Analyses of the scholarly and scientific output from grants funded by the Danish Council for Independent Research from 2005 to 2008

Report to the Danish Ministry of Science, Innovation and Higher Education

Jesper W. Schneider (corresponding author)*, **Carter W. Bloch**, **Kaare Aagaard**, **Lise Degn**, **Sanne Schioldann Haase & Dorte Henriksen**

Danish Centre for Studies in Research and Research Policy (CFA), Department of Political Science and Government, Aarhus University, Denmark

*jws@cfa.au.dk

&

Clara Calero-Medina & Erik van Wijk

Centre for Science and Technology Studies (CWTS), Leiden University, Netherlands

Table of contents

1. Summary 4

Results 9

2. Introduction 20

3. Bibliometric data and methods 25

Data and units of analysis 25

Units of analysis 26

Data collection, cleaning and matching 29

Collection, cleaning and matching: Reported and validated set of grant publications 33

Collection, cleaning and matching: Sets of CI-WoS publications for PIs and rejected applicants 36

Collection, cleaning and matching: Sets of BFI publications for FKK and FSE PIs and rejected applicants 39

Final data sets, their potentials and the benchmark units 42

Bibliometric indicators 46

Output and impact indicators 47

Journal level indicators from the Danish national performance-based indicator 54

4. Analyses of the reported scholarly and scientific output from the DFF-grants (2005 – 2008) 56

Analysis of publication behaviour based on *all* reported and validated publications from eligible grants between 2005 and 2008 56

Summary 66

Performance analysis: Citation impact of the matched WoS-indexed journal publications from eligible grants between 2005 and 2008 68

Coverage of CI-WoS publications in the DFF publication sets 69

Overall impact results for the DFF-publication set 74

Overall impact results for publication sets at the disaggregated level of councils 86

Citation impact according to subject categories 91

Indicators of collaboration 99

Advanced citation analysis: Identification of potential 'breakthrough' articles 103

5. **Comparative citation impact and publication behaviour analyses of grant PIs and rejected applicants 109**

Comparative citation impact analyses of grant PIs and rejected applicants 109

Method 114

Results 116

Summary 121

Comparative analyses of journal publication behaviour among FKK and FSE applicants based on publications from the national BFI database from 2009 to 2012 123

6. Results of surveys and interviews 126

Methods 126

Characteristics of the projects: Types of outputs, contributions and status of the research idea 128

Role of the grant recipient in the funded research project: 131

Importance of receiving a DFF grant or a rejection 133

Funding 138

Status of the rejected projects 143

7. Funding analyses 145

8. Limitations and caveats 149

9. Conclusions 152

10. References 158

11. Appendix 160

Tables and figures supporting Chapter 4. 160

Tables and figures supporting Chapter 5. 168

Tables and figures supporting Chapter 6. 171

1. Summary

The purpose of the present report is to examine the output and citation impact of publications reported as outcomes of various types of grants funded by the Danish Council for Independent Research (DFF) in the period 2005 to 2008. The results presented in the report are based upon state-of-the-art bibliometric indicators calculated on meticulously assembled comprehensive and unique datasets. While the data still has a number of limitations, which we describe in detail in this report, both quality and completeness of the data are high by international standards and form a strong basis for the analyses in this report.

The DFF comprises five field specific research councils: health sciences (FSS), natural sciences (FNU), technical sciences (FTP), social sciences (FSE), and arts and humanities (FKK). The DFF grant types included in the present analyses vary to some extent in amount and duration but can generally be considered as smaller grants, for example compared to Centres of Excellence (CoE) funded by the Danish National Research Foundation (DNRF). The units of analysis in this report are the DFF itself (i.e. the aggregate set of all publications for all five councils) and the individual research councils (i.e., the aggregate set of individual grant publications linked to the different councils). We do not focus on the performance of individual grants. Hence, overall we are examining a heterogenic unit with instruments of different types and scale, but common goals of supporting bottom-up researcher initiated projects with potential impact. The latter is examined quantitatively in this report, but these characteristics of DFF as a unit of analysis also challenge the bibliometric analyses and the comparisons of the results.

Additionally, to explore the performance effects of being funded and to characterize and examine the citation performance of successful applicants, before and after the DFF-funding, the performance of the grants' Principal Investigators (PI) is compared to a set of carefully matched rejected applicants. To supplement and contextualize these bibliometric analyses, surveys and interviews among PIs and rejected applicants have been conducted.

The focal performance measures used in this report to assess impact are citation indicators. Impact in this sense is a measure of reception of a unit's publications in the scientific community. Objections have been raised against this premise, but it is widely assumed that with a sufficient number of publications and especially when focusing on the most highly cited publications sound quantitative evaluations can be made. Citations, however, do not measure "research quality" per se; but it is often assumed that impact may reflect a dimension of research quality at least in certain fields.

While the report examines a number of publication and citation indicators in order to investigate publication behaviour, profiles and impact of the units of analysis, the main focus is upon highly cited publications. In bibliometric studies, the concept of "excellence" is often linked to a unit's ability to produce highly cited publications. Citation distributions are heavily skewed, a small number of publications receive most of the citations, and many publications receive few or no citations. Highly cited is defined as publications cited equal to or more than a certain percentile limit of the distribution (in this report the 90th percentile). Most of the publications at this level are considered influential and the assumption is that a unit's proportion of publications at this level says something about the importance and "excellence" of this unit when it comes to influencing the scientific community. The indicator for highly cited publications is named PPtop10% (a unit's proportion of highly cited articles, where the highly cited in this case is 90th percentile or above in the global citation distribution), whereas the indicator for mean normalized citation scores is named MNCS (a mean normalized citation score where citation scores are comparable between fields due to normalization; the reference value one corresponds to the average citation activity in the database).

The standard publication period covered for all citation analyses is 2005 to 2012 with three year citation windows (except for 2011 and 2012 where the window is shorter). However, for specific comparative analyses we do also examine shorter windows. For the comparison of PIs and rejected applicants, publications from 1996 to the individual application years (2005, 2006, 2007 or 2008) are used to calculate pre-application publication performance, still with three year citation windows.

Assigning publications to a specific funding institution and treating them as if they were a direct result of "belonging" to such an institution is obviously somewhat arbitrary. Publications are usually a result of several influences and funding sources. However, for convenience, we treat publications linked to DFF grants as a distinct set of "DFF-publications" for this analysis (see below and Chapter 7 for a more thorough discussion and analysis of this issue).

Citation impact is examined for the DFF-set of publications, the council-sets, and the PI-oeuvres (the PIs portfolio of (co)authored publications). These publication sets are compared to database reference values and in order to provide more context to the results, the DFF-set and the council-sets of publications are also compared to the performance of other Danish publications published in the same research areas and in the same period as the examined DFF sets, whereas the PI-set of publications is compared to carefully matched publication oeuvres of rejected applicants

for the same period. Finally, we also compare the performance of the DFF-set of publications to a carefully constructed set of publications linked to Danish Centres of Excellence funded by the Danish National Research Foundation.

In scientometric studies we usually compare like with like such as a research institution with other research institutions and preferably of roughly similar size in output. The benchmark units in this report are not without problems. While the set of publications linked to DFF can be seen as a subset of Danish publications, there are considerable differences in size and coverage. In that respect, the DNRF set of publications seems to be a more suitable benchmark unit for DFF. But such a comparison is also not ideal because, while both units are funding institutions, and of approximately similar size when it comes to publications from 2005 to 2010, the two have quite different modes and funding instruments of widely different scales. Essentially, they play different roles in the Danish research funding ecology. This should be taken into consideration when interpreting the results. An ideal benchmark unit would obviously be very similar funding institutions as DFF but such do probably not exist and we have not been able to construct one.

