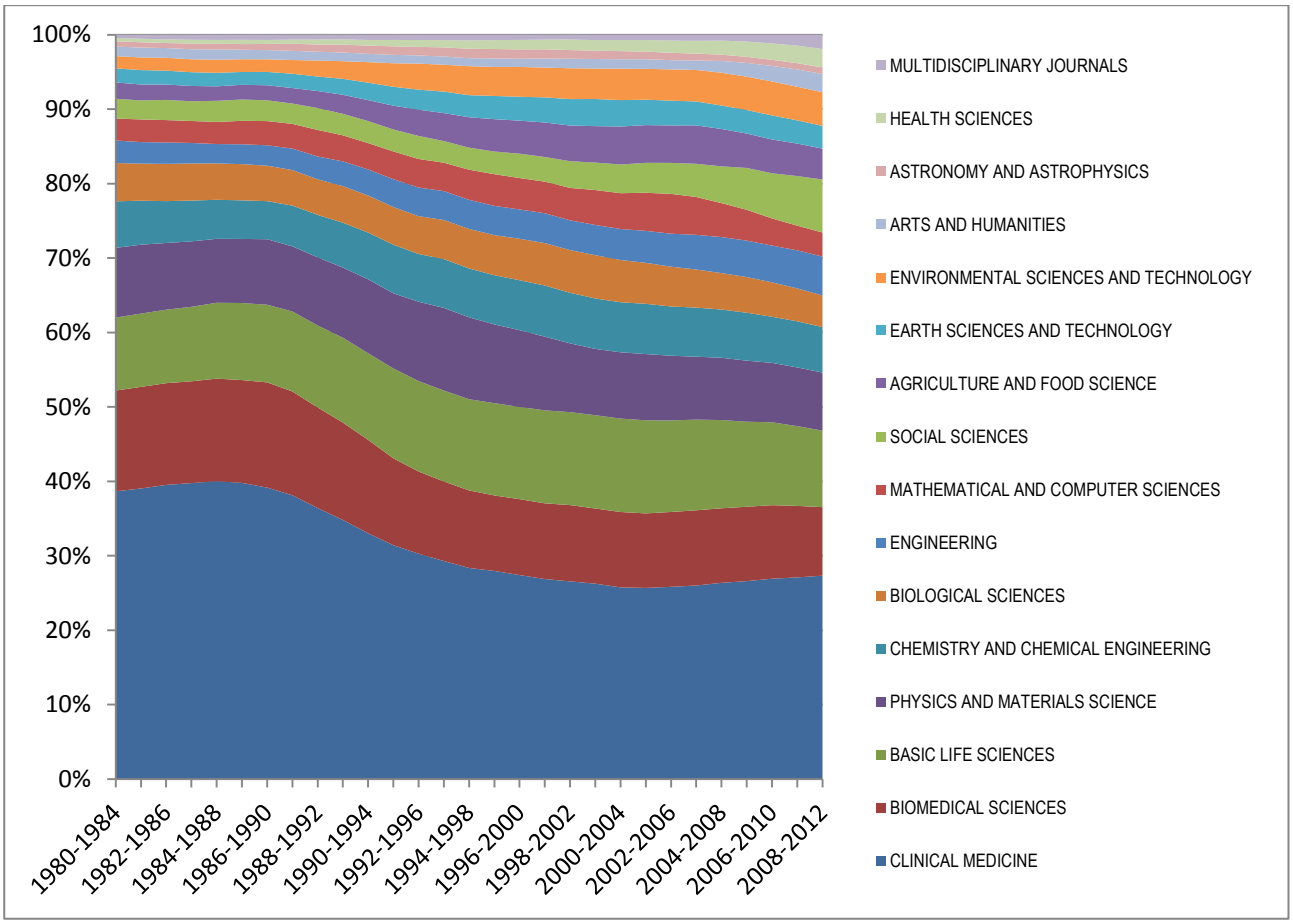


5.2 Performance at subfield level

In addition to the analysis at the OECD-field level shown above this section more briefly presents the development of selected areas at a subfield level. Based on the Dutch NOWT-low classification which operates with 35 categories we have created 16 subfields. The reclassification from 35 to 16 has been made to enhance the overview of the development, to secure data robustness and to minimize random fluctuations. The content of the classification can be seen in the appendix, section 10.1 and 10.2. First we show the relative size of these subfields with regard to the Danish publications indexed in the WoS in order to highlight the importance of each individual field in explaining the overall Danish development. Then we turn to the development in impact for 11 of these subfields. Five of the subfields have thus been excluded in the time-series due to large fluctuations in performance. For four of the subfields the reason for the fluctuations is a too low volume. These subfields are the four smallest in figure 5.9 below: *Multidisciplinary Journals*, *Health Sciences*, *Astronomy and Astrophysics* and *Arts and Humanities*. The fifth excluded category is *Mathematical and Computer Sciences*, not due to too low volume, but rather as a result of too much heterogeneity between the areas included in this category resulting in very large fluctuations as well. However, the size of all areas is shown in figure 5.9 below in order to present the relative size of each sub-field correctly.

As this figure shows the three largest sub-fields are all found within the *Life Sciences*. Not surprisingly, *Clinical Medicine* is by far the largest sub-field. *Clinical Medicine*, *Biomedical Sciences* and *Basic Life Sciences* taken together account for more than 50 percent of all Danish publications indexed in the WoS in the latest period. At the beginning of the period this figure was above 60 percent! Moving on from the bottom of the figure we see that the 4^{th}. 5^{th} and 6^{th} largest subfields (*Physics and Materials Science*, *Chemistry and Chemical Engineering* and *Biological Sciences*) all belong to the *Natural Sciences*. However, these three subfields taken together are only about half the size of the three *Life Science* subfields. The remaining subfields are all relatively small. It is however noticeable that the *Social Sciences* display a strong growth by the end of period. This is most likely both a database-effect (as a result of inclusion of more *Social Science* journals) and a result of a rapidly increasing internationalization within this subfield during the latest decade. As with the analysis at the OECD field level it should be underlined that the volume of each subfield in this figure is not representative of the real size of the fields. Due to differences in coverage across fields some are better represented than others.

Figure 5.9. Developments in the relative distribution of Danish WoS publications among 16 NOWT fields, shares are based on full counts. Notice, the NOWT classification comprises 35 fields at the lowest level; we have reclassified these to 16. A corresponding plot for fractional counts is found in Figure A.15 in the appendix.

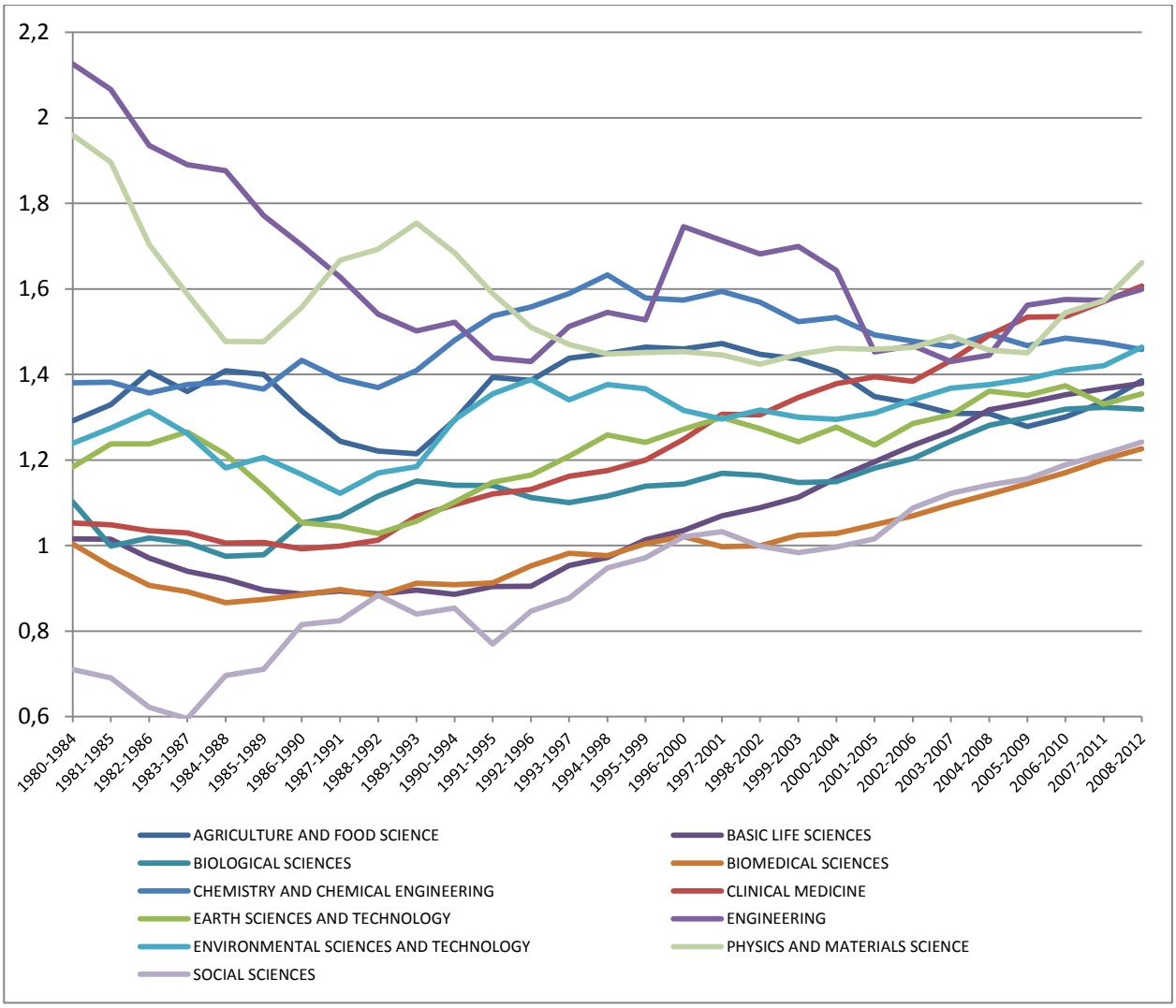


If we then look at the development in MNCS for 11 eleven of these subfields we can observe that the overall picture resembles the one shown above at the OECD-field level. There are however interesting variations which we will comment on below. First we show all the 11 subfields in the same figure (figure 5.10) in order to illustrate the relative standing of each individual subfield. Afterwards we look more closely at three figures showing the developments for three subfields each. The *Social Sciences* subfield and the *Agricultural Sciences* subfield is not shown again as they are identical to the OECD field level categories shown above.

Overall, we see the same picture as at the OECD field level. The *Natural Sciences* subfields and the *Engineering and Technology* subfields perform very well from the beginning of the period and continue to perform well in spite of a drop in the 1980s. The *Life Science* subfields on the other hand perform more modest by the beginning of the period but display a strong catch up in the latter half of the period. In figures 5.11 to 5.13 we look more closely at these developments.

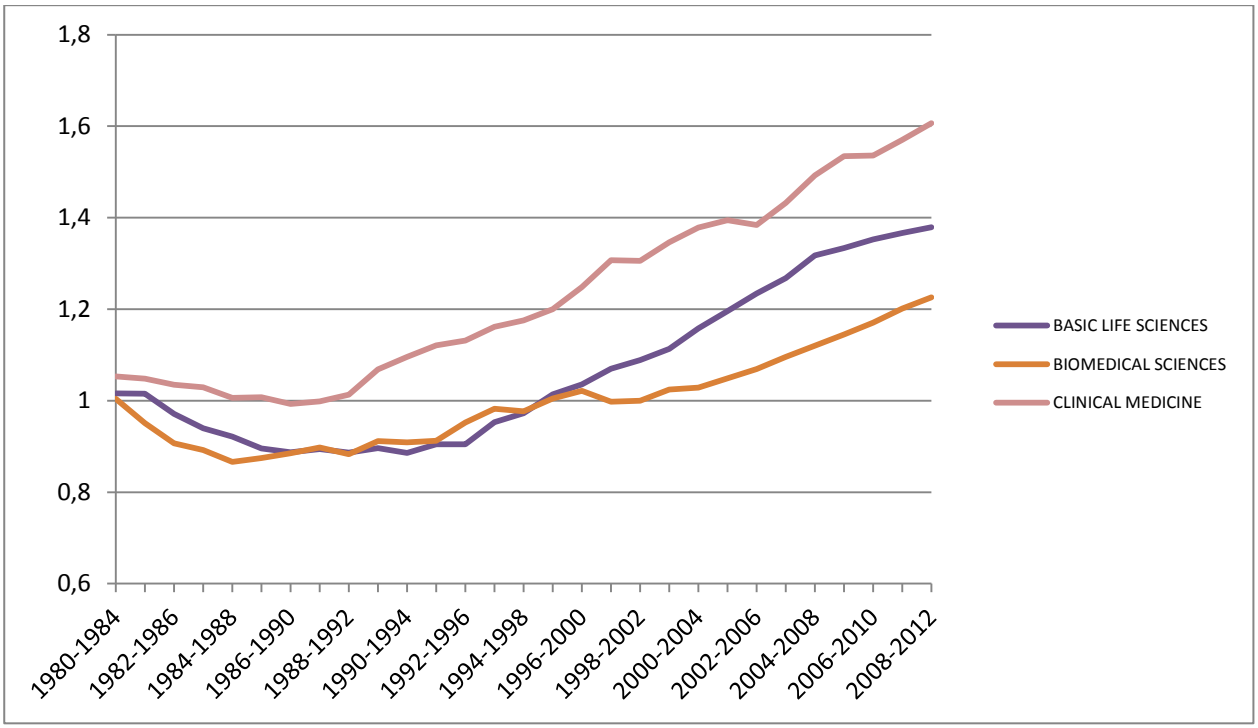
Overall we also observe a clear narrowing of the gaps between different sub-fields over time which mainly is a result of database changes.

Figure 5.10. Developments in mean normalized citation scores (MNCS) for 11 NOWT subfields for Denmark. The indicator is based on full counts and calculated with five year overlapping publication blocks (five year blocks are chosen due to low annual outputs for certain fields).



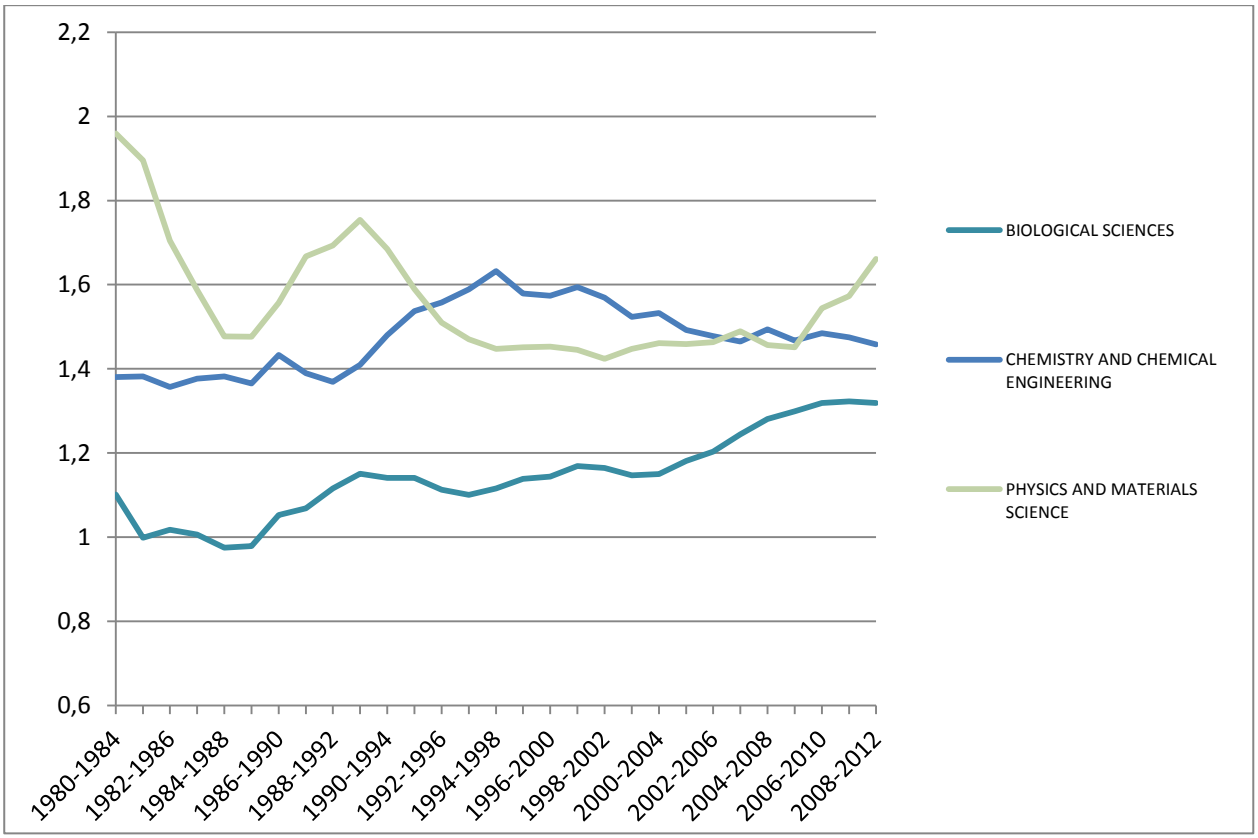
In figure 5.11 the development in performance of *Clinical Medicine*, *Biomedical Sciences* and *Basic Life Sciences* is shown. We again see the pattern of a modest starting point and a strong positive development in the latter half of the period for all three subfields. But we also notice that *Clinical Medicine* has the most positive development of the three. Due to the very large size of this subfield this development plays a major role for the overall Danish development. Finally, we see the stability in the trends for all three areas due to the high volume of them all.

Figure 5.11. Developments in mean normalized citation scores (MNCS) for three subfields in the Life sciences clinical medicine, biomedical sciences and basic life sciences for Denmark. The indicator is based on full counts and calculated with five year overlapping publication blocks (five year blocks are chosen due to low annual outputs for certain fields).



When we then turn to the three subfields within the *Natural Sciences* we see a quite different picture. First of all, we see *Physics and Materials Science* dropping from an exceptionally high level to a very high level which is maintained throughout the period. *Chemistry and Chemical Engineering* on the other hand displays a constant high level throughout the period with an even higher peak during the 1990s. Finally, the development of the *Biological Sciences* resembles the trends shown above for the *Life Science* subfields. As seen above the trends of the *Life Science* subfields are somewhat lower than the trajectories for *Physics and Materials Science* and *Chemistry and Chemical Engineering*. Given the close ties between the *Biological Sciences* and the other *Life Science* subfields (in particular the *basic life sciences*) this resemblance in development is unsurprising.

Figure 5.12. Developments in mean normalized citation scores (MNCS) for three subfields in the Natural sciences physics and materials science, chemistry and chemical engineering and biological sciences for Denmark. The indicator is based on full counts and calculated with five year overlapping publication blocks (five year blocks are chosen due to low annual outputs for certain fields).



Finally, figure 5.13 shows the development for three subfields within the *Engineering and Technology* area. The subfield *Engineering* performs at an extraordinarily high level by the start of the period and then drops to a very high level for the rest of the period. The resemblance between this development and the development of *Physics and Materials Science* shown above is most likely not a coincidence – at least not when we look at the first part of the period. In the early 1980s Denmark had one of highest cited research groups in the world working with super conductivity. Publications from this group lead by Claus Bechgaard probably play a big role for both the high performance of *Physics and Materials Science* and *Engineering* during the first years of the 1980s (see Nørretranders, 1990). The two other subfields within this category start out at a lower level but end up at a very good performance level. Given the smaller size of these subfields we also observe larger fluctuations.