The methodology used for examining potential performance effects of being funded has some strengths and limitations. An important strength is that we have extensive data on publication and citation activity for a relatively large sample of individuals over a long time period. This allows us to compare individuals both before and after grant periods. We are also able to use a variety of indicators which improves robustness and, importantly, these indicators are field normalised which facilitates comparison across disciplines. Furthermore, through the validation process described above, we have been able to identify those publications that are specifically linked to DFF grants for the large majority of individuals in the sample. Finally, rejected applicants are arguably the best possible candidates for a control group to compare with PIs. There are also a number of limitations that complicate efforts to isolate potential effects. The first concerns the nature of bibliometric data itself. Bibliometric data is typically highly skewed, which means that individual values (that may be driven by individual specific factors) can greatly influence aggregated results. A second limitation is unobserved factors that may also affect developments in citation impact, and potentially in different ways for PIs and the control group. Possibly the most important among these is alternative funding sources. It is likely that the far majority of individuals from both groups (PIs and rejected applicants) have received external funding from a variety of sources; this is actually indicated in the survey answers in Chapter 6. Individuals' research activities may often rely on a complex stream of different forms of funding, making it very difficult to isolate the effects

of a single source. We are though able to identify whether individuals have received a DFF grant or not over the period, however even here we do not know whether rejected applicants have been involved in other DFF grants as a participant (and not the PI). Nonetheless, we still view the comparison of PIs with rejected applicants to be very valuable in shedding light on the effects of DFF grants, in particular given that we are able to identify those publications that are directly linked to DFF grants.

It is well-known that impact analyses require comprehensive citation databases and that such databases primarily cover journal publications. Hence, citation impact analyses in scholarly fields where international journal publication is not the primary publication activity and/or where database coverage of journals actually published in is low have lower validity and are less reliable, compared to traditional "journal fields". Most fields in the humanities and many fields in the social sciences do not have international journal publication as their main publication activity and the journal coverage of many of these fields in the citation databases are mediocre or poor. Traditionally, such fields are therefore excluded from impact analyses. Despite these well-known coverage issues, it has been a request for the present report that bibliometric analyses are carried out for all five research councils and their publications. Because impact is the focal performance indicator and because the research councils subsume a number of different fields with different publication characteristics, all international journal publications indexed in the Web of Science (WoS) citation database are included in the analyses and subsequent examinations of coverage at the council level will determine the validity and robustness of the impact measures calculated for each council. Hence, some grants, especially from FKK and FSE will be excluded from the citation analyses and some of the grants included will have a substantial number of publications excluded from the citation analyses. It is therefore extremely important to emphasise that measured impact and performance presented in this report is solely based on journal articles indexed in the WoS. It is therefore only a subset of the reported output from DFF grants which is actually examined for impact, and the relevance of such impact measures varies between the five councils.

Secondarily, the report also provides publication output of all publication types reported as outcomes for the individual grants for all five research councils. The basis for examining publication output are the originally reported (and potentially validated and extended) publication lists submitted to the Danish Ministry of Science, Innovation and Higher Education immediately after the funding period expired. Publication output only provides insights into publication behaviour and activity, and is in itself a poor comparative performance indicator. To supplement

the limitations of using citation analysis in fields covered by FKK and FSE, a simple publication analysis is carried out on all reported grant journal publications published from 2009 to 2012, where the "status" of the journals of these publications in the national Danish bibliometric performance indicator (BFI) is examined[1]. Notice, such an analysis can only indicate something about preferences in publication behaviour, not the actual impact of what is published, however, in many fields publishing in reputable journals is subject to a more rigorous peer review process and generally leads to higher visibility.

The publication sets used in this report have undergone a thorough and labour-intensive cleaning and matching process where the originally reported publication lists have been manually cleaned and validated to the extent possible. Journal publications from the reported publication lists have been extracted and further cleaned in order to be matched with records from CWTS' version of the Web of Science citation database (CI-WoS) and the CFA in-house version of the national Danish bibliometric indicator database (BFI). Likewise, based on names, email addresses and affiliations, PIs and rejected applicants have been identified and publication portfolios constructed. It is important to emphasize that the originally reported publication lists, as well as the information available on PIs and rejected applicants, vary in format and quality and to some extent are deficient when it comes to providing reliable details for automatic identification and matching purposes. The publication lists include valid publications of all kinds, but also publications in planning and submission phases where publication details are highly unreliable and most likely also publications that never materialized. As a consequence, not all eligible publications will be identified in the databases, and name ambiguities and varying degrees of information on the PIs and rejected applicants mean that the identification process is susceptible to attrition among units, and we can also expect some missing publications among those units included in the analysis. Consequently, the total number of DFF-publications (and PI and rejected publications) should be treated cautiously as there will be false positives as well as missing publications. As part of the survey to the PIs, a validation procedure for the initially reported grant outputs was implemented. In total, 1322 grants have contributed with 19,958 reported publication outputs of which 405 were added in the validation process. Some 82 percent of the grants examined come from three research councils FNU, FSS and FTP and together they contribute 78 percent of all reported publication types.

[1] BFI is a national performance-based publication indicator implemented in 2009 which redistributes basic funding among universities in Denmark based on their annual publication activity. Based on a two-tiered categorization of publication channels (i.e., journals, book publishers and conference series), the BFI indicator assigns more points to publication types published in the "most renowned channels" within 68 specific disciplines covering all scholarly and scientific fields (for a more thorough presentation of BFI, see page 54).

Outputs from 805 grants of the 1322 were validated. 108 of the 1322 grants are postdoc grants which are treated separately in several analyses due to request from the Ministry. Approximately 50 percent or 9590 of all reported outputs are claimed to be journal articles

Matching this output to CI-WoS results in an 83 percent match rate, but after removing duplicates, other publication types than articles and reviews, as well as articles published before 2005, 6963 unique CI-WoS journal articles remain and when distributed among councils, 7660, as some publications are linked to several grants and councils. These publications come from 1042 different grants and constitute the publications used for the citation analyses of the DFF and the individual councils. Also, 3946 of the initially reported journal articles published between 2009 and 2012 are matched to the BFI-database and are used for journal publication behaviour analyses. Finally, publication portfolios for 1213 PIs were created comprising in total 85,453 CI-WoS journal articles. Correspondingly, publication portfolios for 1507 rejected applicants were also created comprising in total 40,149 CI-WoS publications. The latter two sets comprise researchers from all five councils and are used as the basis for the comparison analyses between PIs and rejected applicants. Also, 2422 journal articles linked to PIs and rejected applicants from FKK and FSE are matched in the BFI-database and are used for comparative journal publication behaviour analyses. In all, seven different, but also for some of them intervening, publication sets have been established for the different bibliometric analyses from the abovementioned outputs. Despite the deficiencies in the data and in the identification and matching processes, on the aggregate level of analyses, we consider the basis robust given the number of publications involved. The intensive data collection, cleaning and matching procedures are thoroughly outlined and discussed in Chapter 3.

Results

First, it is important to make one thing clear before outlining the main results in roughly the same order as are presented in the report. **The overall performance of publications linked to DFF grants funded in the period from 2005 to 2008 is quite impressive, impact is generally high and far above the international reference levels.** We elaborate on this below, but first some general considerations about publication behaviour and coverage.

As 78 percent of the total reported output comes from councils where journal publication is the main publication activity, it is not surprising that journal articles are by far the most prevalent reported publication type for all councils combined. Though the emphasis upon journal publication varies considerably between the five research councils. For FSS, close to three out of four reported

outputs are journal articles; for FNU it is slightly more than 2 out of three reported outputs. The numbers are lower for FTP, slightly under half of the reported output is journal articles, whereas for FSE it is one in three and for FKK one in five. The analyses thereby reveal some distinct but well-known differences in publication behaviour between the five research councils. **It is very clear that the main publication activity reported for grants funded by FSS, FNU and to lesser extent FTP is journal articles, whereas the publication behaviour for FSE and FKK is more heterogenic and less dependent on journal publication. In a sense, the publication behaviour discernible for the five research councils provides a picture of what is prioritized and what is considered a scholarly or scientific output in the respective areas. Obviously, this is important when interpreting performance results mainly based on journal publication behaviour.** Notice, the publication profiles emerging for the five research councils come from the reported outputs of individual grants. In that respect, it is the aggregated behaviours of different research domains that eventually come to light at the council level. What we see is the reported activities as well as the preferences for publication types. This is informative as it demonstrates the major differences between fields which are especially important to keep in mind in a bibliometric analysis. Publication analyses cannot be used for comparable performance analyses; for this we need citation analyses. However, to supplement the existing publication analyses, we have examined the publication behaviour for the individual councils in relation to the potential preferences for which journals to publish in. This is possible due to the two-tiered classification of journals in the national Danish bibliometric indicator, where level two journals are considered a restricted set of more reputable journals. 3946 of the reported grant journal articles published between 2009 and 2012 were matched to the BFI-database. The results are interesting in as much as **the share of level 2 publications is clearly larger than one would expect given the official BFI-statistics for main research fields. Level 2 publication activities for the natural sciences and technology is around 40 percent, health sciences 37 percent, social sciences 35 percent and the humanities around 30 percent. In that respect, publication activity in journal status level 2 for the five research councils, based on the reported matched articles in the BFI-database, is generally considerably higher than one would expect based on the official statistics.** Obviously, the importance of such results should be weighed against the importance of journal publication activity in the respective fields; however the pattern for DFF is very clear.

The publication analyses have already indicated the aggregated status of journal publication behaviour among the five research councils. Turning to the citation analyses, before calculating the

actual indicators at different levels we first estimate the "coverage" for the units' different publication sets. We do this by determining, from the DFF and council sets of publications, the extent to which researchers cite other CI-WoS journal publications in their articles linked to the DFF grants. While not perfect, this approach to estimating coverage provides a good indication of a unit's reliance on CI-WoS journal publications versus non-CI-WoS publications such as books, book chapters and conference papers. **Coverage in the citation database for the whole DFF set of publications can be considered "excellent". Likewise, at the council level of analysis coverage is "excellent" for FSS, FNU and FTP, but "moderate" for FSE and "poor" for FKK.** Nevertheless, the "poor" coverage of FKK is higher than expected and is due to the inclusion of fields like psychology and philosophy under FKK where journal publication activity is considerably more prominent than many other fields in the humanities.

The citation impact analyses are based on 6963 unique journal articles from 1042 grants. 49 percent of the publications are linked to FNU, 30 percent to FSS, 16 percent to FTP, 4 percent to FSE and 1 percent to FKK.

Overall, three different compositions of the overall DFF set of publications (FNU, FSS and FTP; FNU, FSS, FTP and FSE; and all council publications combined) with two different publication windows (2005-2012 and 2005-2010) have been scrutinized, both with and without the restricted set of publications linked to the 2006 postdoc grants, and similar procedures have been carried out for the postdoc set in isolation. **Regardless of the composition or windows the evidence is clear; the DFF sets of publications perform at a very high level both when it comes to the proportion of highly cited publications (PPtop10%) and mean normalized citation score (MNCS). Overall, the PPtop10% is roughly 19 percent, i.e., 19 percent of the DFF publications are among the top 10 percent cited publications in the database, which is almost twice the expected value, and the MNCS fluctuates some 0.2 points around 1.80.** The small fluctuations in the MNCS are due the inclusion of shorter citation windows for publications from 2011 and 2012. Doing so raises the proportion of non-cited articles simply because they need more exposure time to be cited. **Compared to other units of this size and composition, the indicator values are considerably above the international level and the indicators are very stable across the different sets and publication window blocks. Further, the proportion of non-cited publications (Pnc) is somewhat lower, by around two to three percentage points, than expected for units of the same size and similar citation windows. The stable MNJS indicator (mean normalized journal citation score, an indicator for the average impact of the journals a**

unit publishes in) around 1.47 to 1.51 can also be considered high; testifying that the sets of DFF publications are on average published in journals with relatively high impact in their respective fields.

The publication set linked to the 2006 postdoc grants are considerably smaller than the overall DFF set. The overall performance for the postdoc set is remarkably high, well above the overall DFF set, and the indicators are stable. The articles are published on average in journals with very high impact, and the actual impact of the articles is between 160 to 180 percent above the expected reference value for PPtop10% and 127 to 145 percent above the expected average database citation rate for MNCS. It is especially noteworthy that the proportion of highly cited articles, between 26 and 28 percent, are so much larger in the postdoc set. Obviously, when combining the DFF and postdoc sets of publications, given that the postdoc set is much smaller; we expect some small positive changes in the relative indicators in the overall DFF set of publications. Indeed this is also what happens. The postdoc set constitutes some 4 percent of the total DFF output, yet the slight increase in publications when merging the two sets leads to a general increase in the main performance indicators of some 0.2 or 0.3 percentage points. Contextualizing the performance level of the overall DFF set places it among the highest performing universities in Europe, albeit such comparisons are difficult.

The DFF set of publications constitute some 7.8 percent of all Danish CI-WoS journal articles in the period 2005-2010. These publications receive 9.7 percent of the total number of normalized citations received for Danish articles and they constitute some 9.7 percent of all highly cited Danish publications in the period 2005-2010. Hence, as a unit the DFF set of publications provide a positive surplus in citations and highly cited articles compared to the size of their input (articles); e.g., the publication/citation ratio is that for every DFF publication there is a net gain of 1.25 normalized citations. **Looking at the relative performance indicators for Denmark as a whole, there are drops of 0.3 percentage points in the MNCS and PPtop10% when we exclude the DFF publications. The MNJS drops 0.2 percentage points and the proportion of uncited articles goes up with 0.5 percentage points when the DFF set is excluded. As we argue in detail in Chapter 4, we find this a noticeable drop in Danish indicator values.**

The performance of the DNRF benchmark unit for the period 2005-2010 is above the performance for the DFF set. This was expected because in principle conditions given to Centres of Excellence generally favours conditions known to have positive influence on high performance.

But the differences in indicator values between the two sets are generally small and most importantly both sets perform at very high levels. The DNRF set constitutes some 8.1 percent of the Danish set but receives 10.5 percent of the total number of normalized citations for Danish articles and perhaps more telling some 11.3 percent of the highly cited articles. As expected, the effect of excluding the DNRF set from the overall Danish set is slightly larger compared to the effects of excluding the DFF set. The MNCS drops 0.4 points, the MNJS drops 0.3 points, the proportion of uncited publications goes up 0.8 percentage points, but most interestingly, the PPtop10% drops 0.6 points which is double the effect produced when excluding the DFF set. Consequently, DNRF publications accrue slightly more normalized citations and significantly more of them end up as highly cited compared to the DFF set. What is important to emphasise here is not that the DNRF set performs above the DFF set, this was expected. Instead what is the important point is that fact that the DFF set performs at a very high level too. Consequently, the performance of Denmark is among the highest compared to other countries; 14.6 percent of the Danish publications examined are linked to DFF and/or DNRF. These publications accrue 18.1 percent of the total normalized citations and even more of the highly cited articles. Finally, and very interesting, 759 of the publications credited to the DFF set is also credited to the DNRF, we thus have an overlap between the two sets of 15 percent.

Finally, it is not appropriate to compare the restricted set of publications linked to the postdoc grants to the total set of DNRF publications, the differences are simply too large. Also, 15 percent of the publications linked to the postdoc set are also linked to the DNRF set. Removing these reduces the postdoc set to 203 publications, the MNCS to 1.95 and PPtop10% to 23 percent; still very high performances.

Similar to the principle differences between DFF and DNRF as funding institutions, there are also within differences between the DFF grant types which eventually could lead to potential performance advantages for some, and in that respect the size of grants may be a proxy of such cumulative advantages. **Performance calculated for grant types generally reveals high impact for all grant types, but there is some indication that impact is highest for the largest grant types.**

The disaggregate sets of publications linked to the five individual research councils all perform above the international level. Nevertheless, the FKK set should be treated with much caution due to "poor" coverage in the CI-WoS database. Compared to the overall DFF set, at the disaggregate level of councils we see variation in performance levels for the individual

councils. When including the postdoc set, FSS has the performance level both for PPtop10% at 20 percent and MNCS at 1.91. The set of publications linked to FNU (close to half of all publications) performs at roughly the same level as DFF overall, whereas FTP and FSE, while still performing at a high level, have a slightly lower level than the overall DFF set. Notice, we do not report individual indicators for the postdoc set of publications distributed among research councils as publication numbers become too small and indicators essentially unreliable. Instead we present indicators where all publications except the postdoc publications are included and where all publications are included. In this disaggregate performance analysis we also do not use the DNRF set of publications as a benchmark unit. We only use a specifically constructed Danish set of publications with and without the specific council sets of publications. The specifically constructed Danish publication sets are subsets of publications coming from the same CI-WoS subject categories where the different research councils have published from 2005 to 2012. In this way we can construct a benchmark unit that is comparable to the overall publication activity for the specific councils in given time period.