Figure 5.13. Developments in mean normalized citation scores (MNCS) for three subfields in Engineering and technology earth sciences and technology, engineering and environmental sciences and technology for Denmark. The indicator is based on full counts and calculated with five year overlapping publication blocks (five year blocks are chosen due to low annual outputs for certain fields).

6 Analyses of journal publication behaviour

The previous chapters have focused on the developments in citation impact of the actual journal articles. This and the next chapter focus on some of the characteristics known to influence aggregate citation rates: journal publication behaviour (this chapter) and international collaboration (next chapter).

It is generally a misconception to think that an article published in a high impact journal will be more cited than an article in a lower impact journal. Citation distributions are highly skewed, where a smaller subset of papers attract the large majority of the citations. This is the case both for high and low impact journals. Obviously, high impact journals are designated as such because they attract substantially more citations than low impact journals, but like low impact journals, these citations are received by a smaller subset of the articles in an annual journal volume. So where an article is published is only a weak predictor of the future citation impact of that article. On the aggregate level, however, a unit's general journal publication behaviour becomes a stronger predictor for subsequent impact as a higher publication activity in higher impact journals, other things being equal, raises the likelihood that some of these publications will eventually be among the subset of articles attracting the majority of the citations in these journals.

Below we present two trend analyses of journal publication behaviour: 1) a comparison at the country level and 2) trend analyses for each country. As discussed in Chapter 3, we do not use the traditional "Journal Impact Factor". Instead we apply the MNJS which is an aggregate mean-normalized citation score of the journals in which the country has published in a given period. The MNJS indicator is aggregated to the country level in the first trend analysis where we examine the development in the indicator over time. In the second analysis, we disaggregate the journal publication behaviour for each country by constructing five journal impact classes based on the MNJS (i.e., from A to E where class A contains the journals with the lowest MNJS and class E contains the highest indicator scores) and then examine the relative distribution of the country's three-year overlapping publication outputs among these five classes over time. We are hereby able to examine the potential differences between the countries when it comes to aggregated journal publication behaviour, and examine whether the differences are stable over time. Changes in journal publication behaviour. e.g., increased publication in higher impact journals should, other things being equal, increase the visibility of a country's publications and therefore also increase the likelihood for higher citation impact.

Figure 6.1 shows the development in the overall publication behaviour according to the MNJS indicator for the five countries. From 1991-93 onwards, all countries show a general increase in the indicator, albeit with individual differences, whereas overall trends before 1991-93 are slightly

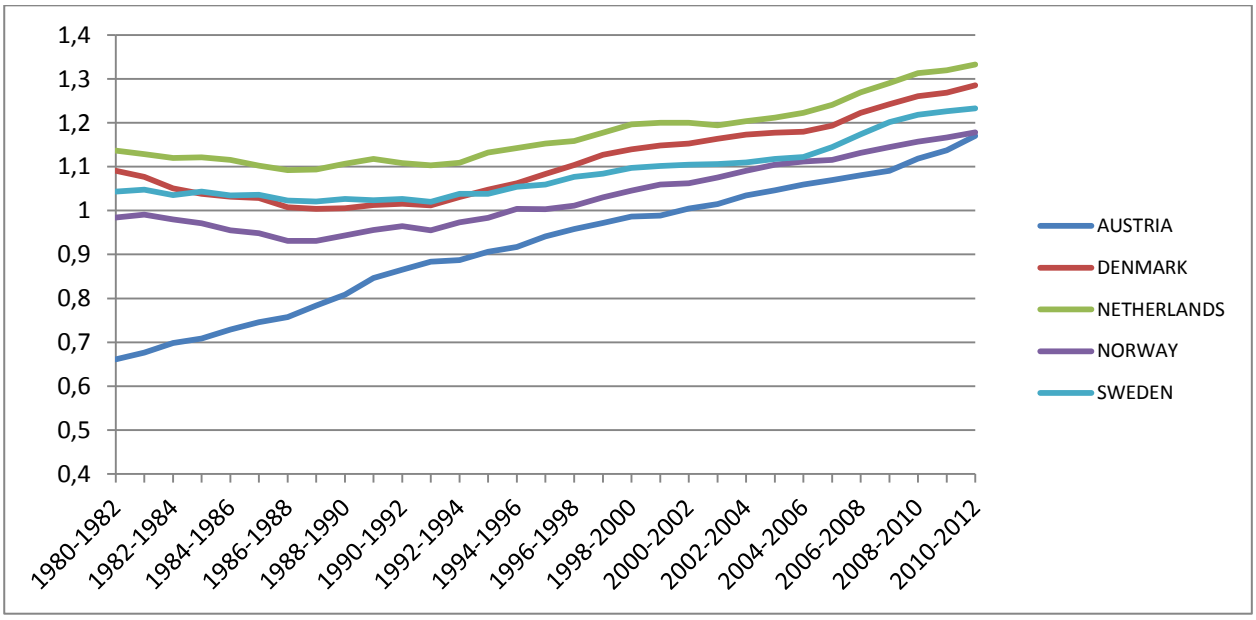
more diverse. The long term development for Austria is somewhat different compared to the other countries. The MNJS value for Austria is by far the lowest in the first three-year publication block (1980-82), but hereafter it continuously increases, almost at a linear growth rate with an approximate growth of 0.02 MNJS points for every three-year publication block. Noticeable, while the individual rank order between the countries in the last three-year publication block is similar to the first block. Austria has closed the gap to Norway and basically has the same overall journal publication profile according to MNJS as Norway.

The general increase in MNJS values, especially from the 1991-93-block and onwards, is to some extent a function of the changes in the database with the expansion of especially Asian journals during the 2000s as described in Chapter 3. As a consequence, the overall MNJS for the "traditional" primarily English language journals already in the database have increased. So far, citation traffic between these "new" journals and the "old" journals in the database is basically one-directional going to the "old" journals who thereby benefit from this. Austria's very low MNJS score in the first three-year block and the special linear trajectory from this origin is to a large extent due to language issues. In the first block (1980-82) 52% of the Austrian publications were in German (48% in English), whereas the percentages of English language publications for countries such as Norway and Denmark are around 95-96%. In the block 1991-93, where the other countries begin their common increase in MNJS scores, the proportion of English language publications has increased to 79% for Austria. And in the final block, where Austria has closed the gap to Norway, the publication language difference is also eliminated as the proportion of English language publications for Austria is now 95% and thereby comparable to the all the other countries. For these countries the proportion has been stable around this number for the whole period examined.

But the development in the database and the language issue are not the whole story, the different trajectories for the individual countries testify to that. All countries (except Austria) experience a drop in MNJS values from the first three-year block in 1980-82 until 1991-93. Noticeable, the drop seems most striking for Denmark. The Danish MNJS score is higher than Sweden in the first block, but is surpassed by Sweden during the 1980s mainly because the Swedish drop is quite small. Around 1993-95 the Danish journal publication profile has again surpassed Sweden and what is noticeable here is that both countries experience an increase in their MNJS scores, but the Danish growth is generally steeper which results in a considerable gap between the two countries by 2004-06. The gap has shrunken a bit since then. If we compare Denmark to the Netherlands, then we see that the more distinct drop in publication behaviour in the 1980s for Denmark results in a widening gap to the Netherlands. But from 1991-93 the Danish rise in MNJS scores is steeper for almost a 10-year period compared to the Netherlands. The result is that around 2001-03 the gap between Denmark and the Netherlands is more or less the same as at the beginning in 1980-82.

As indicated above, the MNJS and MNCS indicators are correlated, so when you see a rise in the MNJS you would also expect to see a rise in the MNCS indicator. Figure 4.3 in section 4.3, presents the development in the overall MNCS scores for the five countries. It is very clear that the overall trends are the same. Denmark experienced a marked drop in the MNCS scores during the 1980s, meaning that Danish research publications were cited less frequently compared to the period in 1980-82. Similar, Denmark also experiences a marked drop in MNJS scores in the same period meaning that Danish publications in this period generally were published in journals with lower impact. From the early 1990s all countries experience general increases in both MNCS and MNJS scores. If we compare the developments for the two indicators for the five countries, the Danish case is again interesting. While the journal publication behaviour according to the MNJS scores generally rises for all countries, the Danish MNCS score catches that of the Netherlands around 2000 and the two impact scores follow each other thereafter. It is quite clear that in the period up to 2000. Danish publication behaviour changes more than the Dutch, but it is also noticeable that while there remains a gap in MNJS scores, the publication profile scores for the Netherlands are continuously above those of Denmark. Danish and Dutch impact (MNCS), however, is basically equal. One probable reason for this is that Danish articles in lower impact journals receive relatively more normalized citations than the corresponding Dutch articles, or similarly, the Netherlands are not able to "cash in" on their general higher visibility in higher profiled journals on citations compared to Denmark.

Figure 6.1. Development in mean normalized journal scores (MNJS) based on full counts for Denmark and the four benchmark countries; three year overlapping publication blocks.

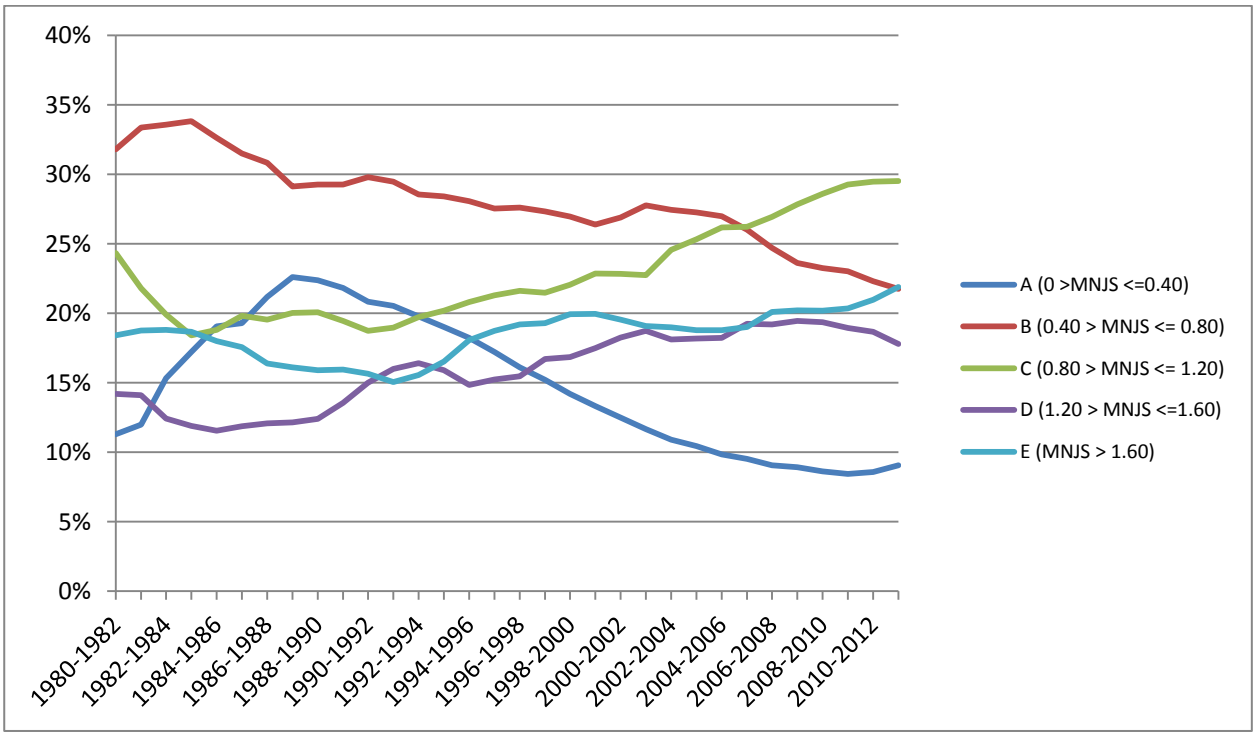


Following this aggregated analysis we now examine the publication behaviour for individual countries where we break down the MNJS score into five classes and examine the trend in the

proportion of articles published in each of the five classes for the five countries. We focus on the development for Denmark in figure 6.2 and use the remaining four countries as comparisons for the Danish development (figures 6.3 to 6.6).

For each three-year publication block we calculate for all journals in the database their mean normalized journal (citation) scores (MNJS). As the scores are normalized they are comparable across fields and thus between journals. Subsequently, journals are assigned to one of five impact classes independent of their respective subject fields. Thus, the lowest impact class A contains all journals in the database in a given publication block with an MNJS score < 0.4 and the journals with highest normalized impact scores, i.e., > 1.60 are assigned to class E. The "average" impact journals in the database for a given period are assigned to Class C. Notice, as we recalculate the MNJS scores for each period journals can change impact classes over the period.

Figure 6.2. Development in distribution of journal output between five MNJS impact classes for Denmark based on full counts and three year overlapping publication blocks.



If we first compare the situation in 1980-82 with the final publication block from 2010-12, we see that the publication behaviour has changed in as much as the shares of publications in the two lowest impact classes have dropped 2 and 10 percentage points respectively for class A and class B (from 11% to 9% (A) and 32% to 22% (B)). Correspondingly, the "average" impact class C has risen 5 percentage points (from 25% to 30%), whereas the shares in the two highest impact classes has increased by 4 and 3 percentage points respectively (from 14% to 18% (D) and from 18% to 21% (E)). Hence, from this long-term perspective the Danish publication behaviour has in general

moved towards publication in higher impact journals. But there are very interesting fluctuations in the intervening years. From 1980 until 1990 the share of publications in the lowest impact journals in class A actually increased from 11% to 23%. This peak happens to be around the same time when the MNCS score for Denmark was at its lowest. The publication shares for the second lowest impact class B also starts to increase from 31% to 34% peaking in 1984-86. Consequently, when the Danish MNCS score decreased rapidly in 1980s. Danish publication activity in the lowest impact journals in the database peaked around 52% of the publications. The share of publications in the lowest impact journals in the latest period examined is 31%. While the drop has been continuous since the peak in the 1980s, the drop becomes steeper around 2000. Class C comprising of what could be called the "average" journals in the database, sees an immediate drop from 24% in the first period to around 18% in the middle of 1980s. For a number years the shares of publications fluctuates between 18-20%, but from 1990 onwards the shares in this class increases consistently and is currently at 30%, the largest of the five impact classes. The two highest impact classes also show interesting fluctuations between the first and last period examined. Class D sees an immediate drop and remains at its lowest in the 1980s, but from 1990 onwards the share of publications in this class steadily increases to 18-19%, although there has been a small recent drop. Finally, the share of publications in the highest impact class E also sees an immediate drop in the 1980s to a low point around 1991 at 15%; nevertheless a distinct rise sets in from 1991 to 2008-2009 raising the share to 20% of the Danish publication activity among the highest impact journals. A period of a slight drop then follows, but in the most recent publication blocks the share rises again.

What emerges from Figure 6.3 is accordingly both an overall trend towards publication in higher impact journals, but also a distinct publication activity in lower impact journals around the time when the Danish citation impact was at its lowest in late 1980s. The sudden shift in publication behaviour towards higher impact journals sets in when Danish citation impact begins to rise again in the early 1990s. The question is therefore: how distinct is the Danish development compared to the other countries?

As discussed above, the Austrian development in publication behaviour is unique and less interesting in this context. In general, trends for the other countries are similar; a reduction in shares in the two lowest impact classes over the period and increases in the other three. While the actual numbers do not differ substantially, it is noteworthy that the two highest performing countries in 1980-82, Denmark and the Netherlands are also the two highest performing countries in 2010-12. In the first period Sweden's MNCS performance was nearly similar to Denmark and the Netherlands, whereas in 2010-12 the gap has widened considerably. What is noticeable is that while the intervening trends vary to some extent, and while all countries reduce their share of publications in lowest two impact classes, Denmark and the Netherlands has the largest overall share of their papers in the two upper impact classes.

Figure 6.3. Development in distribution of journal output between five MNJS impact classes for Norway based on full counts and three year overlapping publication blocks.)

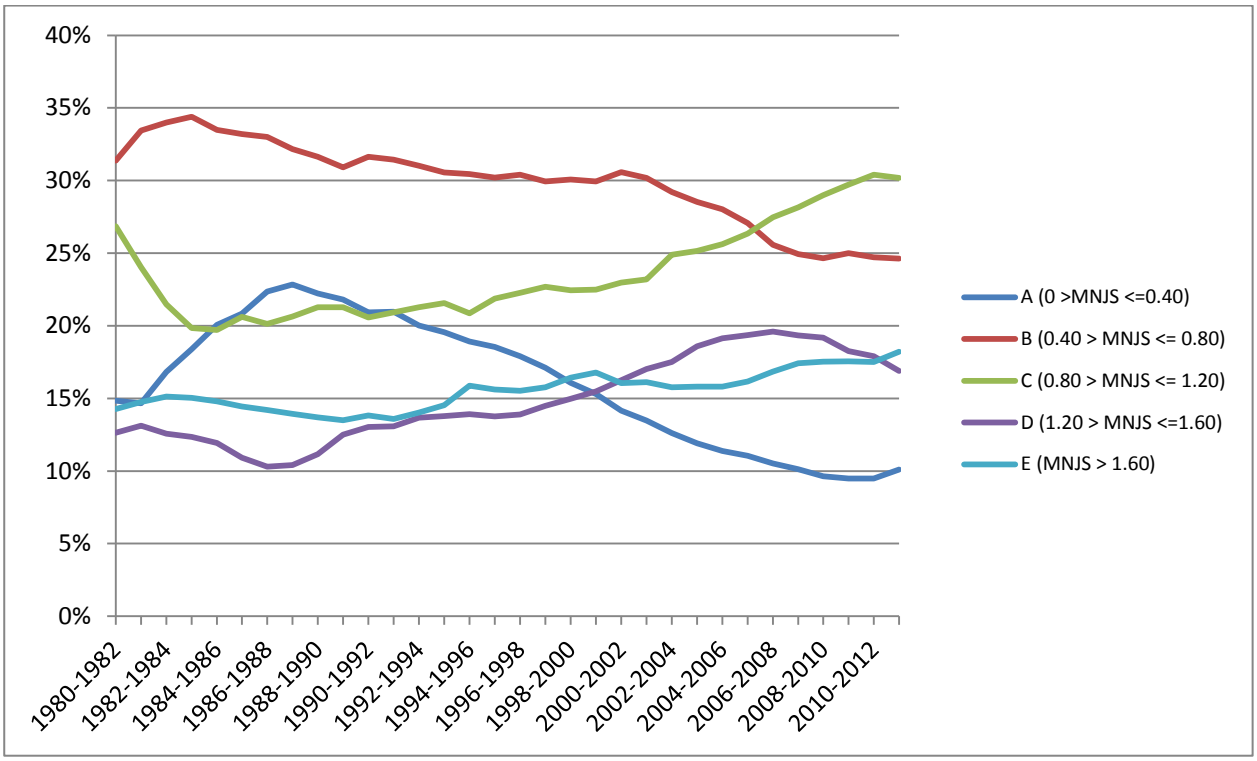


Figure 6.4. Development in distribution of journal output between five MNJS impact classes for Sweden based on full counts and three year overlapping publication blocks.

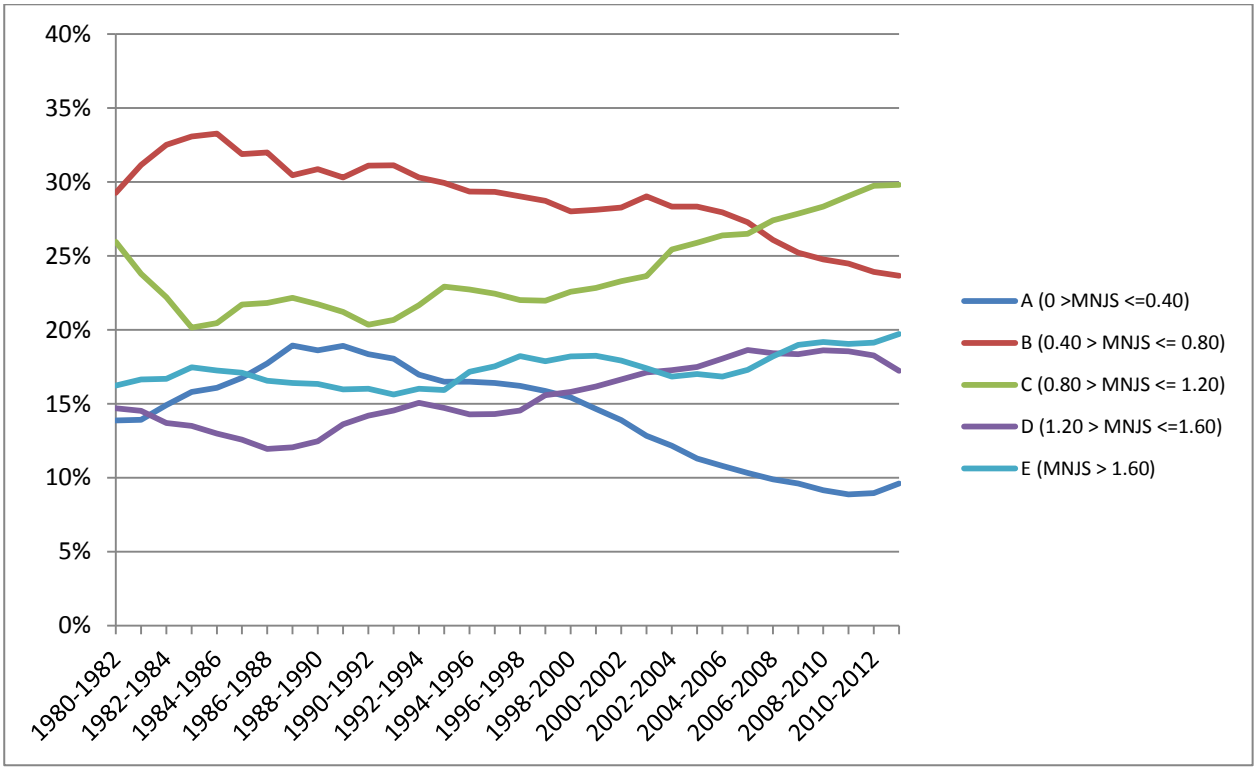


Figure 6.5. Development in distribution of journal output between five MNJS impact classes for Netherlands based on full counts and three year overlapping publication blocks.

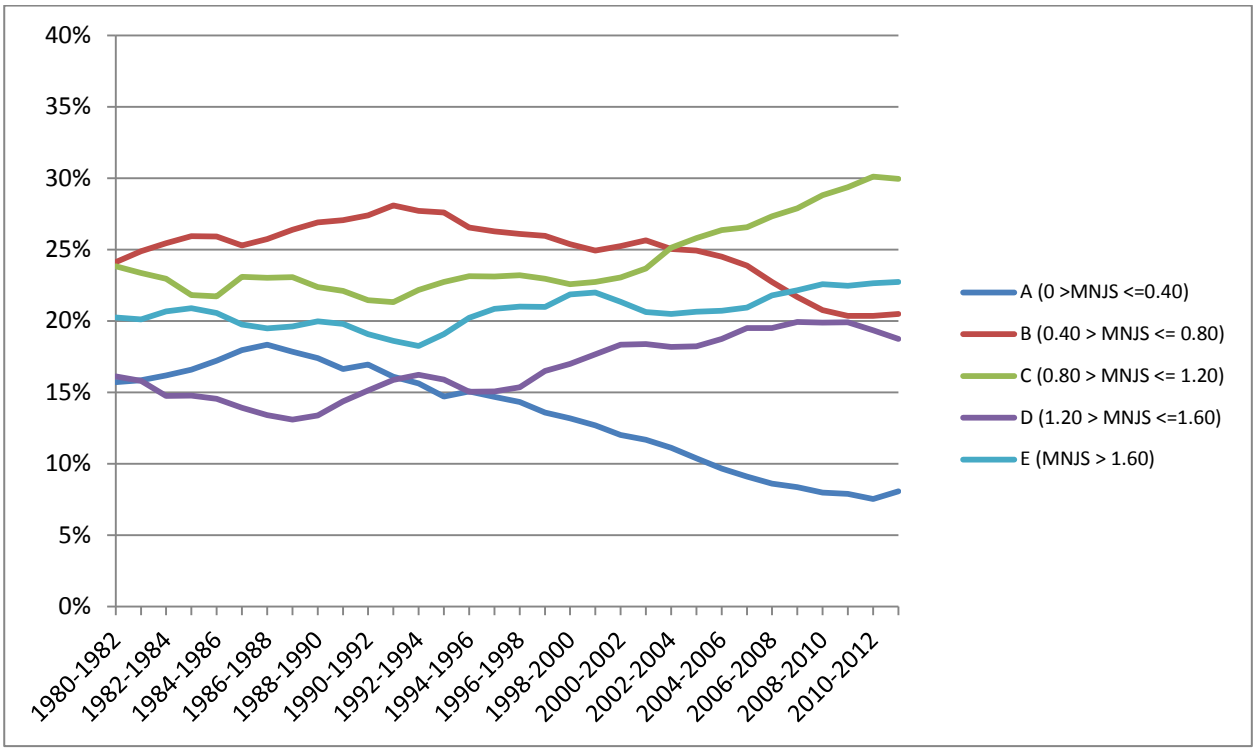


Figure 6.6. Development in distribution of journal output between five MNJS impact classes for Austria based on full counts and three year overlapping publication blocks.

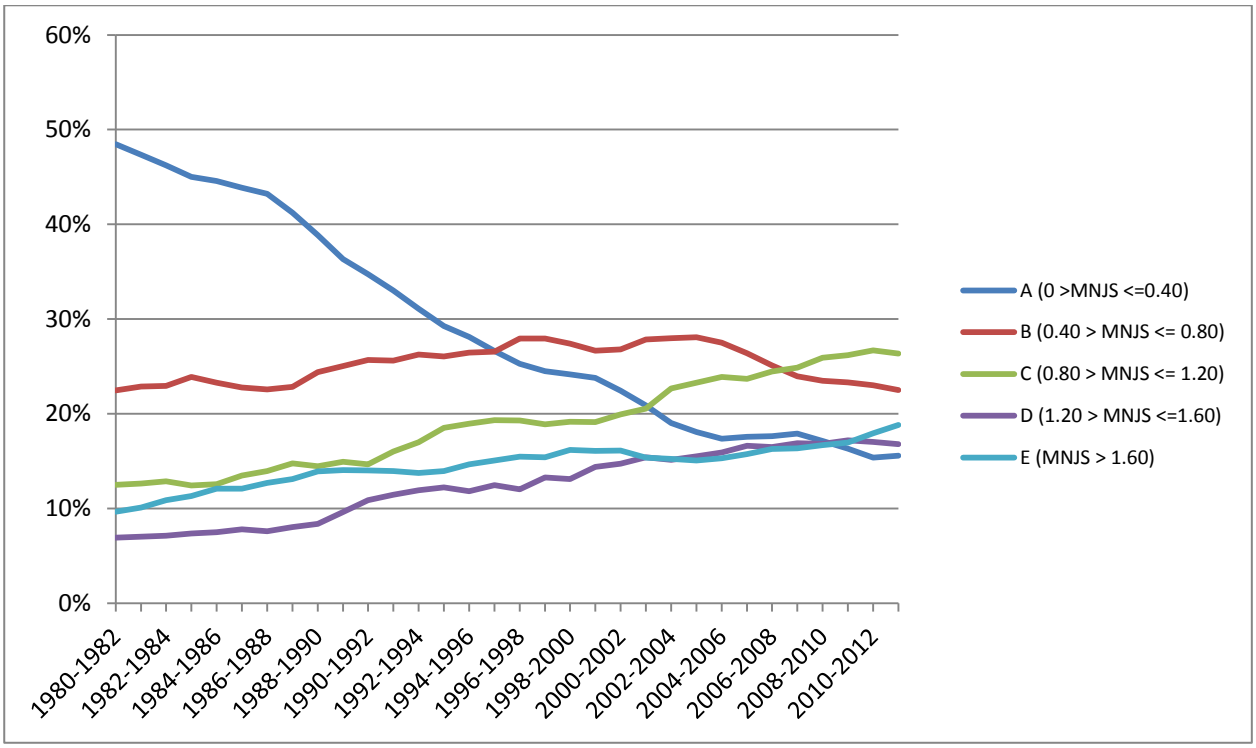
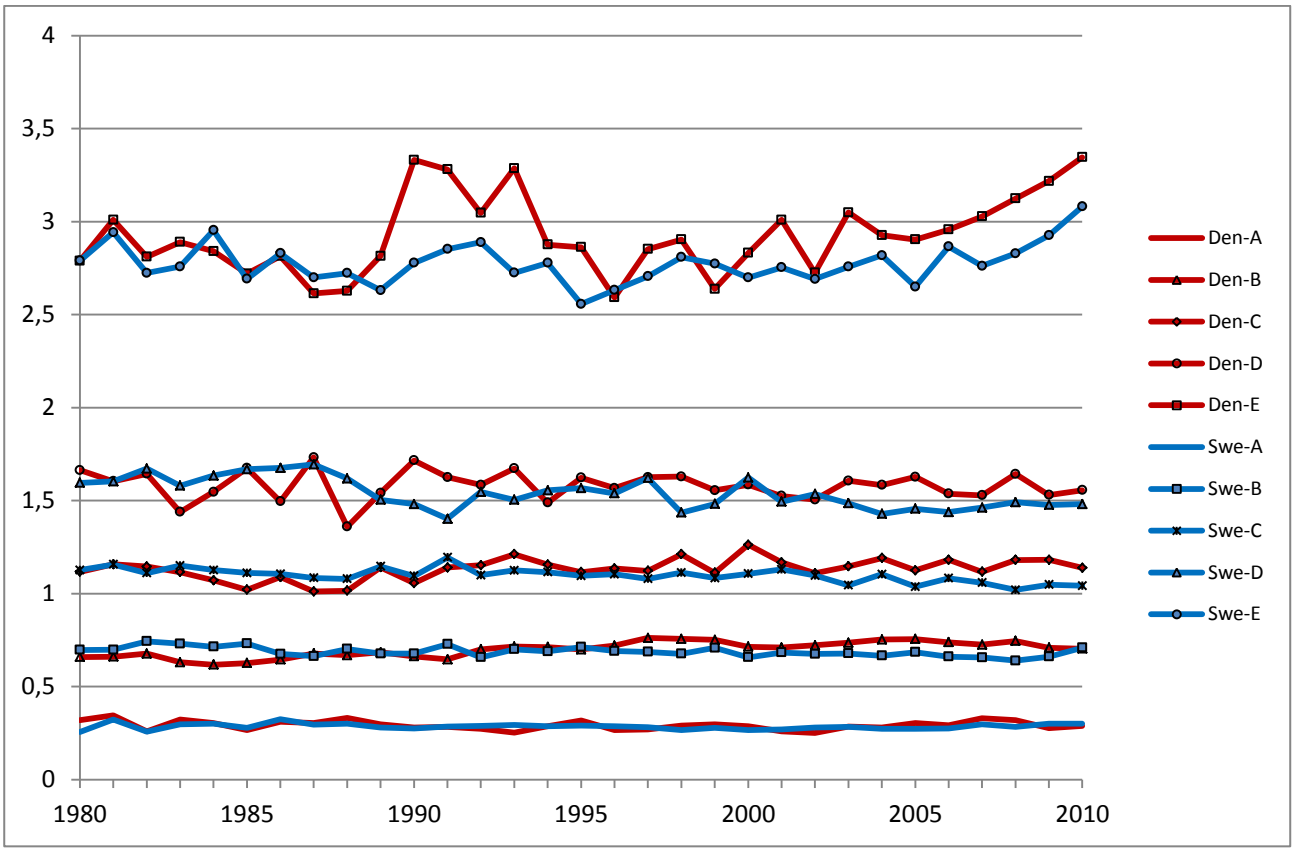


Figure 6.7 below presents a comparison between the citation impact (MNCS) of Danish and Swedish publications published in journals belonging to the different MNJS impact classes. As mentioned in Chapter 3, MNCS and MNJS are correlated so one would also expect the actual impact of papers to somehow vary around the MNJS score for the specific class. Obviously, class E has no upper bound, so here one would expect average citation scores somewhat above the threshold of 1.60. As is discernible from figure 6.7, at least in the comparison between Denmark and Sweden, Danish papers from class B and upwards, seem to have equal to higher average citation rates except for the period in 1980s where Denmark experienced the marked drop in impact. In other words, Danish papers as a cohort seem in general to attract more citations on average than Swedish papers independent of the impact class of the journal.

Figure 6.7. Development in mean normalized citation scores of Danish and Swedish papers published in the five MNJS impact classes based on full counts and one year publication blocks.



7 Internationalisation and collaboration:

As with the previous chapter on journal publication behaviour, this chapter also focuses on characteristics known to influence aggregated citation rates, namely "international collaboration". We use co-authorships as a proxy for measuring a country's degree of "internationalization", although research collaboration as such is a much more complex concept (see Katz and Martin, 1997). The operationalization is very simple; a country is credited with a publication if the country name appears in the address by-line of a publication. We do not weight contributions to individual papers. Hence, it makes no difference in this context whether a country has one author or more on a given international paper.

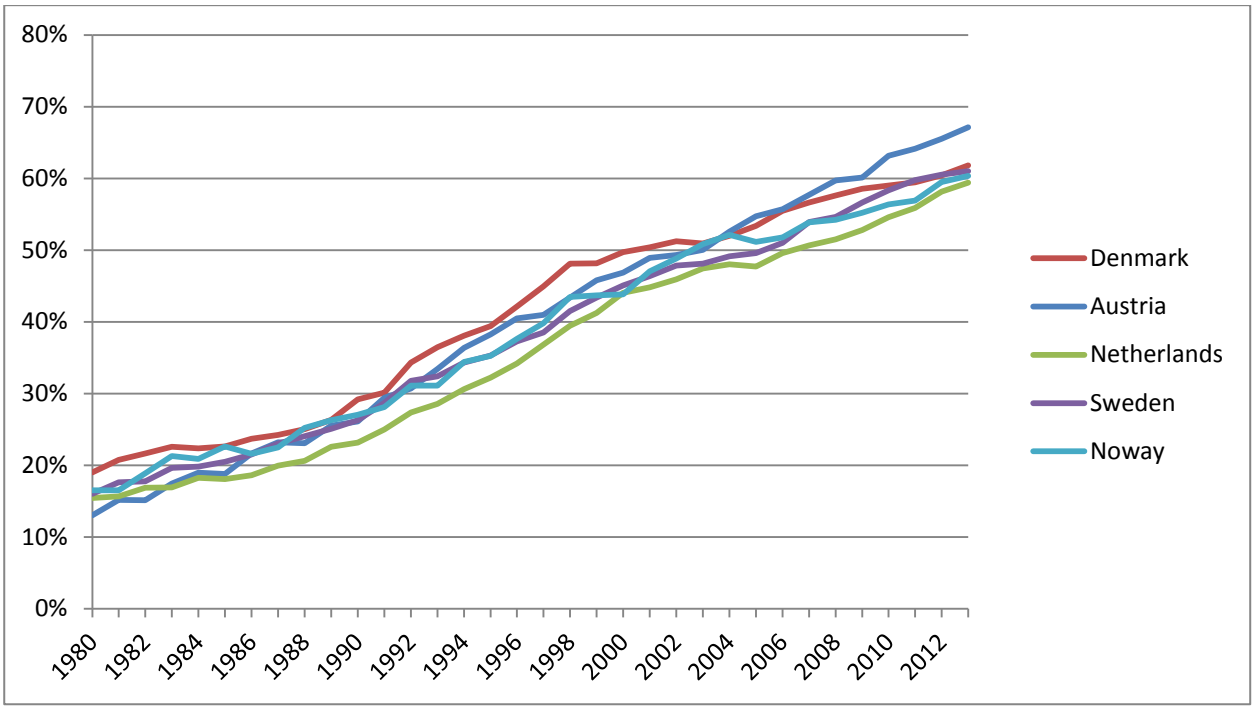
We examine the long-term development in international collaboration and differences in citation impact between papers that are a product of international collaboration and national papers (i.e., such papers can be a product of national collaboration; however we do not address this in the present report). The comparative analyses will reveal the degree of "internationalization" of Danish research relative to the benchmark countries. Further, the analyses will also reveal the potential variations in citation impact between the countries for the two different publication groups, national and international papers. We thereby want to examine to what extent "internationalization" can contribute to the explanation for the development in Danish citation impact.

Figure 7.1 shows the development in the countries' shares of international publications based on full counts. The overall trend is similar (and well-known) for all countries, the degree of "internationalization" has increased in 30 years from around one in five papers in the early 1980s being the result of international participation, to roughly two out of three papers today. The trend is not surprising as it is well-known that research in general has become more international in the period under examination. For example, the European framework programs require international consortia which will be reflected in the address by-lines of the subsequent research papers. However, there are some interesting nuances in these trends, especially for Denmark and the Netherlands. To take the Netherlands first. As documented in Chapter 4, the Netherlands is by far the largest of the five countries. However, their share of international collaborative papers is consistently below the other four countries in the present analysis. This is not surprising as larger countries in general have lower shares of international collaboration. One potential reason for this is the larger sizes of the national research systems which, other things equal, lessen the need for international collaboration.

The Danish trajectory is also very interesting and corresponds well with the previous findings in relation to the trends in MNCS and MNJS scores. In the early 1980s, when Danish citation impact

ranked very high, the share of international papers was the highest among the five countries starting around 20% in 1980.

Figure 7.1. Development in the share of papers with international collaboration for Denmark and the four benchmark countries, shares are based on full counts. A corresponding plot for fractional counts is shown Figure A.16 in the appendix.