All councils perform considerably better than their benchmarks. The largest drop in indicator values happen in the case of FNU where both MNCS and PPtop10% drops by 0.2 percentage points when DFF publications are excluded. The FNU set comprises 6.5 percent of the publications in the Danish benchmark set and it contributes with 7.8 percent of the total number of normalized citations for Danish articles and 7.9 percent of all highly cited Danish articles. **The difference between the performance with and without the FSS publications is 0.1 percentage points.** The FSS set comprises 4.1 percent of the publications in the Danish benchmark set and it contributes with 5.1 percent of the total number normalized citations and 4.9 percent of all highly cited Danish articles. **A drop in PPtop10% of 0.1 is the only visible difference for FTP.** The FTP set comprises 2 percent of the publications in the Danish benchmark set and it contributes with 2.4 percent of the total normalized citations and 2.5 percent of all Danish highly cited articles (Ptop10%). **Finally, the difference between the performance with and without the FSE publications is 0.1 percentage points.** The FSE set comprises 4.3 percent of the publications in the Danish benchmark set and contributes with 5.4 percent of the total number of normalized citations to Danish articles and 5.3 percent of all highly cited Danish articles. Notice, the contributions are within the restricted subject sets.

While several research fields, defined from the subject classification of the grants, show high performance, the most stable seems to be "community medicine & epidemiology"

and "biochemistry & biophysics", as well as "micro and nanotechnology", "geosciences" and "ict". The presence of articles from the WoS subject category "multidisciplinary sciences" (e.g., journals such as Nature, Science or PNAS) seem to decisively influence the performance level in many research fields. Comparing the performance of research fields to somewhat similar subject categories in WoS, where the latter does not include articles from "multidisciplinary" journals, shows a marked drop in performance. However, **examining the performance of the DFF set of publications for the WoS subject category "multidisciplinary sciences" shows an exceptionally high performance level with PPtop10% of 44 percent and an MNCS of 6 for a set of 275 articles.**

Some 57 percent of the publications from the DFF set are a result of international collaboration. As expected the **impact is markedly higher among publications with international collaboration, with PPtop10% around 20 percent (25 percent for the postdoc set alone) and MNCS levels slightly above 2.** But **also interesting, when collaborating with international colleagues, publication behaviour tends to be directed toward the highest impact journals as measured by the MNJS reaching 1.60 for the overall and combined DFF** set and astoundingly 2.27 for the postdoc set alone. Collaboration patterns are somewhat more varied at the council level. As expected, international collaboration is generally more widespread in areas where journal publication is the main publication activity. Nevertheless, highest impact levels are distinctively among the articles with international collaboration and this is true for all councils.

As a final citation analysis, we explore the DFF's involvement in potential 'breakthrough' research. This is done by use of refined citation analyses and large-scale clustering of journal articles from 2005 to 2010 in CI-WoS to detect potential breakthrough papers. The approach was developed and tested for a previous bibliometric evaluation of the DNRF. 'Breakthrough' research is obviously a challenging concept to define, operationalize and detect. We want to emphasize that our approach is a modest one, certainly with limitations, but also an interesting one in as much as we seek to detect potential 'breakthrough' papers among an exclusive set of the most highly cited papers in WoS in a carefully constructed network of relevant research fields. We define a 'breakthrough' paper as: 'a highly cited paper, with an important spread over its own field(s) and also other research fields, and it must be a paper that is not a mere follower of other highly cited publication(s) but that it has a genuine relevance on its own'. **In terms of producing potential "breakthrough" articles from 2005 to 2010 according to our proposed methodology, the DFF set of publications basically come up with the same proportions of articles relative to their size**

as the Danish benchmark set for all three breakthrough categories. The DNRF benchmark set has markedly higher proportions in all three categories and a markedly larger share of all Danish "breakthrough" articles. Again this is not surprising, considering the special conditions under which CoEs operate and given the fact that the DNRF set produces many highly cited articles. Results from the surveys and interviews indicate that a large majority of the research proposals submitted and funded were relatively developed or "safe" projects, perhaps an indication of less risk taking but also an effect of shorter funding periods. Nevertheless, this may also support the hypothesis that the DNRF setup is more tailored to produce "breakthrough" articles. But here again we emphasise the different roles played by these two funding institutions in the overall Danish funding landscape.

An advanced methodological approach is constructed in order to compare the effect of receiving a grant from the DFF. The comprehensive dataset that this analysis is based on has a number of strengths in assessing the relative performance of recipients of DFF grants; however, there are also a number of limitations that can bring into question whether we are fully able to isolate the potential effect of DFF grants on citation impact. **In the comparative analysis, we utilize a non-experimental approach where PIs (grantees) are compared to the control group consisting of comparable applicants that did not receive a grant from the DFF in the period 2003-2008.** For each individual, indicators are calculated *ex ante*, *ex post* and in the difference before-after. For PIs, the *ex post* period is from the year of grant award to 2012, and *ex ante* from 1996 to the year prior to grant award. For rejected applicants, the *ex ante* and *ex post* periods are set to 1996-2004 and 2005-2012, respectively. For both groups, differences are simply calculated as *ex post* minus *ex ante* values. The analysis relies in particular on two indicators, the MNCS and the PPtop10%, though we have also examined the MJNS and will discuss these results occasionally. Given that PIs on average have greater citation activity both in the *ex ante* and *ex post* periods, the most appropriate measure in examining effects is the before-after difference. We consider two different sets of publications in calculating *ex post* indicators for PIs. The first is based on all publication activity in the *ex post* period while the second is based on publications that are directly linked to the DFF grant (where the PI is author or co-author). **The results of the comparative analysis where we reduce the set of researchers to those highly comparable based on propensity score matching are generally supportive of a positive effect of grant receipt for PIs.** Both MNCS and PPtop10% are higher for grantees. **When comparing the full sample of researchers without matching procedures, we do not find evidence for differences in citation**

impact. It appears that this result is particularly influenced by the lowest performing PIs. While their citation impact increases, it does not increase more so than for comparable rejected applicants. Comparing subsamples, before and after differences in citation impact among the highest performers are greater for PIs; however, average citation impact declines for both groups. The strongest results were found for the middle group of grantees, who experienced large increases in citation impact that was also higher than for rejected applicants.