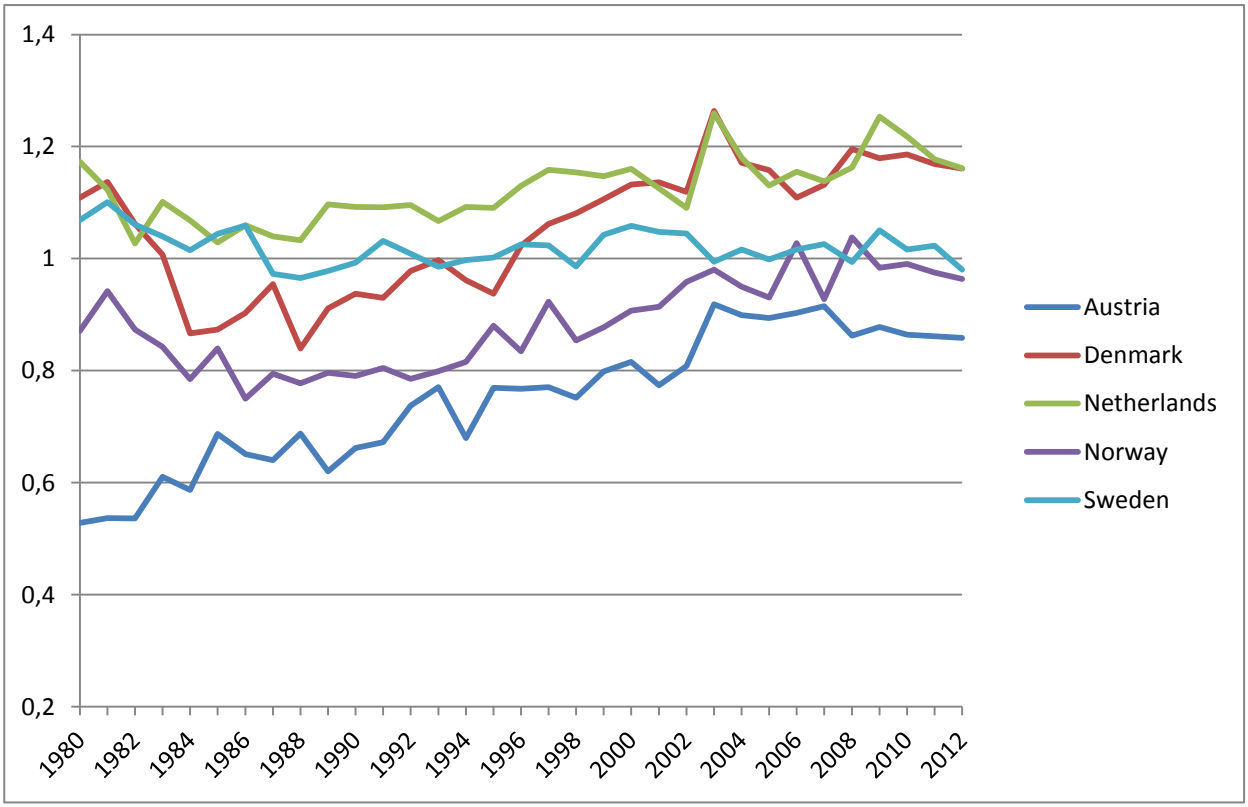


Very interestingly, during the 1980s when we see a marked drop in Danish citation impact, the rise in the share of international papers flattens somewhat so that the share resembles the other countries except the Netherlands. As documented in Figure 4.3. Denmark experienced a marked drop in citation scores during the 1980s culminating around 1990. Shortly hereafter Denmark experienced a marked increase in impact that corresponds well with the distinct rise in shares of international papers during the 1990s. Up until 2003 Danish shares were between 3 to 5 percentage points higher than the benchmark countries with the second highest share of international collaboration. Hereafter the Danish increase flattens and at the end of the period all countries except Austria has similar shares of international collaborative papers. The question is to what extent the international (and national) papers have influenced the trends in Danish impact and to what extent journal publication behaviour also plays a role in this? We know that the highest journal impact class E accumulates on average a bit more than 40% of the annual Danish citations and that there is a larger share of papers with international collaboration in this class.

When studying the impact of international papers it is also important to examine the impact of national publications and assess their common contribution to the overall national impact. In the early period, national publications constituted the majority of publications, so their impact

obviously played a relatively larger role for the overall national impact. Figure 7.2 shows the development in MNCS scores for the national publications of the five countries. As expected, the overall impact of national publications is lower compared to international publications (see Figure 7.3 below).

Figure 7.2. Development in the mean normalized citation scores (MNCS) for papers with no international collaboration for Denmark and the four benchmark countries (full and fractional counting yields the same result here as all author addresses are from one country).



Notice, the five countries show different trajectories. Austria and Norway have low impact to begin with but experience a more or less continuous increase throughout the period. At the end of the period their impact has improved, but still the mean normalized citation rate for their national publications is considerably lower than the same indicator for Denmark and the Netherlands. It is also interesting that Sweden commences with an impact for their national publications at the same level as Denmark and the Netherlands, but Sweden does not seem to experience a permanent improvement in impact as the score fluctuates around the value of one during most of the period. Indeed, if we compare 1980 to the last years examined, the overall impact of Swedish national papers has dropped a bit. This is not the case for Denmark or the Netherlands. If we compare the first period to the last we see that both countries have improved their MNCS score with some 0.1 points. But more importantly, they have experienced a permanent improvement. Where the Netherlands more or less have experienced a continuous increase, Denmark

experienced a marked drop in the 1980s and a continuous and at times a steep rise through the 1990s and early 2000s, entirely in conjunction with our previous findings. What should be remembered is that the marked drop came at a time when these publications constituted approximately 75% of the annual national output. Also, the Danish impact for the national publications rises at the same time as their relative shares of the national output drops (i.e., the absolute numbers increase). But it would probably be safe to conclude that for the later period, national Danish (and Dutch) publications have a remarkable impact compared to the other countries and that this factor most likely contribute both to the drop in 1980s and to the subsequent rise in the 1990s and to the present high performance.

Figure 7.3.Development in the mean normalized citation score (MNCS) for papers <u>with</u> international collaboration for Denmark and the four benchmark countries. The indicator is based on full counts.

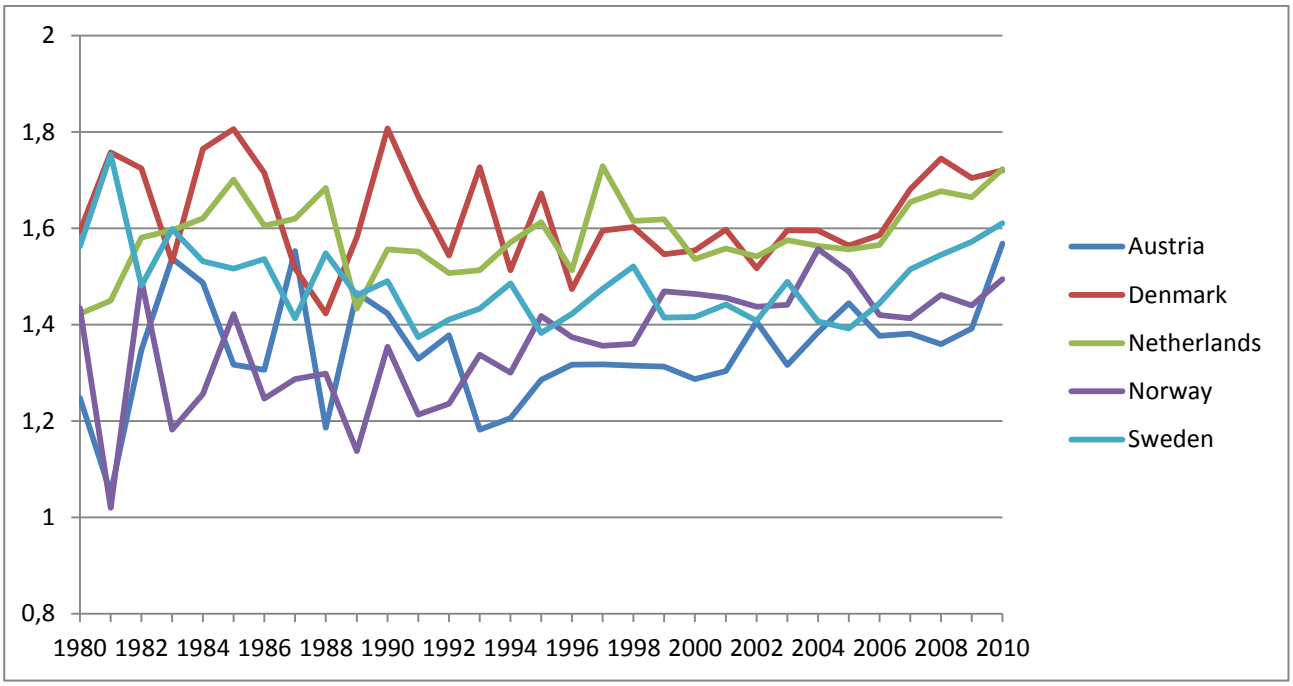


Figure 7.3 depicts the overall MNCS scores for the international papers. It is evident that overall international papers have higher citation rates compared to national papers. It is also noticeable that the MNCS scores fluctuate considerably, especially in the first half of the time series. To a large extent this is a function of smaller numbers and the fact that we have not smoothed data into three-year publication blocks. Nevertheless, the Danish case is interesting. Being a smaller country, the fluctuations are more drastic than larger countries such as Sweden and the Netherlands, yet Denmark experience some drastic peaks and valleys in the first decade. Denmark experiences the highest impact value and rank of all countries in 1985 and then immediately drops to rank three in 1988, below Sweden and the Netherlands, and then rises to a new high point in 1990. Hereafter the international papers from Denmark more or less continuously show the highest impact, in the later period almost identical with the development of the Netherlands.

There is no doubt that the fluctuations in the early period for Denmark are influenced by some very highly cited papers as shown in Chapter 5. It is also noticeable that the sudden drop from 1986 to 1988 corresponds with the overall drop in MNCS values for Denmark, amplifying the corresponding drop in impact for the national papers. But despite the fluctuations, it is remarkable that Danish international papers overall have very high impact. This is true in the early 1980s and it is also the case now. We have to remember that between the five countries, in 1980 Denmark is already the most "internationally" research-oriented of them (on the premise that the share of papers with international collaboration can be seen as a proxy of this).

The final two time series compare the impact for national and international papers and we depict the trend with relatively scaled circles that show the annual publication output. Notice, the red and blue circles are full counts. Obviously, fractional counting at the country level does not alter anything in relation to impact of national papers, whereas the international papers are affected in that respect. This we demonstrate by inserting grey circles again scaled according to relative size. The minor vertical gridlines enable direct (annual) comparisons of impact between national and international papers, as well as international papers with full and fractional counts. i.e., in most cases MNCS scores based on fractional counts will be below scores of full counts. For comparative purposes we show these trends for both Denmark and the Netherlands.

Figure 7.4. Comparison of mean normalized citation scores (MNCS) for annual volumes of Danish articles with and without international collaboration, where volume is depicted relative through circle size (full and fractional count combined).

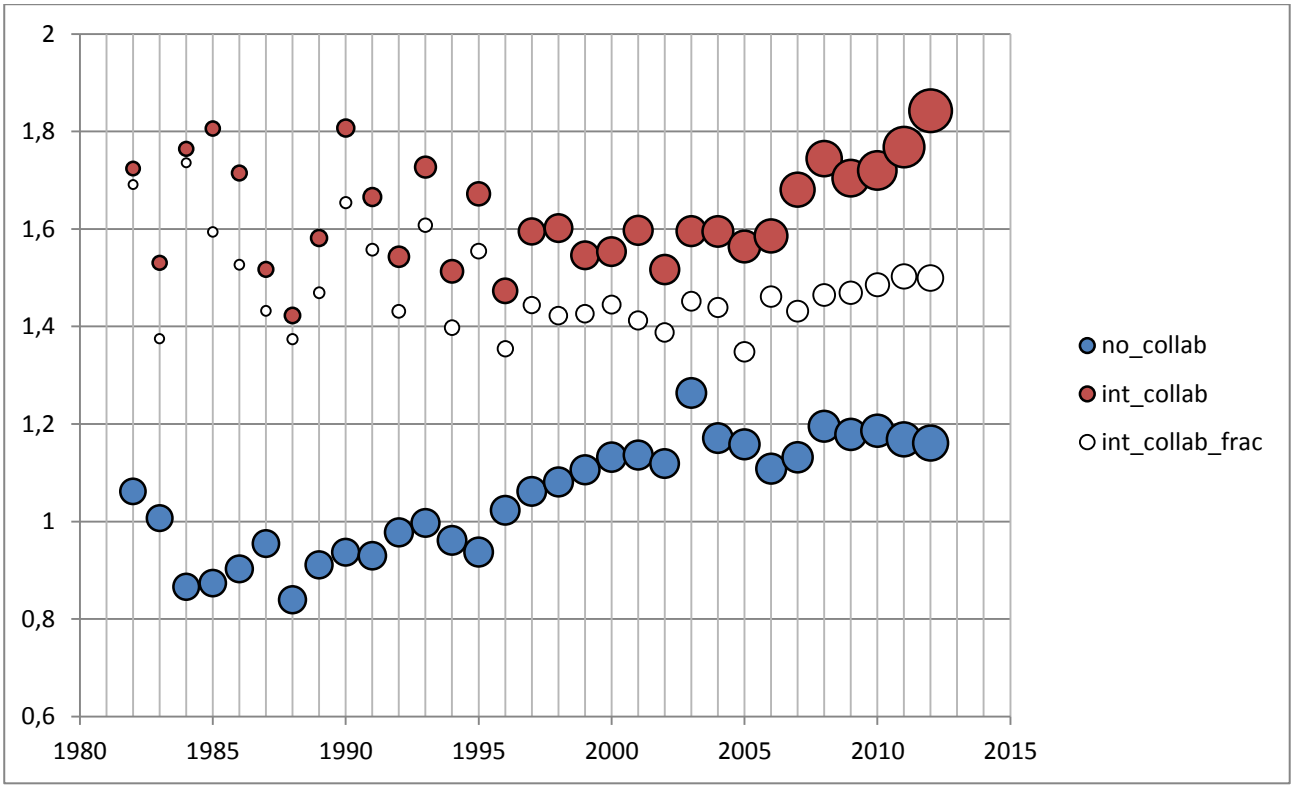
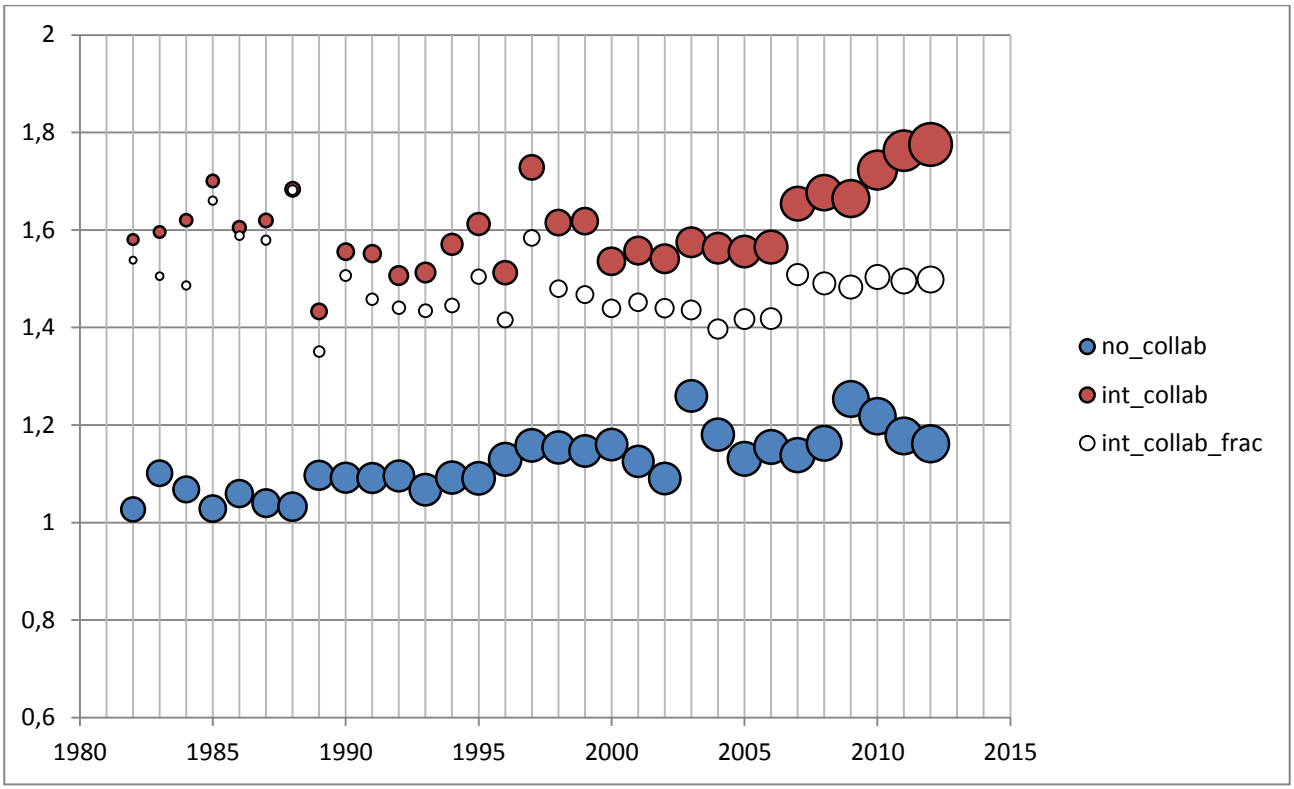


Figure 7.5.Comparison of mean normalized citation scores (MNCS) for annual volumes of Dutch articles with and without international collaboration, where volume is depicted relative through circle size (full and fractional count combined).



Both figures confirm and underscore previous findings. We see the marked difference in annual output between national and international papers (relative circle sizes) and how this in the early period seems to influence the international papers. The MNCS scores for the international papers are volatile in this period, most likely a combination of fewer papers and the overall skewed citation distribution. Hence, the impact becomes more vulnerable from year to year when we examine annual cohorts of papers. Conversely, the larger publication volume for the national papers and the fact that many of these papers have mediocre citation rates makes the MNCS values more stable. Indeed we can see that the values remain stable for the national papers during the whole period and that the international papers also become more stable as their size grow. As shown in Figure 7.3 above, all countries experience a rise in the impact of their international papers in the last years of the time series. While some of this rise may be real, some of it is also an artefact since the last years do not have full four year citation windows. In that sense the MNCS scores become more vulnerable. Comparing Denmark and the Netherlands show that the performance of both national and international papers is very high. In that sense both groups of papers contribute to the development in the overall impact.

Finally, the figures showing both full and fractional counting demonstrates that the overall trends are quite similar both within and between the countries, albeit there is some reversal in trends for the Netherlands in the early years.

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9 Appendix

9.1 OECD classification scheme and its concordance with WoS journal subject categories.

OECD major field	WoS journal subject categories
NATURAL SCIENCES	LOGIC
	MATHEMATICS, APPLIED
	MATHEMATICS, INTERDISCIPLINARY APPLICATIONS
	MATHEMATICS
	PHYSICS, MATHEMATICAL
	STATISTICS & PROBABILITY
	COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE
	COMPUTER SCIENCE, CYBERNETICS
	COMPUTER SCIENCE, INFORMATION SYSTEMS
	COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS
	COMPUTER SCIENCE, SOFTWARE ENGINEERING
	COMPUTER SCIENCE, THEORY & METHODS
	ACOUSTICS
	ASTRONOMY & ASTROPHYSICS
	OPTICS
	PHYSICS, APPLIED
	PHYSICS, FLUIDS & PLASMAS
	PHYSICS, ATOMIC, MOLECULAR & CHEMICAL
	PHYSICS, MULTIDISCIPLINARY
	PHYSICS, CONDENSED MATTER
	PHYSICS, NUCLEAR
	PHYSICS, PARTICLES & FIELDS
	CHEMISTRY, APPLIED
	CHEMISTRY, MULTIDISCIPLINARY
	CHEMISTRY, ANALYTICAL
	CHEMISTRY, INORGANIC & NUCLEAR
	CHEMISTRY, ORGANIC
	CHEMISTRY, PHYSICAL
	CRYSTALLOGRAPHY
	ELECTROCHEMISTRY
	POLYMER SCIENCE
	GEOCHEMISTRY & GEOPHYSICS
	ENVIRONMENTAL SCIENCES
	GEOGRAPHY, PHYSICAL
	GEOLOGY
	GEOSCIENCES, MULTIDISCIPLINARY
	METEOROLOGY & ATMOSPHERIC SCIENCES
	MINERALOGY
	OCEANOGRAPHY
	PALEONTOLOGY
	WATER RESOURCES
	BIODIVERSITY CONSERVATION
	BIOCHEMICAL RESEARCH METHODS
	BIOCHEMISTRY & MOLECULAR BIOLOGY
	BIOLOGY
	BIOPHYSICS
	PLANT SCIENCES
	CELL BIOLOGY
	ECOLOGY
	EVOLUTIONARY BIOLOGY

	DEVELOPMENTAL BIOLOGY
	ENTOMOLOGY
	GENETICS & HEREDITY
	MATHEMATICAL & COMPUTATIONAL BIOLOGY
	LIMNOLOGY
	MARINE & FRESHWATER BIOLOGY
	MICROBIOLOGY
	MYCOLOGY
	ORNITHOLOGY
	REPRODUCTIVE BIOLOGY
	VIROLOGY
	ZOOLOGY
	MULTIDISCIPLINARY SCIENCES
ENGINEERING AND TECHNOLOGY	CONSTRUCTION & BUILDING TECHNOLOGY
	ENGINEERING, CIVIL
	TRANSPORTATION SCIENCE & TECHNOLOGY
	AUTOMATION & CONTROL SYSTEMS
	COMPUTER SCIENCE, HARDWARE & ARCHITECTURE
	ENGINEERING, ELECTRICAL & ELECTRONIC
	ROBOTICS
	TELECOMMUNICATIONS
	ENGINEERING, AEROSPACE
	THERMODYNAMICS
	ENGINEERING, MECHANICAL
	MECHANICS
	NUCLEAR SCIENCE & TECHNOLOGY
	ENGINEERING, CHEMICAL
	MATERIALS SCIENCE, PAPER & WOOD
	MATERIALS SCIENCE, CERAMICS
	MATERIALS SCIENCE, MULTIDISCIPLINARY
	METALLURGY & METALLURGICAL ENGINEERING
	MATERIALS SCIENCE, CHARACTERIZATION & TESTING
	MATERIALS SCIENCE, COATINGS & FILMS
	MATERIALS SCIENCE, COMPOSITES
	MATERIALS SCIENCE, TEXTILES
	ENGINEERING, BIOMEDICAL
	MEDICAL LABORATORY TECHNOLOGY
	CELL & TISSUE ENGINEERING
	ENERGY & FUELS
	ENGINEERING, ENVIRONMENTAL
	ENGINEERING, MARINE
	ENGINEERING, OCEAN
	ENGINEERING, PETROLEUM
	ENGINEERING, GEOLOGICAL
	REMOTE SENSING
	MINING & MINERAL PROCESSING
	BIOTECHNOLOGY & APPLIED MICROBIOLOGY
	MATERIALS SCIENCE, BIOMATERIALS
	NANOSCIENCE & NANOTECHNOLOGY
	ENGINEERING, MULTIDISCIPLINARY
	ENGINEERING, INDUSTRIAL
	ENGINEERING, MANUFACTURING
	FOOD SCIENCE & TECHNOLOGY
	INSTRUMENTS & INSTRUMENTATION
	MICROSCOPY
	IMAGING SCIENCE & PHOTOGRAPHIC TECHNOLOGY
	SPECTROSCOPY
MEDICAL AND HEALTH SCIENCES	AUDIOLOGY & SPEECH-LANGUAGE PATHOLOGY
	ANATOMY & MORPHOLOGY

	CHEMISTRY, MEDICINAL
	PSYCHOLOGY, CLINICAL
	IMMUNOLOGY
	MEDICINE, RESEARCH & EXPERIMENTAL
	NEUROSCIENCES
	PATHOLOGY
	PHARMACOLOGY & PHARMACY
	PHYSIOLOGY
	TOXICOLOGY
	ALLERGY
	ANDROLOGY
	ANESTHESIOLOGY
	ONCOLOGY
	CARDIAC & CARDIOVASCULAR SYSTEMS
	CRITICAL CARE MEDICINE
	EMERGENCY MEDICINE
	DENTISTRY, ORAL SURGERY & MEDICINE
	DERMATOLOGY
	ENDOCRINOLOGY & METABOLISM
	GASTROENTEROLOGY & HEPATOLOGY
	GERIATRICS & GERONTOLOGY
	GERONTOLOGY
	HEMATOLOGY
	INTEGRATIVE & COMPLEMENTARY MEDICINE
	MEDICINE, GENERAL & INTERNAL
	CLINICAL NEUROLOGY
	NEUROIMAGING
	OBSTETRICS & GYNECOLOGY
	OPHTHALMOLOGY
	ORTHOPEDICS
	OTORHINOLARYNGOLOGY
	PEDIATRICS
	PSYCHIATRY
	RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING
	RESPIRATORY SYSTEM
	RHEUMATOLOGY
	SURGERY
	TRANSPLANTATION
	UROLOGY & NEPHROLOGY
	PERIPHERAL VASCULAR DISEASE
	SUBSTANCE ABUSE
	HEALTH CARE SCIENCES & SERVICES
	HEALTH POLICY & SERVICES
	PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH
	INFECTIOUS DISEASES
	MEDICAL ETHICS
	MEDICINE, LEGAL
	MEDICAL INFORMATICS
	NURSING
	NUTRITION & DIETETICS
	PARASITOLOGY
	PSYCHOLOGY, PSYCHOANALYSIS
	REHABILITATION
	SOCIAL SCIENCES, BIOMEDICAL
	SPORT SCIENCES
	TROPICAL MEDICINE
	PRIMARY HEALTH CARE
AGRICULTURAL SCIENCES	AGRICULTURE, MULTIDISCIPLINARY
	AGRONOMY

	FISHERIES
	FORESTRY
	HORTICULTURE
	SOIL SCIENCE
	AGRICULTURE, DAIRY & ANIMAL SCIENCE
	VETERINARY SCIENCES
	AGRICULTURAL ENGINEERING
	AGRICULTURAL ECONOMICS & POLICY
	FOOD SCIENCE & TECHNOLOGY
SOCIAL SCIENCES	PSYCHOLOGY, BIOLOGICAL
	BEHAVIORAL SCIENCES
	PSYCHOLOGY, EDUCATIONAL
	ERGONOMICS
	PSYCHOLOGY, DEVELOPMENTAL
	PSYCHOLOGY, APPLIED
	PSYCHOLOGY
	PSYCHOLOGY, MULTIDISCIPLINARY
	PSYCHOLOGY, MATHEMATICAL
	PSYCHOLOGY, EXPERIMENTAL
	PSYCHOLOGY, SOCIAL
	BUSINESS
	BUSINESS, FINANCE
	ECONOMICS
	INDUSTRIAL RELATIONS & LABOR
	MANAGEMENT
	OPERATIONS RESEARCH & MANAGEMENT SCIENCE
	EDUCATION & EDUCATIONAL RESEARCH
	EDUCATION, SCIENTIFIC DISCIPLINES
	EDUCATION, SPECIAL
	ANTHROPOLOGY
	DEMOGRAPHY
	ETHNIC STUDIES
	FAMILY STUDIES
	SOCIAL SCIENCES, MATHEMATICAL METHODS
	SOCIAL ISSUES
	SOCIAL WORK
	SOCIOLOGY
	WOMEN'S STUDIES
	CRIMINOLOGY & PENOLOGY
	LAW
	INTERNATIONAL RELATIONS
	POLITICAL SCIENCE
	PUBLIC ADMINISTRATION
	AREA STUDIES
	ENVIRONMENTAL STUDIES
	GEOGRAPHY
	PLANNING & DEVELOPMENT
	TRANSPORTATION
	URBAN STUDIES
	COMMUNICATION
	INFORMATION SCIENCE & LIBRARY SCIENCE
	HOSPITALITY, LEISURE, SPORT & TOURISM
	ASIAN STUDIES
	CULTURAL STUDIES
	SOCIAL SCIENCES, INTERDISCIPLINARY
HUMANITIES	ARCHAEOLOGY
	HISTORY
	HISTORY & PHILOSOPHY OF SCIENCE
	HISTORY OF SOCIAL SCIENCES

MEDIEVAL & RENAISSANCE STUDIES
CLASSICS
FOLKLORE
LINGUISTICS
LITERARY THEORY & CRITICISM
LANGUAGE & LINGUISTICS
LITERARY REVIEWS
LITERATURE
LITERATURE, AFRICAN, AUSTRALIAN, CANADIAN
LITERATURE, AMERICAN
LITERATURE, BRITISH ISLES
LITERATURE, GERMAN, DUTCH, SCANDINAVIAN
LITERATURE, ROMANCE
LITERATURE, SLAVIC
POETRY
ETHICS
PHILOSOPHY
RELIGION
ARCHITECTURE
ART
DANCE
FILM, RADIO, TELEVISION
MUSIC
THEATER
HUMANITIES, MULTIDISCIPLINARY

9.2 Adjusted NOWT low classification and its concordance with WoS journal subject categories.

Adjusted NOWT categories	NOWT low: 35 research areas	WoS journal subject categories
AGRICULTURE AND FOOD SCIENCE	AGRICULTURE AND FOOD SCIENCE	AGRICULTURE, DAIRY & ANIMAL SCIENCE
		AGRICULTURE, MULTIDISCIPLINARY
		AGRICULTURAL EXPERIMENT STATION REPORTS
		AGRONOMY
		FOOD SCIENCE & TECHNOLOGY
		NUTRITION & DIETETICS
		SOIL SCIENCE
		AGRICULTURAL ENGINEERING
ARTS AND HUMANITIES	CREATIVE ARTS, CULTURE AND MUSIC	ARCHITECTURE
		ART
		HUMANITIES, MULTIDISCIPLINARY
		CLASSICS
		DANCE
		FILM, RADIO, TELEVISION
		FOLKLORE
		ASIAN STUDIES
		MUSIC
		THEATER
	HISTORY, PHILOSOPHY AND RELIGION	ARCHAEOLOGY
		HISTORY
		HISTORY & PHILOSOPHY OF SCIENCE
		HISTORY OF SOCIAL SCIENCES
		MEDIEVAL & RENAISSANCE STUDIES
		PHILOSOPHY
		RELIGION
		ETHICS
		MEDICAL ETHICS
	LANGUAGE AND LINGUISTICS	LINGUISTICS
		LANGUAGE & LINGUISTICS THEORY
	LITERATURE	LITERARY REVIEWS
		LITERATURE
		LITERATURE, AFRICAN, AUSTRALIAN, CANADIAN
		LITERATURE, AMERICAN
		LITERATURE, BRITISH ISLES
		LITERATURE, GERMAN, DUTCH, SCANDINAVIAN
		LITERATURE, ROMANCE
		LITERATURE, SLAVIC
		POETRY
		LITERARY THEORY & CRITICISM
ASTRONOMY AND ASTROPHYSICS	ASTRONOMY AND ASTROPHYSICS	ASTRONOMY & ASTROPHYSICS
BASIC LIFE SCIENCES	BASIC LIFE SCIENCES	BIOCHEMICAL RESEARCH METHODS
		BIOCHEMISTRY & MOLECULAR BIOLOGY
		BIOPHYSICS
		BIOTECHNOLOGY & APPLIED MICROBIOLOGY
		CELL BIOLOGY
		DEVELOPMENTAL BIOLOGY
		GENETICS & HEREDITY
		MICROBIOLOGY
		REPRODUCTIVE BIOLOGY
		CELL & TISSUE ENGINEERING
	BASIC MEDICAL SCIENCES	CHEMISTRY, MEDICINAL
		ENGINEERING, BIOMEDICAL
		MEDICAL INFORMATICS

		MATERIALS SCIENCE, BIOMATERIALS
BIOLOGICAL SCIENCES	BIOLOGICAL SCIENCES	BEHAVIORAL SCIENCES
		BIOLOGY
		PLANT SCIENCES
		EVOLUTIONARY BIOLOGY
		ENTOMOLOGY
		FISHERIES
		HORTICULTURE
		MARINE & FRESHWATER BIOLOGY
		MYCOLOGY
		ORNITHOLOGY
		ZOOLOGY
		MATHEMATICAL & COMPUTATIONAL BIOLOGY
BIOMEDICAL SCIENCES	BIOMEDICAL SCIENCES	ANATOMY & MORPHOLOGY
		IMMUNOLOGY
		MEDICAL LABORATORY TECHNOLOGY
		MEDICINE, RESEARCH & EXPERIMENTAL
		NEUROSCIENCES
		PHARMACOLOGY & PHARMACY
		PHYSIOLOGY
		RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING
		TOXICOLOGY
		VIROLOGY
		INTEGRATIVE & COMPLEMENTARY MEDICINE
		NEUROIMAGING
CHEMISTRY AND CHEMICAL ENGINEERING	CHEMISTRY AND CHEMICAL ENGINEERING	CHEMISTRY, APPLIED
		CHEMISTRY, MULTIDISCIPLINARY
		CHEMISTRY, ANALYTICAL
		CHEMISTRY, INORGANIC & NUCLEAR
		CHEMISTRY, ORGANIC
		CHEMISTRY, PHYSICAL
		ELECTROCHEMISTRY
		ENGINEERING, CHEMICAL
		MATERIALS SCIENCE, PAPER & WOOD
		MATERIALS SCIENCE, TEXTILES
		POLYMER SCIENCE
		SPECTROSCOPY
CLINICAL MEDICINE	CLINICAL MEDICINE	ALLERGY
		ANDROLOGY
		ANESTHESIOLOGY
		ONCOLOGY
		CARDIAC & CARDIOVASCULAR SYSTEMS
		EMERGENCY MEDICINE
		DENTISTRY/ORAL SURGERY & MEDICINE
		DERMATOLOGY
		ENDOCRINOLOGY & METABOLISM
		GASTROENTEROLOGY & HEPATOLOGY
		HEMATOLOGY
		PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH
		INFECTIOUS DISEASES
		MEDICINE, GENERAL & INTERNAL
		CLINICAL NEUROLOGY
		OBSTETRICS & GYNECOLOGY
		OPHTHALMOLOGY
		ORTHOPEDICS
		OTORHINOLARYNGOLOGY
		PARASITOLOGY

		PATHOLOGY
		PEDIATRICS
		PSYCHIATRY
		RESPIRATORY SYSTEM
		RHEUMATOLOGY
		SURGERY
		TRANSPLANTATION
		TROPICAL MEDICINE
		UROLOGY & NEPHROLOGY
		VETERINARY SCIENCES
		PERIPHERAL VASCULAR DISEASE
		CRITICAL CARE MEDICINE
		PRIMARY HEALTH CARE
		AUDIOLOGY & SPEECH-LANGUAGE PATHOLOGY
EARTH SCIENCES AND TECHNOLOGY	EARTH SCIENCES AND TECHNOLOGY	GEOCHEMISTRY & GEOPHYSICS
		ENGINEERING, MARINE
		ENGINEERING, OCEAN
		GEOGRAPHY, PHYSICAL
		GEOLOGY
		GEOSCIENCES, MULTIDISCIPLINARY
		METEOROLOGY & ATMOSPHERIC SCIENCES
		MINERALOGY
		OCEANOGRAPHY
		REMOTE SENSING
		PALEONTOLOGY
		IMAGING SCIENCE & PHOTOGRAPHIC TECHNOLOGY
		ENGINEERING, GEOLOGICAL
ENGINEERING	CIVIL ENGINEERING AND CONSTRUCTION	CONSTRUCTION & BUILDING TECHNOLOGY
		ENGINEERING, CIVIL
	ELECTRICAL ENGINEERING AND TELECOMMUNICATION	AUTOMATION & CONTROL SYSTEMS
		ENGINEERING, ELECTRICAL & ELECTRONIC
		TELECOMMUNICATIONS
		TRANSPORTATION
		TRANSPORTATION SCIENCE & TECHNOLOGY
		ROBOTICS
	ENERGY SCIENCE AND TECHNOLOGY	ENERGY & FUELS
		ENGINEERING, PETROLEUM
		NUCLEAR SCIENCE & TECHNOLOGY
		MINING & MINERAL PROCESSING
	GENERAL AND INDUSTRIAL ENGINEERING	ENGINEERING, MULTIDISCIPLINARY
		ENGINEERING, INDUSTRIAL
		ENGINEERING, MANUFACTURING
		ERGONOMICS
	INSTRUMENTS AND INSTRUMENTATION	INSTRUMENTS & INSTRUMENTATION
		MICROSCOPY
	MECHANICAL ENGINEERING AND AEROSPACE	ACOUSTICS
		ENGINEERING, AEROSPACE
		THERMODYNAMICS
		ENGINEERING, MECHANICAL
		MECHANICS
ENVIRONMENTAL SCIENCES AND TECHNOLOGY	ENVIRONMENTAL SCIENCES AND TECHNOLOGY	BIODIVERSITY CONSERVATION
		ECOLOGY
		ENGINEERING, ENVIRONMENTAL
		ENVIRONMENTAL SCIENCES
		ENVIRONMENTAL STUDIES
		FORESTRY
		GEOGRAPHY

		LIMNOLOGY
		URBAN STUDIES
		WATER RESOURCES
HEALTH SCIENCES	HEALTH SCIENCES	SUBSTANCE ABUSE
		GERIATRICS & GERONTOLOGY
		HEALTH POLICY & SERVICES
		NURSING
		REHABILITATION
		SOCIAL WORK
		SPORT SCIENCES
		HEALTH CARE SCIENCES & SERVICES
		GERONTOLOGY
MATHEMATICAL AND COMPUTER SCIENCES	COMPUTER SCIENCES	COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE
		COMPUTER SCIENCE, CYBERNETICS
		COMPUTER SCIENCE, HARDWARE & ARCHITECTURE
		COMPUTER SCIENCE, INFORMATION SYSTEMS
		COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS
		COMPUTER SCIENCE, SOFTWARE ENGINEERING
		COMPUTER SCIENCE, THEORY & METHODS
	MATHEMATICS	MATHEMATICS, APPLIED
		MATHEMATICS, INTERDISCIPLINARY APPLICATIONS
		MATHEMATICS
		LOGIC
	STATISTICAL SCIENCES	OPERATIONS RESEARCH & MANAGEMENT SCIENCE
		SOCIAL SCIENCES, MATHEMATICAL METHODS
		STATISTICS & PROBABILITY
MULTIDISCIPLINARY JOURNALS	MULTIDISCIPLINARY JOURNALS	MULTIDISCIPLINARY SCIENCES
PHYSICS AND MATERIALS SCIENCE	PHYSICS AND MATERIALS SCIENCE	CRYSTALLOGRAPHY
		MATERIALS SCIENCE, CERAMICS
		MATERIALS SCIENCE, MULTIDISCIPLINARY
		METALLURGY & METALLURGICAL ENGINEERING
		MATERIALS SCIENCE, CHARACTERIZATION & TESTING
		MATERIALS SCIENCE, COATINGS & FILMS
		MATERIALS SCIENCE, COMPOSITES
		OPTICS
		PHYSICS, APPLIED
		PHYSICS, FLUIDS & PLASMAS
		PHYSICS, ATOMIC, MOLECULAR & CHEMICAL
		PHYSICS, MULTIDISCIPLINARY
		PHYSICS, CONDENSED MATTER
		PHYSICS, NUCLEAR
		PHYSICS, PARTICLES & FIELDS
		PHYSICS, MATHEMATICAL
		NANOSCIENCE & NANOTECHNOLOGY
SOCIAL SCIENCES	ECONOMICS AND BUSINESS	AGRICULTURAL ECONOMICS & POLICY
		BUSINESS
		BUSINESS, FINANCE
		ECONOMICS
		INDUSTRIAL RELATIONS & LABOR
	EDUCATIONAL SCIENCES	EDUCATION & EDUCATIONAL RESEARCH
		EDUCATION, SCIENTIFIC DISCIPLINES
		EDUCATION, SPECIAL
		PSYCHOLOGY, EDUCATIONAL
	INFORMATION AND COMMUNICATION SCIENCES	COMMUNICATION

	INFORMATION SCIENCE & LIBRARY SCIENCE
LAW AND CRIMINOLOGY	CRIMINOLOGY & PENOLOGY
	LAW
	MEDICINE, LEGAL
MANAGEMENT AND PLANNING	AREA STUDIES
	MANAGEMENT
	PLANNING & DEVELOPMENT
POLITICAL SCIENCE AND PUBLIC ADMINISTRATION	INTERNATIONAL RELATIONS
	POLITICAL SCIENCE
	PUBLIC ADMINISTRATION
PSYCHOLOGY	PSYCHOLOGY, BIOLOGICAL
	PSYCHOLOGY, CLINICAL
	PSYCHOLOGY, DEVELOPMENTAL
	PSYCHOLOGY, APPLIED
	PSYCHOLOGY, MULTIDISCIPLINARY
	PSYCHOLOGY, PSYCHOANALYSIS
	PSYCHOLOGY, MATHEMATICAL
	PSYCHOLOGY, EXPERIMENTAL
	PSYCHOLOGY, SOCIAL
SOCIAL AND BEHAVIORAL SCIENCES, INTERDISCIPLINARY	DEMOGRAPHY
	SOCIAL ISSUES
	SOCIAL SCIENCES, INTERDISCIPLINARY
	SOCIAL SCIENCES, BIOMEDICAL
SOCIOLOGY AND ANTHROPOLOGY	ANTHROPOLOGY
	ETHNIC STUDIES
	FAMILY STUDIES
	SOCIOLOGY
	WOMEN'S STUDIES
	HOSPITALITY, LEISURE, SPORT & TOURISM
	CULTURAL STUDIES

9.3 Supplementary figures: Chapter 4.

Figure A.1. Development in mean normalized citation scores (MNCS) based on fractional counts for 14 countries; three year overlapping publication blocks. Corresponds to Figure 4.1.