Like the publication behaviour analysis outlined above, where we examined the proportion of level one and level two journal articles in the BFI indicator from the set of reported grant publications published between 2009 and 2012 for the councils and compared them to overall national trends, we perform a corresponding analysis where we examine the BFI journal publication behaviour for FKK and FSE PIs and rejected applicants. The background for doing this analysis was the perceived poor coverage of especially FKK journal articles in the CI-WoS. As the main focus of this report is performance analyses based on impact, poor coverage of FKK and to a lesser extent FSE makes such analyses questionable. Hence, to support the overall publication analyses and in order to be able to better characterize these poorly covered fields, a journal publication behaviour analysis was included. Obviously, we still focus upon journal publication behaviour, which indeed plays a less important role in the social sciences and especially the humanities compared to the traditional STEM fields. But the two-tiered Danish classification of publication channels needed for an examination of "preferences for publication" is a selectively chosen subset of outlets where only categories journals in the examined period; in turn, however all language journal are covered. So, journal publication behaviour is the only viable means for examining FKK and FSE according to "preferences for publication". **Given the complicated identification and matching procedures, combined with attrition and the fact the journal status may turn out to be somewhat elusive in many FKK fields, we really cannot draw any firm conclusions for small differences between PIs and rejected applicants in the FKK set. The differences, however, is marked for FSE, here we are able to say that PIs seem to have a preference for publishing in level two journals over level one journals compared to the rejected applicant set.**

Finally, we return to the issue of treating a publication as 'belonging' to a funding institution which is somehow problematic. Publications initially 'belong' to authors who are affiliated and employed by research institutions. These are normally the units of analysis in bibliometric analyses. However, researchers and research groups, on top of their base funding, often also

receive external funding. In order to approximate in what respect a publication can be credited as "belonging" to a funding institution and thus by implication be a product of that particular funding, an exploratory analysis of the funding acknowledgements present in a restricted subsample of the CI-WoS journal publications for the DFF was carried out. We found that **in 82 percent of the publications linked to DFF, at least one other funding source was acknowledged** and **in 57 percent of the DFF publications at least one other Danish funding source was acknowledged (i.e., approximately in 50 percent of the cases with at least one private foundation or company and/or in approximately 37 percent of the cases, at least one other public research foundation or institution). The results are only suggestive, but they stress the challenges of "ownerships" of publications and emphasize that publications can be a result of many influences and several funding organizations. One successful funding often leads to another; this is the well-known phenomenon of preferential attachment, also popularly known as the "Matthew effect".**

In general we hesitate to bring general conclusions from the surveys and interviews; as they are constructed to support and contextualize the bibliometric analyses and not "evaluate" DFF and its funding instruments. However, a few results could be highlighted. **Survey results among rejected applicants suggest that for two-thirds of the respondents, rejection has had consequences for their career. The shares are highest within FSE and FKK and lowest within FNU and FTP. Survey results among PIs show that DFF grantees have in general been quite successful in obtaining other grants prior to the ones in focus here. Interestingly, survey results among the rejected applicants also suggest that they appear to be quite successful in securing other funding**. Finally, results from the survey among rejected applicants suggest that almost half of all projects are still seeking funding or are completely dropped after rejection. **Among FSS grant seekers this share is however only a fourth. On average only 21.4 percent of the projects were fully implemented or initiated at the time of the survey.**

The main conclusion of the report is that the DFF sets of publications perform at a high level both when it comes to the proportion of highly cited publications (PPtop10%) and the mean normalized citation scores (MNCS). Performance at the council level is also high albeit with some small variations among individual councils. As expected, coverage for FKK is "poor", so performance indicators for this council should be treated very carefully or simply dismissed. The sets of DFF publications contribute noticeably to the overall Danish impact given its relative size. Interestingly, while there are variations in performance between subject areas, all areas with publication numbers above 50 seem to perform consistently above the

international level. **The comparative analyses between PIs and rejected applicants are generally supportive of a positive effect of grant receipt for PIs. When comparing subsamples, the strongest results were found for the middle group of grantees, who experienced large increases in citation impact that was also higher than for rejected applicants.**

We encourage readers to carry on reading; in the following chapters we discuss and reflect upon the methodology, results and limitations in detail.

2. Introduction

The present report examines the output and citation impact of publications reported as outcomes of various types of grants funded by the Danish Council for Independent Research (DFF) in the period 2005 to 2008. The DFF comprises five field specific research councils: health sciences (FSS), natural sciences (FNU), technical sciences (FTP), social sciences (FSE), and arts and humanities (FKK). The primary units of analysis in this report are the five research councils (i.e., the aggregate set of individual grant publications linked to the different councils) and the DFF itself (i.e. the aggregate set of *all* publications for *all* councils[2]). We do not focus on the performance of individual grants in the analyses, but we do provide some insights into the individual differences in publication behaviour and citation performance between individual grants in order to contextualize the overall results. Additionally, to explore the importance of being funded and to characterize and examine the citation performance of successful applicants before and after the DFF-funding, the performance of the grant's Principal Investigators (PI) is compared to a set of carefully matched rejected applicants.

In order to support the bibliometric analyses, two surveys are conducted, one among the PIs and one among rejected applicants. The former survey gives the PIs an opportunity to validate and extend their originally reported output of the grants. The survey also includes questions in relation to the role of the PIs in the project, other funding activities in the period, as well as questions regarding the nature of the research project and assessment of the importance of the actual grant. The survey to the rejected applicants includes questions relating to other funding opportunities in the period examined, as well as an assessment of the importance of not being funded for the realization of the proposed research project and the immediate consequences of not being funded for the involved applicants. Finally, the questions in the surveys relating to the relative importance of being funded are followed up and extended in 30 interviews with successful and rejected applicants from all five research councils.

The focal performance indicator used in this report is citation impact. Contrary to what is often the impression, citations do not measure research quality *per se*; but, it is often assumed that citation impact may reflect a dimension of research quality (Gläser & Laudel, 2007). Impact refers to use (Martin & Irvine, 1983), i.e., in principle researchers cite their colleagues' work when it is useful for their argument, which means that the cited work, for various reasons, has had a certain

[2] For convenience we name these "council name" publications and DFF-publications.

impact on the citing author's work. Objections have been raised against this premise, but it is widely assumed that with a sufficient number of publications (i.e., aggregate unit of analyses' publication oeuvres) and especially when focusing on the most highly cited publications, which in the skewed distributional universe of citations attracts some 60% of all citations, sound quantitative evaluations can be made. Nevertheless, given the indistinct or partial relation to research quality, citation impact analyses should always be subjected to peer evaluations to better inform the latter. Citation impact is a measure of reception of a unit's publications in the scientific community, not where it is published or the quantity published. The latter are secondary, supplementary and conceptually different indicators providing no information on actual impact of one or a set of publications.

It is well-known that impact analyses require comprehensive citation databases and that such databases primarily cover journal publications. Hence, citation impact analyses in scholarly fields where international journal publication is not the primary publication activity and/or where database coverage of relevant journals is low have lower validity and are less reliable compared to traditional "journal fields". Most fields in the humanities and many fields in the social sciences do not have international journal publication as their main publication activity and the journal coverage of many of these fields in the citation databases is poor. Traditionally, such fields are therefore excluded from impact analyses.

Despite these well-known coverage issues, it has been a request for the present report that bibliometric analyses are carried out for all five research councils and their publications. Because impact is the focal performance indicator and because the research councils subsume a number of different fields with different publication characteristics, *all* international journal publications indexed in the Web of Science (WoS) citation database will be included in the analyses and subsequent examinations of coverage at the council level will determine the validity and robustness of the impact measures calculated for each council. Hence, some grants, especially from FKK and FSE will be excluded from the citation analyses and some of the grants included will have a substantial number of publications excluded from the citation analyses. We do not *a priori* exclude grants from FKK and FSE but instead decide upon inclusion and exclusion based on an eligible measured journal coverage.

Secondly, the report also provides the publication output of *all* publication types reported as outcomes for the individual grants for all five research councils. The basis for examining publication output are the originally reported (and potentially validated and extended) publication

lists submitted to the Danish Ministry of Science, Innovation and Higher Education shortly after the funding period expired. Publication output only provides insights into publication behaviour and activity, and is in itself a poor comparative performance indicator. To supplement the limitations of using citation analysis in fields covered by FKK and FSE, a simple publication analysis is carried out on all reported grant journal publications published from 2009 to 2012, where the "status" of the journals of these publications in the national Danish bibliometric performance indicator (BFI) is examined. Notice that such an analysis can only indicate something about preferences in where you publish, not the actual impact of what you publish (though at the aggregate level where you publish does influence total impact).

Citation impact is examined for the DFF-set of publications, the council-sets, and the PI-oeuvres (the PIs portfolio of (co)authored publications). These publication sets are compared to database reference values and in order to provide more context to the results, the DFF-set and the council-sets of publications are also compared to the performance of other Danish publications published in the same research areas and in the same period as the examined sets, whereas the PI-set of publications is compared to carefully matched publication oeuvres of rejected applicants for the same period. Finally, we also compare the performance of the DFF-set of publications to a carefully constructed set of publications linked to Danish Centers of Excellence funded by the Danish National Research Foundation (DNRF). The DNRF set of publications was previously constructed for a recent evaluation and is restricted for the present purpose[3].