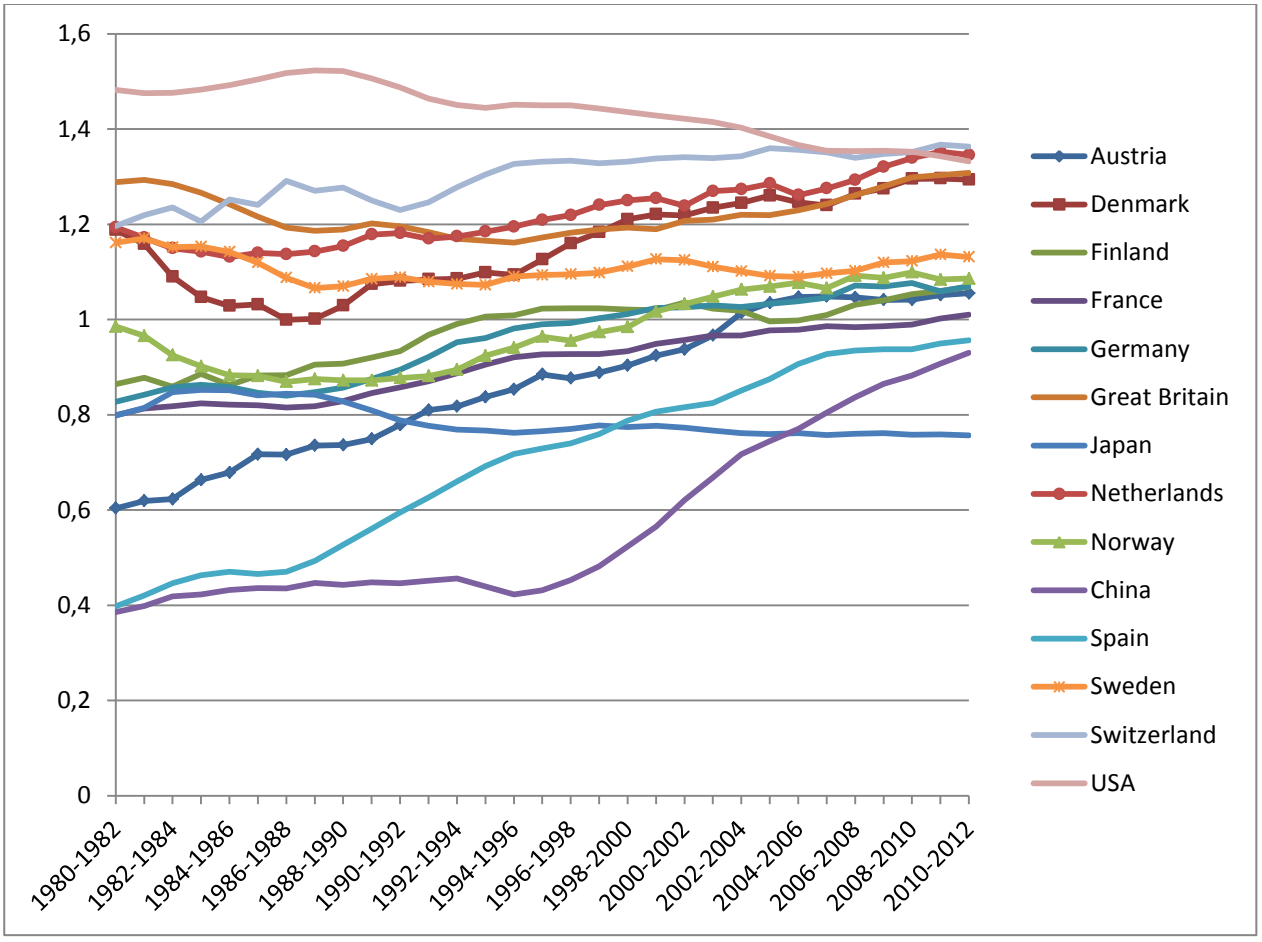


Figure A.2. Developments in mean normalized citation scores (MNCS) for Denmark and the four benchmark countries, the indicator is based on fractional counts and calculated for three year overlapping publication blocks. Corresponds to Figure 4.3.

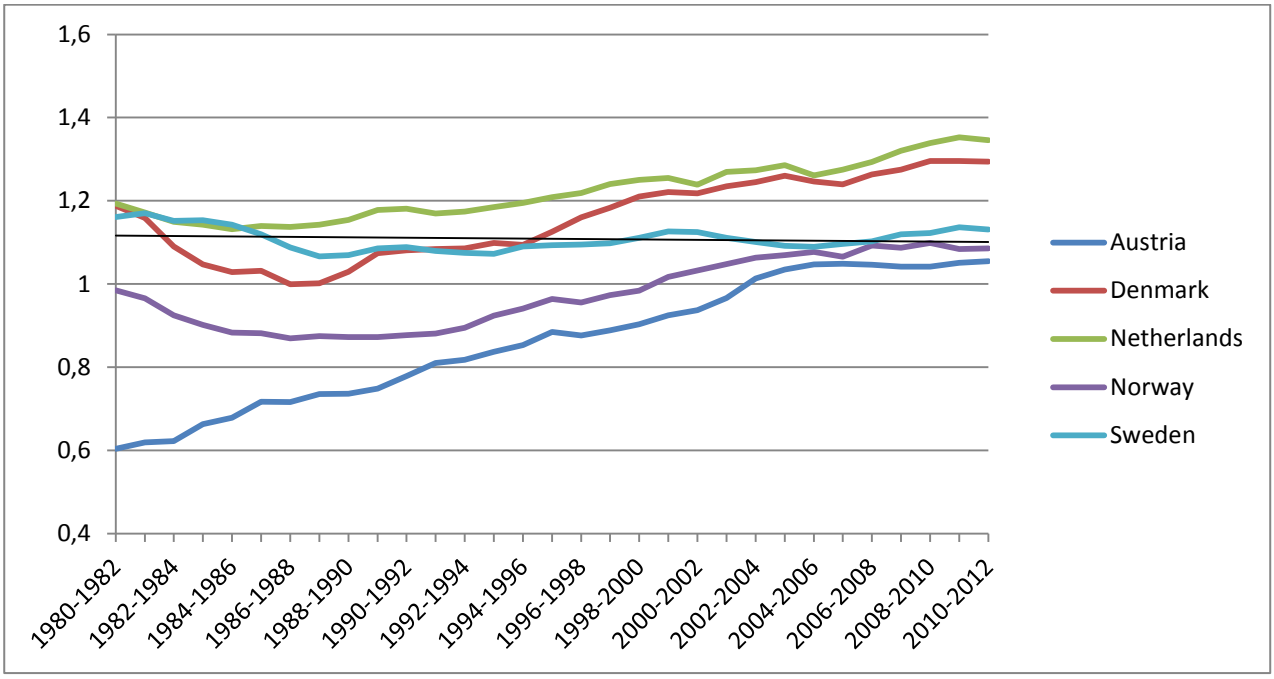


Figure A.3. Developments in PPtop10% for Denmark and the four benchmark countries, the indicator is based on fractional counts and calculated for three year overlapping publication blocks. Corresponds to Figure 4.4.

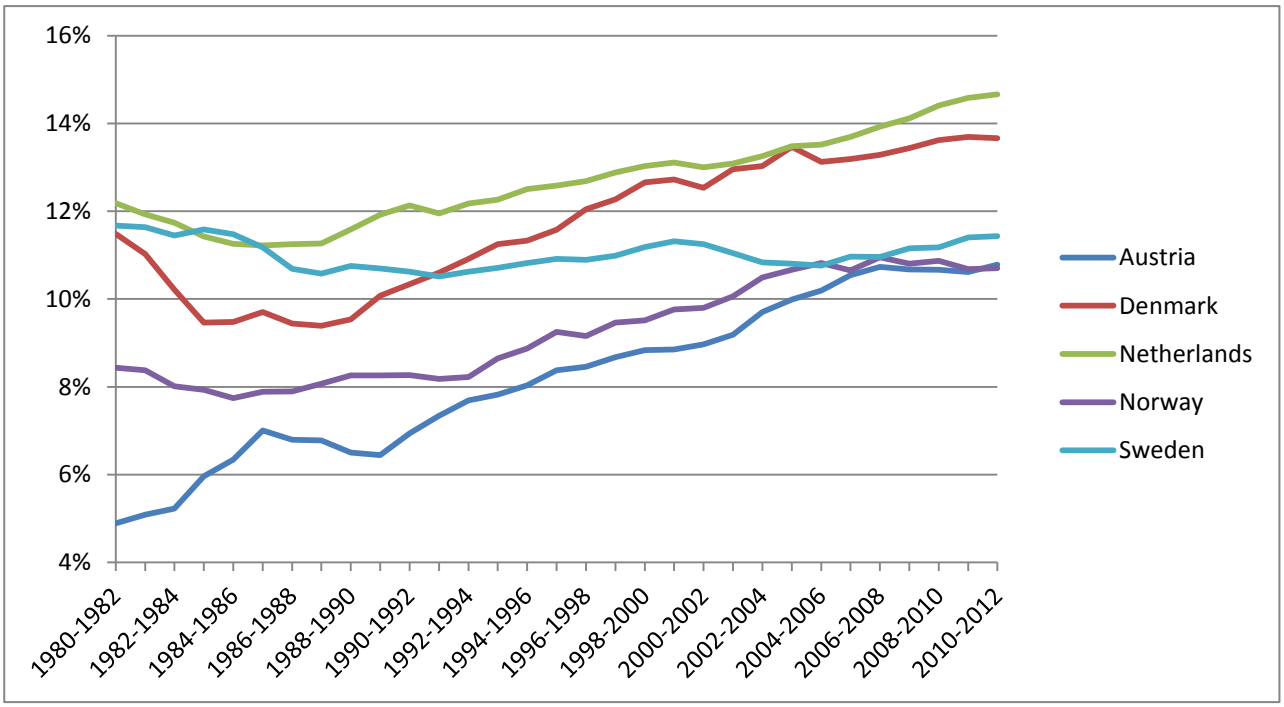


Figure A.4. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Denmark. Indicators are based on full counts. Corresponds to Figure 4.7.

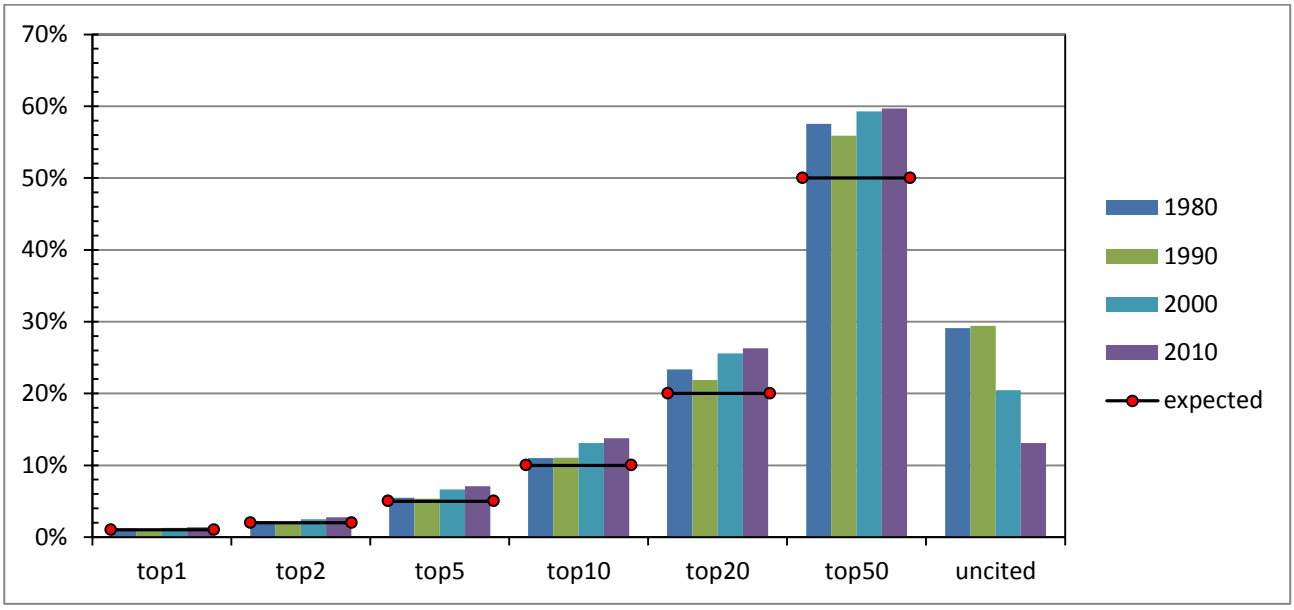


Figure A.5. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for the Netherlands. Indicators are based on full counts. Corresponds to Figure 4.8.

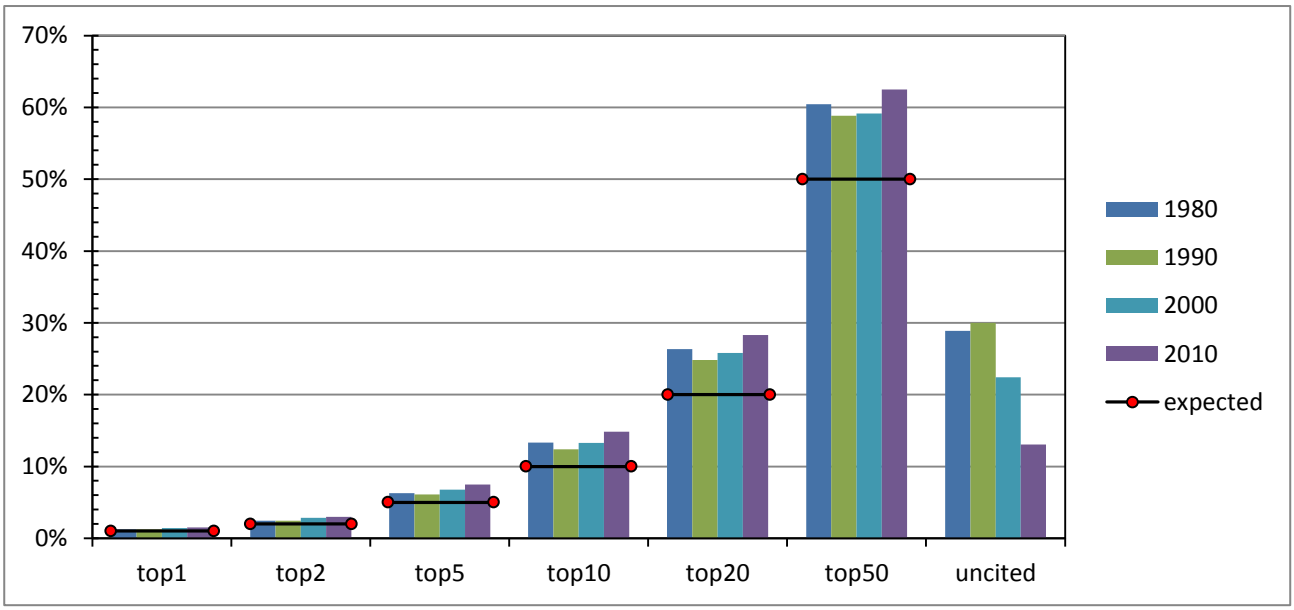


Figure A.6. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Sweden. Indicators are based on full counts. Corresponds to Figure 4.9.

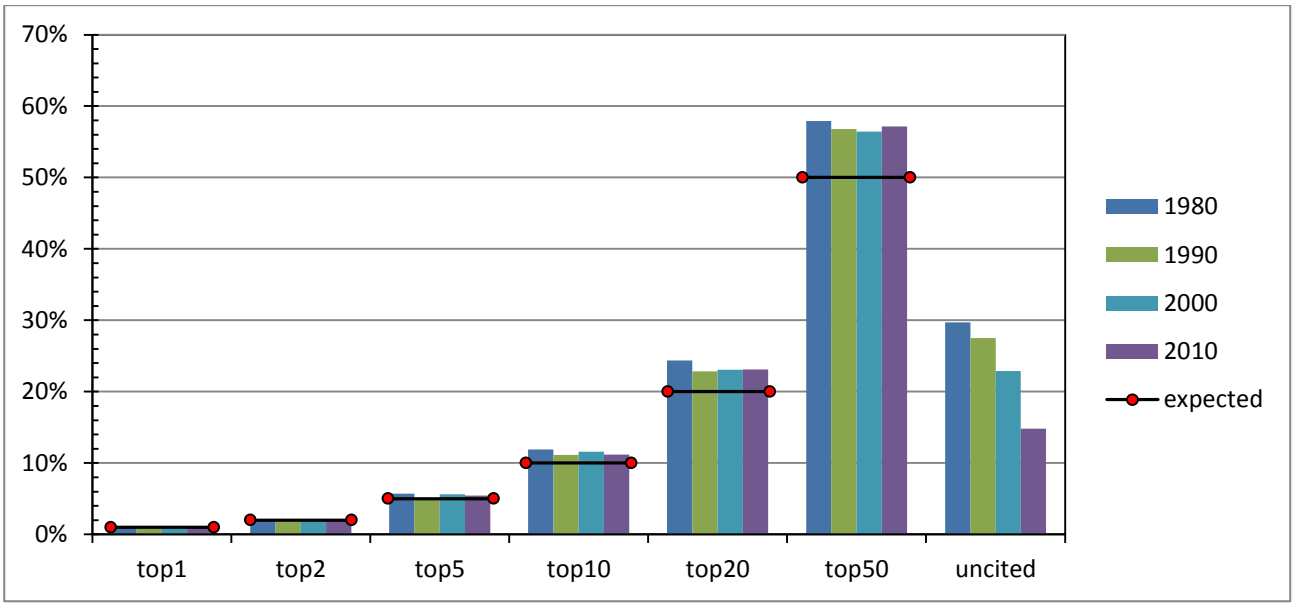


Figure A.7. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Norway. Indicators are based on full counts. Corresponds to Figure 4.10.