The standard publication period covered for all citation analyses is 2005 to 2012 with three year citation windows (except for 2011 and 2012 where the window is shorter). However, for specific comparative analyses we do also examine shorter windows. Also, for the comparison of PIs and rejected applicants, publications from 1996 to the individual application years (2005, 2006, 2007 or 2008) are used to construct pre-application publication performance, still with three year citation windows. The citation analyses are based on CWTS' enhanced version of the WoS database (for short CI-WoS) including the Science Citation Index, the Social Science Citation Index (SSCI) and the Arts and Hummanities Citation Index (A&HCI). Based on an advanced citation analysis methodology developed and tested for the recent evaluation of the Danish National Research Foundation[4] (Schneider & Costas, forthcoming), the report also examines the extent to which the set of DFF-publications contain potential "breakthrough" research papers published between 2005 and 2011. Finally, based on survey data, data from the reported publication outputs

[3] http://ufm.dk/en/publications/2013/evaluation-of-the-danish-national-research-foundation.
[4] http://ufm.dk/en/publications/2013/files-2013/appendiks-5_bibliometrisk_report_03122013.pdf.

and international journal publications indexed in WoS, the report also examines the "funding flows" (i.e., other funding institutions acknowledged as contributors) in the examined grants and their affiliated publications.

The publication sets used in this report have undergone a thorough and labour-intensive cleaning and matching process where the originally reported publication lists have been manually cleaned and validated to the extent possible. Journal publications from the reported publication lists have been extracted and further cleaned in order to be matched with records from CI-WoS and the BFI-databases. Likewise, based on names, email addresses and affiliations, PIs and rejected applicants have been identified and publication portfolios constructed. It is important to emphasize that the originally reported publication lists, as well as the information available on PIs and rejected applicants, vary in format and quality and to some extent are deficient when it comes to providing reliable details for automatic matching purposes. The publication lists include valid publications of all kinds, but also publications in planning and submission phases where publication details are highly unreliable and most likely also publications that never materialized. As a consequence, not all eligible publications will be identified in the databases, and name ambiguities and varying degrees of information on the PIs and rejected applicants, means that the identification process is susceptible to attrition among units, and we can also expect some missing publications among those units included in the analysis. Consequently, the total number of DFF-publications (and PI and rejected publications) should be treated cautiously as there will be false positives as well as missing publications. Nevertheless, on the aggregate level of analyses, we consider the results robust given the number of publications involved.

The structure of this report is as follows: Chapter 3 gives a general description of the methodology and terminology used in the report, including the data collection and various matching processes that were carried out, as well as an overview of the bibliometric indicators that were calculated in the analyses. Chapter 4 presents the publication performance of the reported scholarly and scientific output from the DFF-grants from 2005 to 2008. The chapter presents results at the level of the DFF and the individual councils. The chapter describes output and presents citation analyses for the eligible units of analysis, as well as analyses of FKK and FSE journal publications in the BFI-database. Finally, the chapter also provides some general characteristics of the grants included in the analyses and includes an enhanced explorative citation analysis used to detect potential "breakthrough" articles in the DFF publication set from 2005 to 2012. In Chapter 5 the comparative citation analyses of PIs and rejected applicants is presented and discussed. Chapter 6

follows up on and supports the two previous chapters on bibliometric performance, by presenting results from the surveys and interviews among PIs and rejected applicants. Chapter 7 presents results of analyses into potential other funding institutions linked in to the examined DFF-grants and their publications. Chapter 8 outlines some of the caveats and limitations of the study, and finally Chapter 9 presents the main conclusions of this study.

3. Bibliometric data and methods

In this chapter we outline and discuss the data, units of analysis and benchmarks used in the report, as well as the data collection and matching techniques applied to the established data sets for the bibliometric analyses. The chapter also outlines the general assumptions behind selected indicators and presents the major indicators used in this report.

The main purpose of the bibliometric analyses is to examine the performance of the publications coming out of the research projects funded by the DFF from 2005 to 2008. A secondary purpose is to examine the performance of those PIs responsible for research projects funded by the DFF. Surveys and interviews are carried out to contextualize the latter analyses. When it comes to data, units of analysis and benchmarks, both performance analyses are challenging. This we will address in the following sections. First we describe the basic data and units of analysis used. Next we outline the data collection and cleaning processes applied, as well as the various matching procedures used to identify reported publications in other databases. Subsequently we briefly outline the different cleaned data sets available for the analyses and describe the benchmarks units used. Next up is a thorough description of the assumptions behind citation analyses and an outline of indicators used. Description of the surveys and interviews are kept in a separate chapter together with the results.

Data and units of analysis

Originally the Ministry of Science, Innovation and Higher Education provided a list containing 1491 projects funded by the DFF from 2005 to 2008. Included herein were 135 postdoctoral grants from 2006, which will be examined separately in the subsequent analyses based on wishes from the Ministry. Eventually, the Ministry of Science, Innovation and Higher Education was able to provide publication lists from 1321 funded projects. The publication lists are part of the reporting done by the PIs when the DFF-funding for the projects expires. The reporting is done a few months after the funding has expired; therefore publications which can be considered a result or partly a result of the funding will in many cases continue to be published some time after the reporting has been done. These reported publication lists are the basis for the main performance analyses. The reported publication lists varies in technical quality and informational quality. Technical quality refers to the degree of information provided for identification of already published publications, whereas informational quality refers to the scarce bibliographic information provided for the

substantial number of publications mentioned in the lists as "planned", "to be submitted", "submitted", "in review", "under revision", "accepted" or "forthcoming". The latter complicates identification processes in other databases needed to obtain data for the subsequent performance analyses. To try to alleviate this, a survey was constructed and distributed to all 1348 PIs responsible for the 1491 projects (including those with no publications reported) giving them an opportunity to validate existing publication data and extending the lists with new publications published after the reporting. The survey is discussed below, here we just note that approximately 60 percent used the opportunity to validate the original list and one more grant with publications was included so that the publication analyses comprise publications from 1322 grants. Nevertheless, the quality and exhaustiveness of the validation also varies considerably. Consequently, the reported and validated publications (i.e., 19,513 publications were listed in the reports and the set was expanded to 19,958 after the survey validation) are of all sorts, both scholarly and non-scholarly, many are published, some are in the process and some never materialized. The publication lists should therefore be seen more as the reported estimated output of the grants and not the precise activity although we will treat them as such in this analysis. Under the given circumstances, it is impossible to verify every publication. For impact analyses, however, only the subset of potential journal publications are used, initially some 9590 publications. All these journal publications are subjected to identification and matching procedures in the CI-WoS database in order to obtain citation indicators for the positively matched publications. Likewise, for potential FKK and FSE journal publications, we carry out identification and matching procedures in the Danish national bibliometric indicator database (BFI-database) in order to obtain information of the status level of the journals in which the matched publications are published. Notice, these subsequent steps, where data sets are created for performance analyses, eventually contains attrition where some publications and or grants will be excluded; hence the data sets cannot be considered either the full population of grants from the period, nor a probability sample from such a population. As an addendum, the output analyses will also report other outputs such as patent applications from the grants either initially reported or mentioned in the survey.

Units of analysis

The two main performance analyses (i.e., the impact of the councils' and DFF's reported international journal output and the impact differences between PIs and rejected applicants) include different units of analysis. Basically units of analysis correspond to sets of publications. For

example, an application is made to a specific DFF research council for a grant to fund a research project. The application is headed by a PI and in many cases comprises a number of other researchers. Some projects are funded, others are not. The fate of the latter projects is unknown, though it can be expected that the rejected applicants will try to seek funding elsewhere and will continue to publish (this we will examine in the survey). The funded projects run for a certain period and after the termination the PI must report the outcomes of the project including publications. Consequently, a number of publications will eventually be linked to a grant (funded research project) and publication details are available through the reported publication lists. From this basis we can select a number of different units of analysis (i.e., sets of publications) at different aggregation levels: e.g.: 1) the individual grants; 2) pooling grant publications at the higher aggregation level of the five specific research councils and 3) further pooling and aggregation of publications, so that the DFF itself is the unit of analysis. Essentially, when it comes to the performance analyses only potential journal publications from the reported publication lists are eligible, and of those eligible, only those matched in CWTS' CI-WoS database (2005-2012) and the Danish BFI-database (2009-2012) will constitute the final basis for the publication sets. In the presented performance analyses we focus upon the specific research councils and the DFF as the units of analyses. There are several reasons for choosing these levels of aggregation. The most important from a methodical point of view is robustness. Indicators need some publications in order to be reliable and robust. Many grants do not produce a sufficient number of journal publications indexed in the WoS for indicators at that level to be robust. We do, however, examine publications at the grant level in order to examine the within-variance between the outputs of the grants.

As indicated above, researchers affiliated with a grant can also be considered as units of analysis. From a delimitation perspective it is very difficult to establish who is directly involved with the funding and to what degree, and then subsequently link that information to the publication lists (notice, not all authors in a byline is necessary part of the actual funding). What can be done is to designate the PIs as units of analysis, if we assume that they are responsible for the successful application and thus eventually the project, although the division of labour within the project and thus their actual involvement may vary considerably. In the present report we include PIs as units of analysis in order to characterize those who are funded and to try to examine whether the actual funding seems to have had any performance effects on the PIs publication oeuvres. If we take the basic set of eligible journal publications reported as output for the grant then we can isolate those

publications where the PI is author and co-author. These are the publications in the project affiliated to the PI (usually this is a considerable part of the publications, as PIs in many fields get "honorary" authorships for their conceptual contribution to a project). In this way we can establish three sets of publications from the grant: 1) all publications, 2) only those where the PI is an author or co-author, and 3) publications were the PI is not involved. In order to be able to examine the performance of one or more of these sets, as well as potential benefits of being funded, we need to establish further sets of publications affiliated to the PI. In principle, we search the CI-WoS database to identify publications linked to the PIs from 1996 up until the granting year. This is the pre-application publication set and it will be used to measure pre-application performance for the PI. We further search the CI-WoS database for publications linked to the PI from the granting year until 2012. This set constitutes the post-application publication set and it is further broken down into those publications affiliated to the grant and those that can be considered not affiliated to the grant. The latter is possible due to the originally reported list of grant publications. These different publication sets enable different comparisons of pre- and post-publication performance, i.e., see sub-section below, where we outline the different publication sets. Finally, in order to examine the potential performance effects of being funded, we need to compare the PI publication sets to a "control group" in this case rejected applicants, i.e., applicants applying for grants in the same year as the PIs were funded. In principle, the same searching procedures are carried out for the rejected applicants in order to establish a pre-application publication set and a post-application publication set, but obviously, there is no grant set.

The units of analyses used in this report are not without problems. Usually publications are assigned to researchers, research groups, departments, institutions or countries, well-defined discrete units. Assigning publications to a funding institution is somewhat fuzzier as publications are a result of many influences and often several funding organizations, and most importantly, determining to what extent a publication is a result of a certain funding can be elusive. Likewise, it is difficult to identify benchmark units comparable to a specific funding institution, council or even grant. While it is more straightforward to assign publications to PIs and rejected applicants, it is also not without problems to single out "grant publications" for PIs, or to assume that publications from rejected applicants are somewhat comparable to the set of PI publications just because they happen to have no DFF-funding in the examined period.

Data collection, cleaning and matching

In this section we outline the three main data collection, cleaning and matching processes used to establish the publication sets for the bibliometric analyses. The aim with these three processes is to establish five, to some extent, overlapping publication sets:

- From the reported grant outputs, we create:
  - A publication set containing all reported publication outputs; this set will be used for publication profile analyses.
  - From this set we will further establish a subset of journal articles which will be subjected to two matching procedures in two databases: 1) CI-WoS citation databse in order to identify international journal publications and to collect citation data for impact analyses of these journal publications; and 2) the national Danish bibliometric indicator (BFI) in order to collect data on the journal "status" of these published journal publications. The latter approach is performed due to the expected relative poor coverage of FKK and FSE journal publications in CI-WoS and to include potential Danish or other non-English language journal publications. The resulting two publication sets will subsequently be used for citation performance and funding analyses, i.e., the CI-WoS set, and publication behaviour analyses, i.e., the BFI set.
- From lists of PIs and rejected applicants, we will try to construct publication portfolios for these two groups in CI-WoS and for FKK and FSE applicants also the Danish national research database (NRD). The publication portfolios established from the CI-WoS will be used for comparative citation performance analyses between funded and rejected applicants. The publications from PIs and rejected applicants from FKK and FSE identified in the NRD database will subsequently be matched in the BFI database again in order to examine the journal publication behaviour of these researchers. Notice, we cannot comprehensively search the BFI database on names and affiliations, therefore we have to the use the search facilities in the NRD database to identify PIs and rejected applicants, as well as their portfolio of journal publications. Subsequently, the titles from these retrieved publications can be used for further matching to the BFI database and from this we can get information on journal "status".

The publication sets used in this report have undergone thorough and labour-intensive cleaning and matching processes where the originally reported publication lists have been manually

cleaned and validated to the extent possible given the time and resource restrictions for this project. Several different starting points and databases have been involved in the data identification, matching and collection processes to create different publication sets to be used in the performance analyses in this report:

- The list of reported and validated publications coming out of the grants (potentially validated and extended through the survey).
- CWTS' enhanced in-house version of the WoS database (CI-WoS).
- The publicly available but non-standardized national Danish research database (NRD).
- The CFA in-house version of the database containing publication performance data linked to the national Danish performance indicator (BFI).
- The CFA in-house database of applicants for DFF-grants in the period 2001 to 2009, including both granted and rejected applicants.
- A specific benchmark data set of publications linked to Danish Centres of Excellence (CoE) funded by DNRF, created by CFA and CWTS from the CI-WoS database for a previous bibliometric evaluation.

Figures 3.1, 3.2, and 3.3 below show flow charts of the three main processes of data collection, cleaning and matching (notice to some extent these processes are intertwined as we are able to utilize information between sets and eventually construct publication sets for PIs based on two of the approaches). Before we present the data collection processes outlined in the flow charts some issues of quality and challenges should be outlined.

It is important to emphasize that the originally reported publication lists vary in format and quality and are to some extent somewhat deficient when it comes to providing reliable publication details for automatic matching purposes. The publication lists include valid publications of all kinds, but also publications in planning and submission phases where publication details are unreliable or missing. Given that the publication lists are reported immediately after the funding expired, we can expect that some publications which can be considered an outcome of the funding is not mentioned on the lists simply because there is a publication lag. The survey gives an opportunity to fill in more publications (and validate those already mentioned), but response rates and still ongoing publication activity means that we cannot establish a complete publication set. In fact, the reported publication set should not be considered as the exact output of the grants; it is rather the reported and thus estimated output of the grants. Unfortunately, it is not feasible to use the NRD database as a tool for verifying the publication status of the mentioned publications. The

coverage and indexing of the NRD database is unreliable and considerable manual effort must be put into the verification of search results from this database. Further, to use the NRD database also requires considerable manual effort in cleaning non-journal publications from the publication set. This is not worth the effort as at best it will only fine-tune the reported publication output, but more likely many publications come out as questionable matches or non-matches, which eventually will not strengthen the validity of the original publication set. Notice, in itself publication output is a poor performance indicators and it is should only be used for secondary purposes such as profiling publication behaviour. As such, verifying the exact number of reported publications becomes a minor issue in as much as a "sufficient" number of reported publications will enable us to characterize the main publication activity, preferences of publication types and thus publication behaviour.