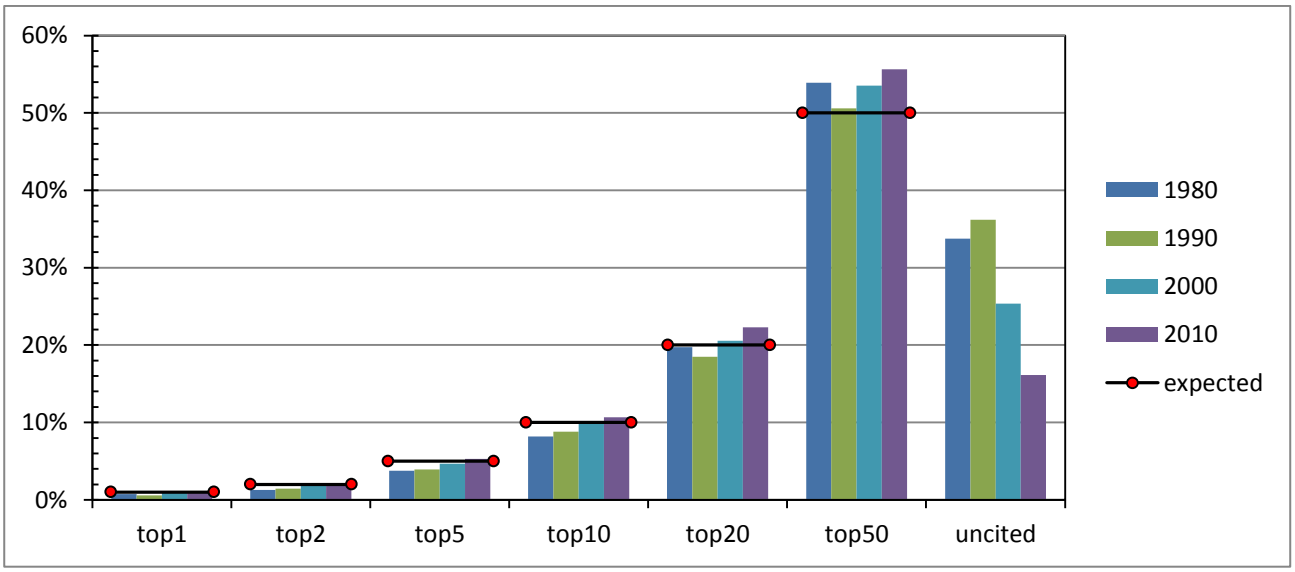
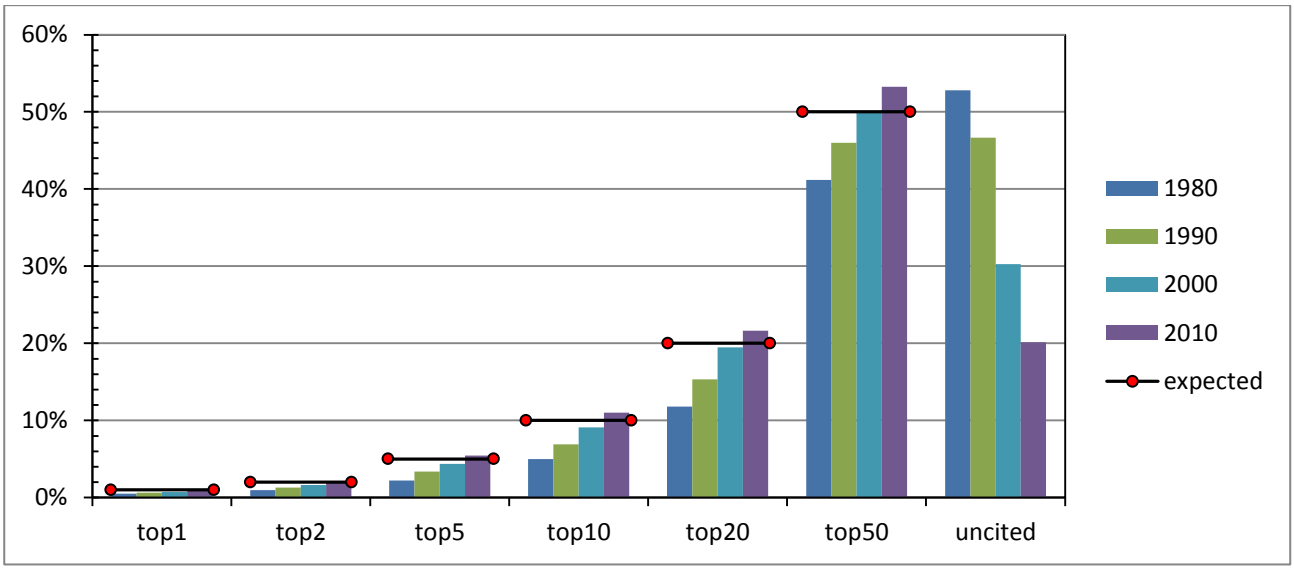


Figure A.8. Development in publication shares within selected percentile classes of the global citation distribution in the WoS database for 4 three year publication blocks, as well as shares of uncited publications for Austria. Indicators are based on full counts. Corresponds to Figure 4.11.



9.4 Supplementary figures: Chapter 5.

Figure A.9. Developments in the relative distribution of Danish WoS publications among six main OECD fields, shares are based on full counts. Corresponds to Figure 5.1.

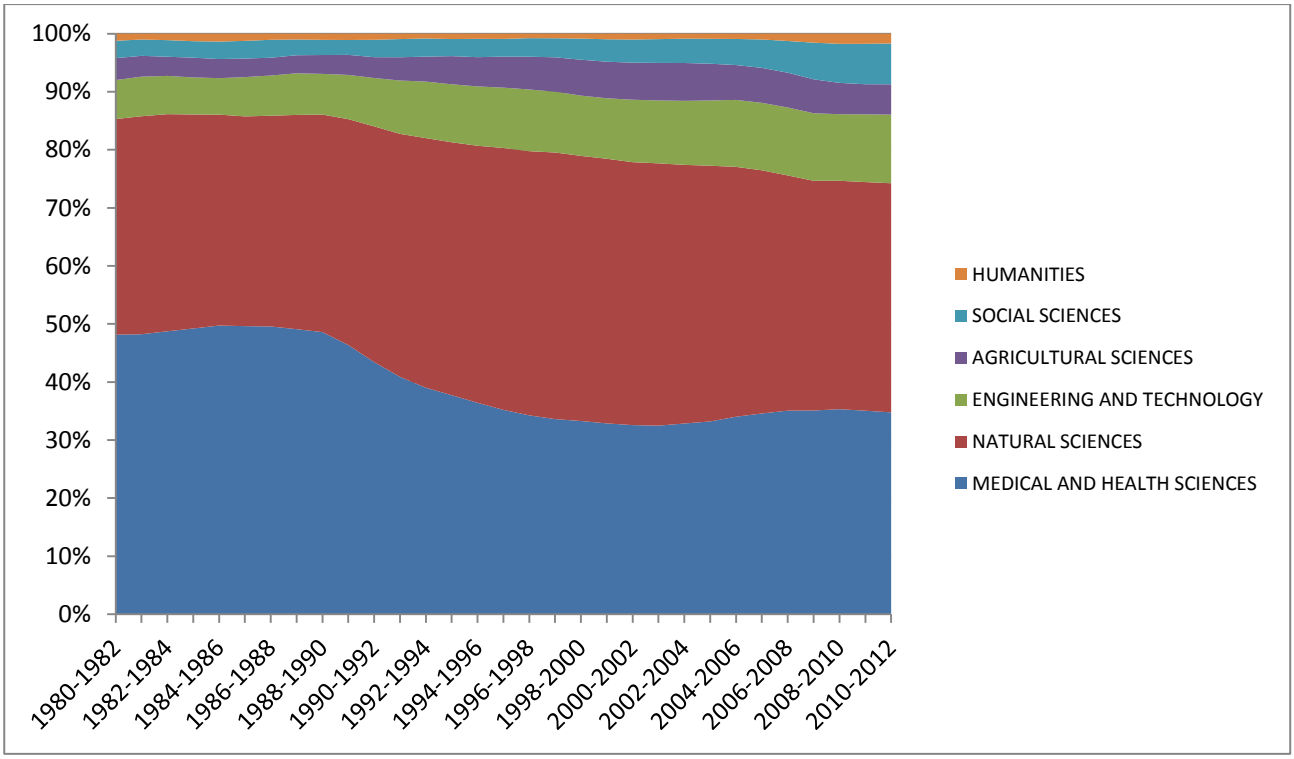


Figure A.10. OECD main field level, mean normalized citation score (MNCS) for Denmark, fractional counts., corresponds to Figure 5.2

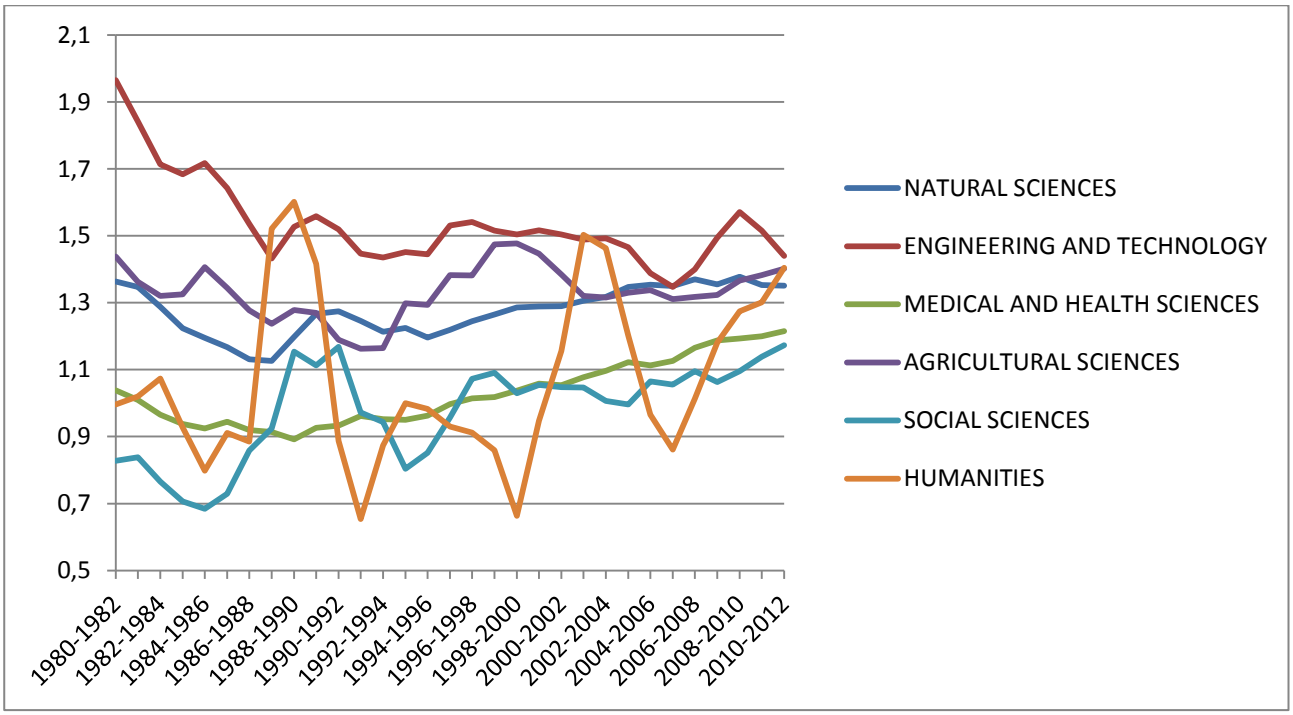


Figure A.11 OECD main field level, proportion of top 10% highly cited publications (PPtop10%) for Denmark, full counts.

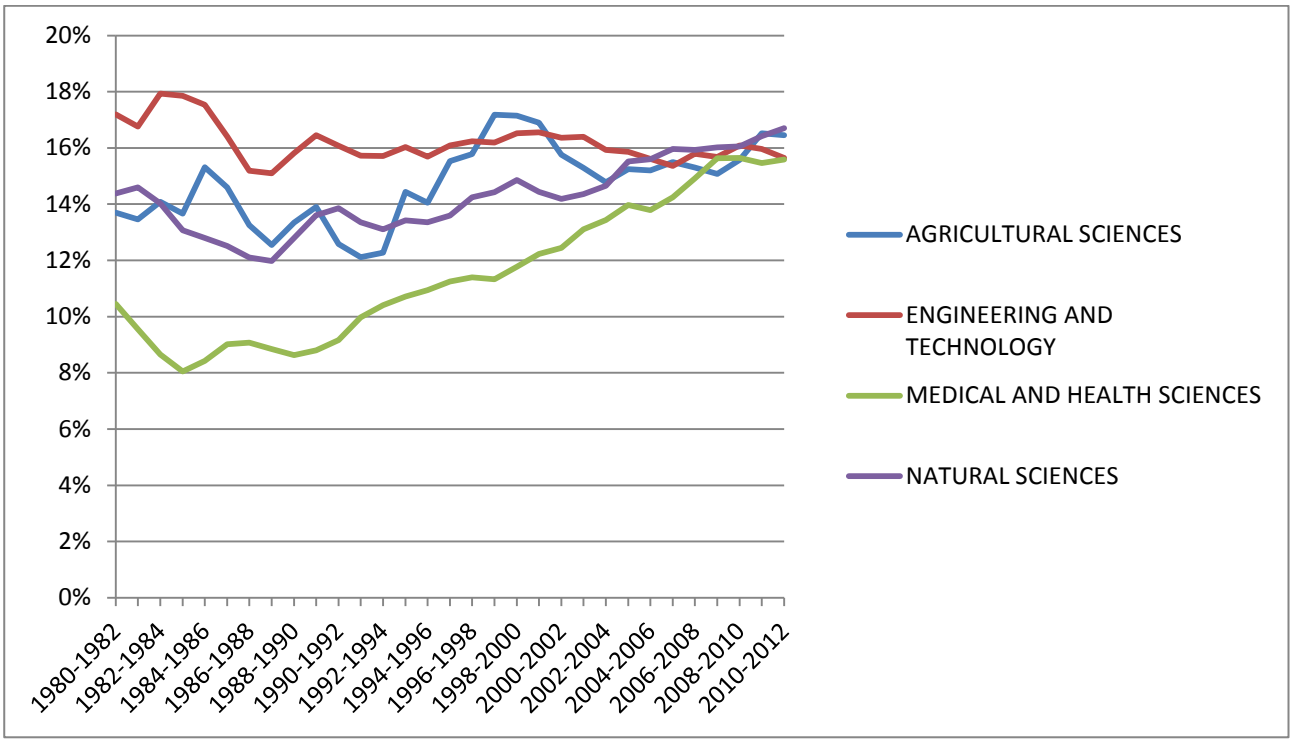


Figure A.12. OECD main field level, proportion of top 5% highly cited publications (PPtop5%) for Denmark, full counts.

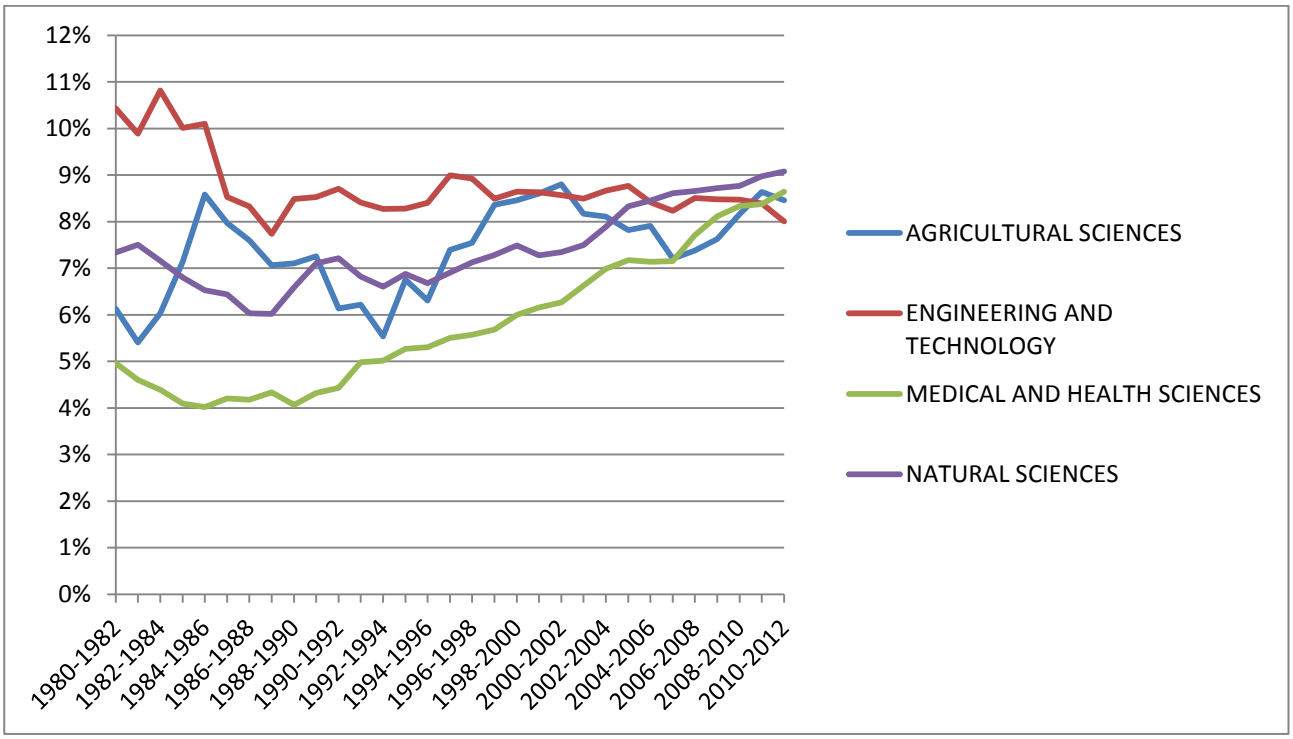


Figure A.13. OECD main field level, proportion of top 1% highly cited publications (PPtop1%) for Denmark, full counts.

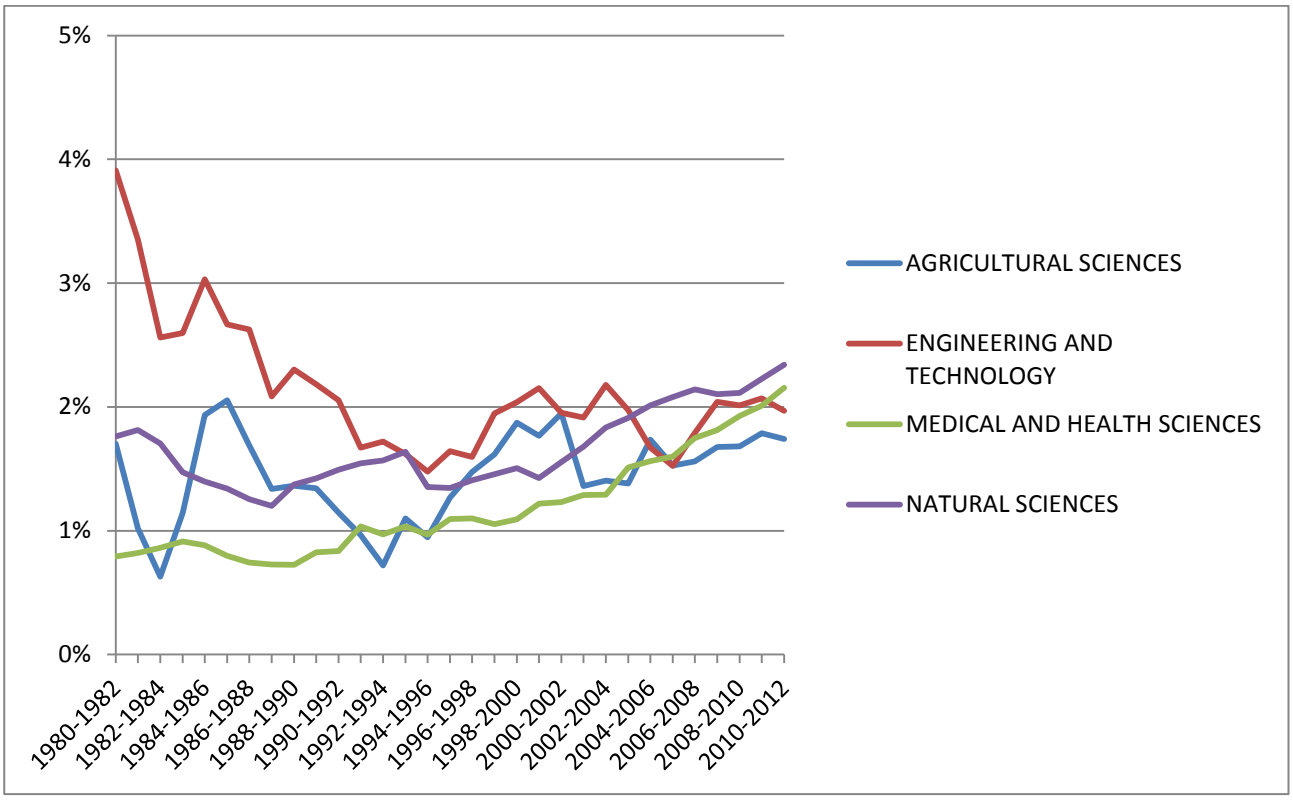


Figure A.14. OECD main field level: Share of uncited publications at field level for Denmark, full counts.

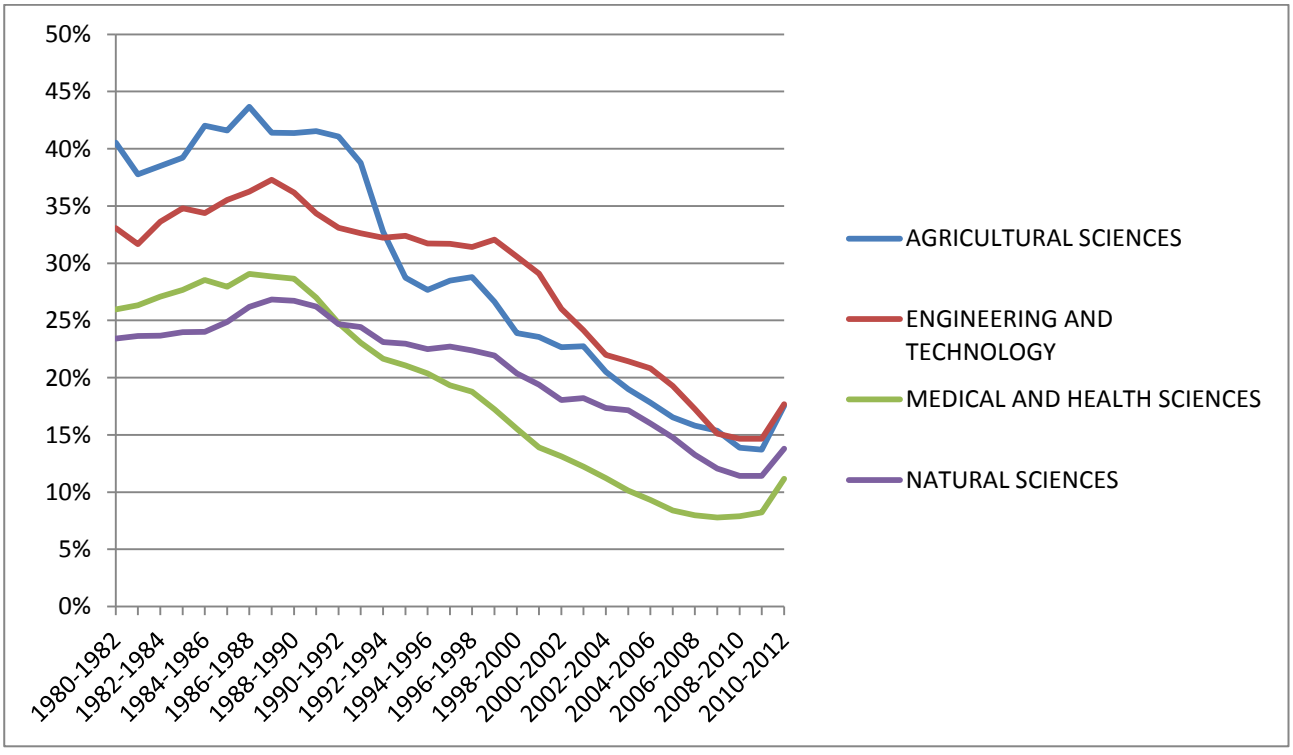
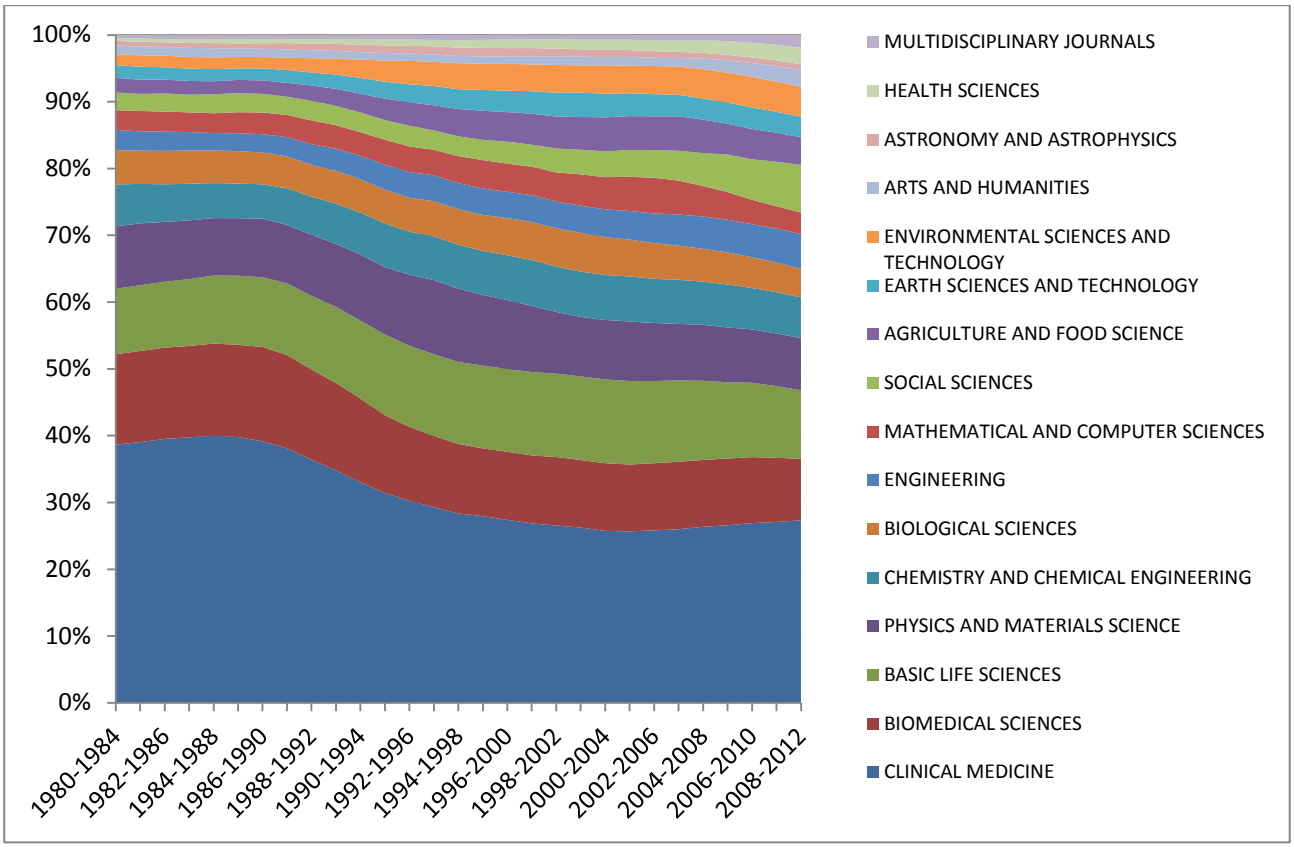
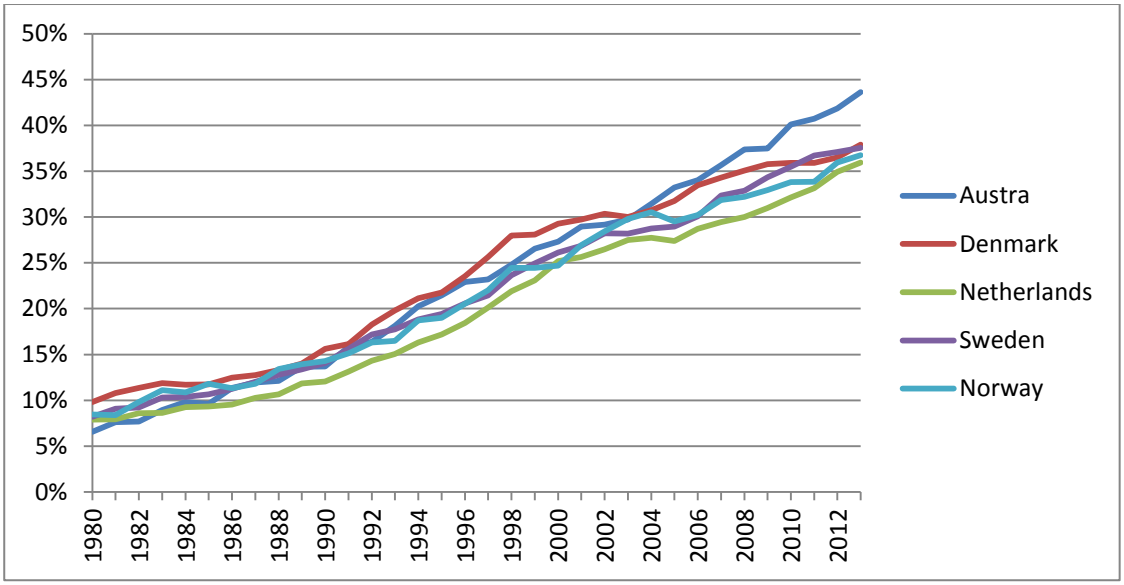


Figure A.15. Developments in the relative distribution of Danish WoS publications among 16 NOWT fields, shares are based on fractional counts Corresponds to Figure 5.9.



9.5 Supplementary figures: Chapter 6.

A.16. Share of international collaboration based on fractional counts, corresponds to Figure 7.1.



9.6 Supplementary figures: Citation impact for clinical medicine (NOWT-classification).

Figure A.17. Clinical medicine (NOWT field), mean normalized citation score (MNCS) for the five benchmark countries, fractional counts.

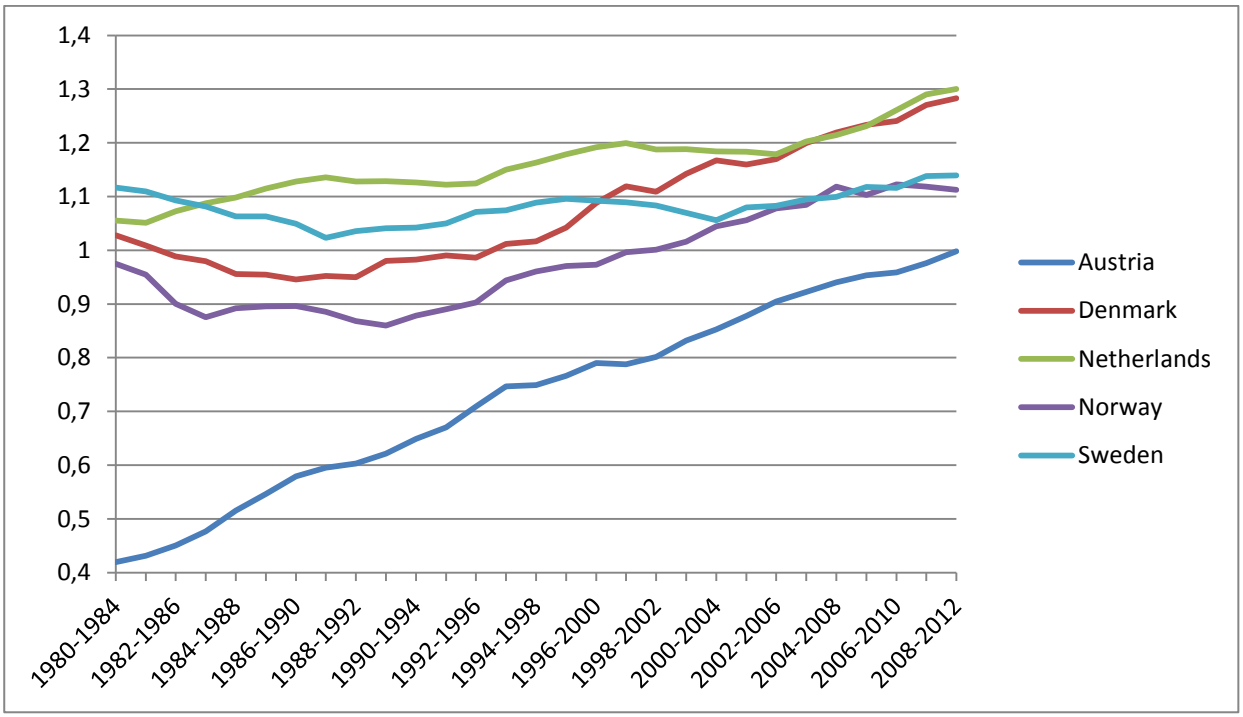


Figure A.18. Clinical medicine (NOWT field), proportion of top 10% highly cited publications (PPtop10%) for the five benchmark countries, fractional counts.

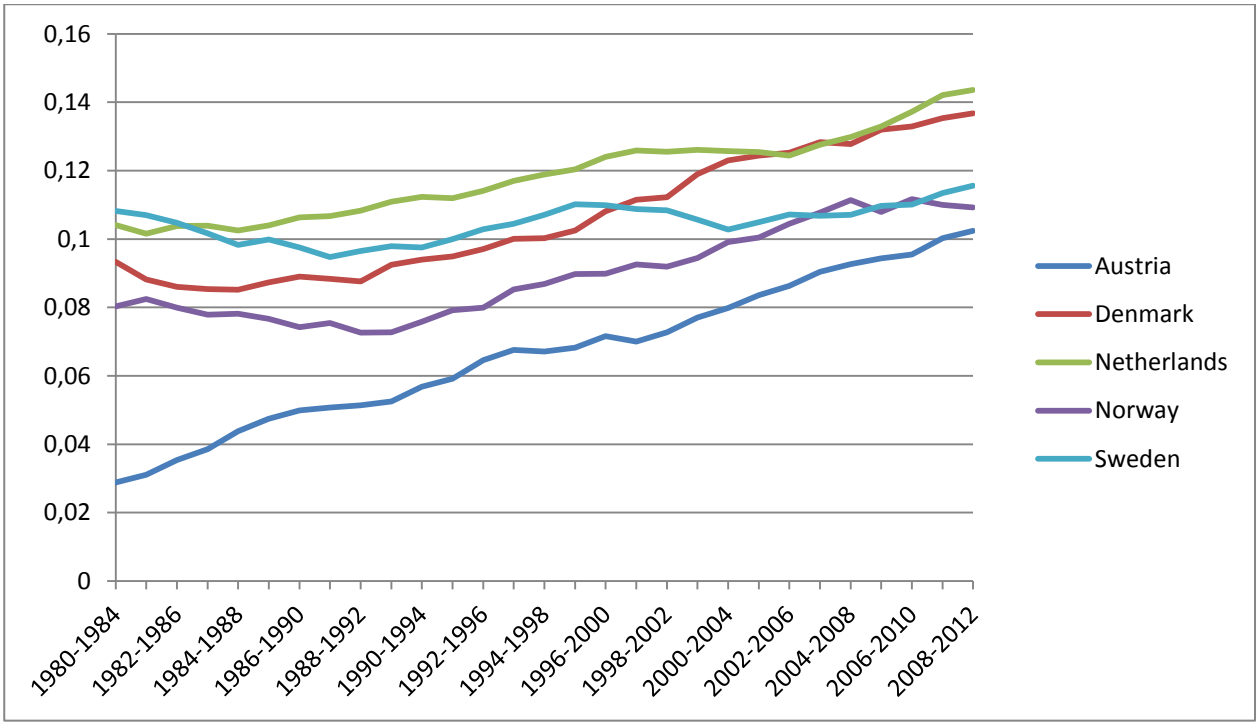


Figure A.19. Clinical medicine (NOWT field), mean normalized citation score (MNCS) for the five benchmark countries, full counts.

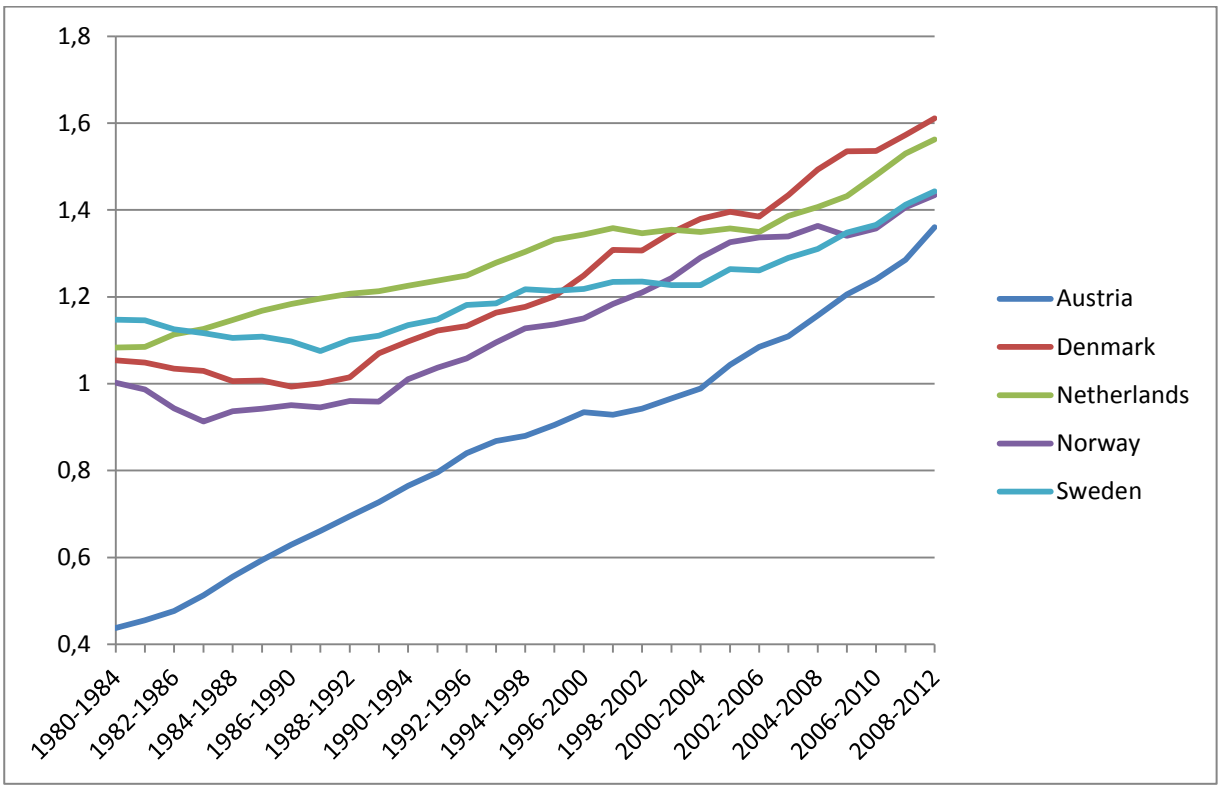


Figure A.20. Clinical medicine (NOWT field), proportion of top 10% highly cited publications (PPtop10%) for the five benchmark countries, full counts.