What we have done is to manually clean all journal publications as they are needed for potential matching in the CI-WoS and BFI databases, but given the above-mentioned deficiencies in publication detail, not all eligible publications will be identified in these databases. Likewise, the name ambiguities and varying degrees of information on the PIs and rejected applicants, mean that the identification process is susceptible to attrition among units, and we can also expect some missing publications among those units included in the analysis. Consequently, the total number of DFF-publications (and PI and rejected publications) should be treated cautiously as there will be false positives, as well as missing publications. Nevertheless, on the aggregate level of analyses, we consider the results robust given the number of publications involved.

Table 3.1. Initial set of grant types distributed among councils going into the various publication matching and identification processes.

	FKK	FNU	FSE	FSS	FTP	Total
Larger research projects	58	56	17	113	10	259
Ole Rømer-grants		3				3
Postdoc-grants	18	37	11	37	32	135
Research centre	2	6	1		1	10
Research projects	50	224	118	399	204	995
Skou-grants		27				27
Steno-grants		62				62
Total	128	415	147	549	252	1491

Table 3.1 shows the distribution of the initial set of grant types provided by the Ministry among research councils. Initially, 1491 grants were recorded by the Ministry for the period 2005

to 2008, distributed among 1347 different PIs (143 PIs had more than one funded project in the period). Of the 1491 grants 135 were postdoctoral grants funded in 2006. Eventually, 1322 grants were eligible for publication analyses (i.e., grants with a reported publication output). Table 3.2 shows the distribution of grant types among councils for the 1322 grants with reported publication output included in the analyses.

Table 3.2. Number of grant types distributed among councils for the 1322 grants with reported publication output included in the analyses.

	FKK	FNU	FSE	FSS	FTP	Total
Larger research projects	53	54	16	101	13	237
Ole Rømer-grants		3				3
Postdoc-grants	16	29	9	36	24	108
Research centre	1	6	1			8
Research projects	44	199	102	358	179	882
Skou-grants		26				26
Steno-grants		52				52
Total	114	369	128	495	216	1322

For the comparison between PIs and rejected applicants all 1347 PIs were initially included and a set of 2306 rejected applicants were also included for publication oeuvre matching in the CI-WoS database (selection criteria and details are given below). The group of rejected applicants includes all applicants according to the following criteria:

- Applied for a DFF grant in the period 2005-2008 and within the grant types listed in table 3.2.
- Did not receive any DFF grant over 100,000 DKK in the period 2003-2008

This procedure produced a sufficient number of rejected applicants in all research councils with the exception of FNU. In order to increase the number of rejected applicants for FNU, we also included: 1) researchers that had not applied in 2005-2008, but had applied and been rejected in 2003-2004; and 2) researchers that had received a small grant (under 500,000 DKK) in 2002, but had not applied in 2003-2008.

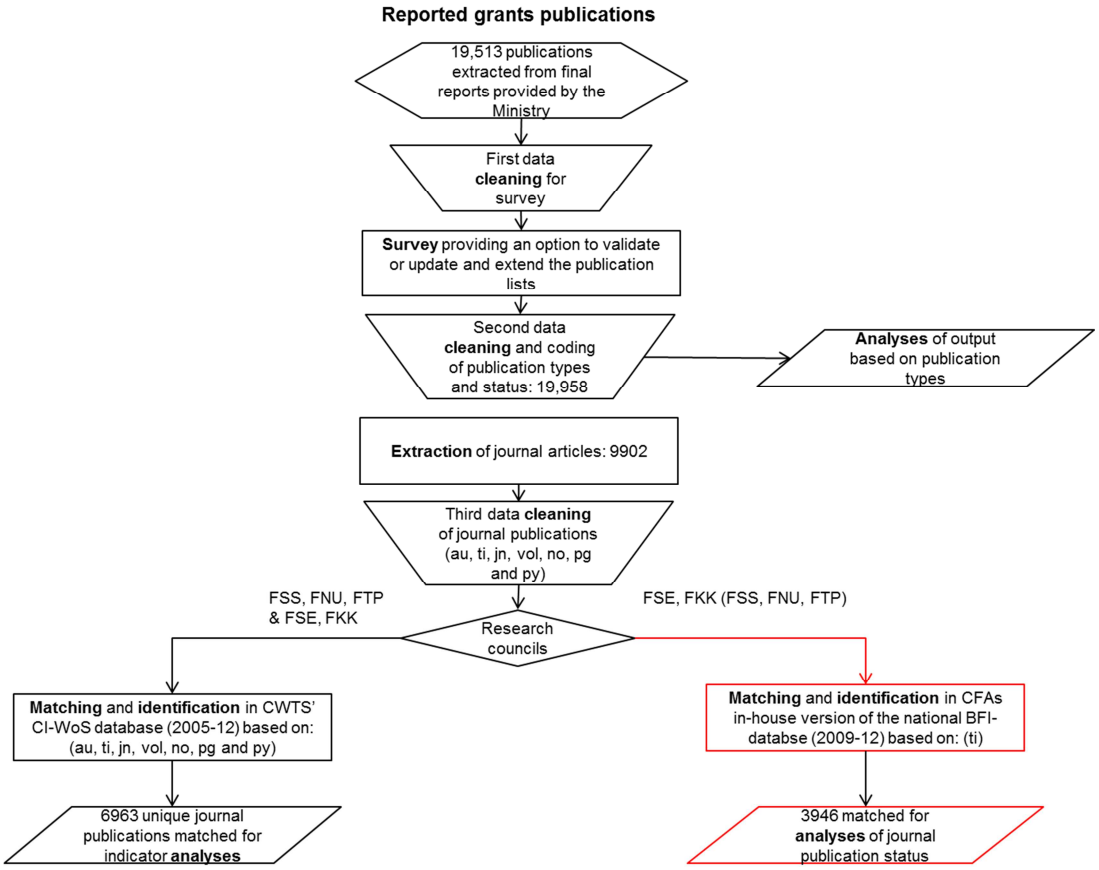
Some grants ended up being discarded before the performance analyses mainly due to lack of coverage or non-matching publications. As will be shown below, the initial set of rejected applicants suffered a larger attrition not only because of coverage issues or non-matching publications, but also because of difficulties in identifying distinct affiliations and email addresses needed for positive identification.

Finally, the manual validation procedures of the publication portfolios identified for PIs and rejected applicants based on the CI-WoS database primarily focused on false positive matches whereas identification of potentially missing journal publications have not been prioritized due to time constraints (i.e., it is a substantial task requiring external information) but fortunately CWTS' name disambiguation algorithm together with validation procedures have hitherto shown very high general recall rates (90-95%) especially with sets of non-Asian author names and affiliations (Caron & van Eck, forthcoming).

Collection, cleaning and matching: Reported and validated set of grant publications

The flow chart in Figure 3.1 below shows the collection, cleaning and matching procedures carried out on the reported and validated set of grant publications.

Figure 3.1. Flow chart outlining the data collection, cleaning and matching procedures carried out on the reported and validated set of grant publications.



- The Ministry provided a crude list of publications extracted from the final reports handed in to the Ministry by the PIs at the end of the funding period; some 19,513 “publications” of all sorts.
- Hereafter CFA made a first general cleaning of the publication lists in order to prepare the lists for the PI survey.
- A survey was sent out to all PIs (for which it was possible to find valid email addresses), comprising two parts, some general questions and an opportunity to validate and extend the original publication lists. The validation response rate was 64.9 percent for PI’s (excluding postdocs) and 57.8 percent for postdocs, approximately 60 percent in total. Some 805 grants were validated, corresponding to 4919 publications, roughly 25 percent of the total and 405 new publications were added. The largest publication types were journal articles, constituting some 62 percent of the added publications.
- After completion of the survey validation, a second data cleaning process was initiated by CFA where, amongst other things, all remaining publications (19,958) were uniquely coded in relation to their publication type and status.
- The publication set of 19,958 reported (and for some also validated) publications comprises the first publication set for analyses. The set will document the actual and planned outputs of the grants funded by the DFF from 2005 to 2008. The results are presented in Chapter 4.
- Subsequently, all publications coded as “journal articles” was extracted from the grant publication set, some 9590 publications.
- The journal publications were subjected to a labour-intensive third cleaning process where all publications were standardized to the same format; first author names and initials (au) were validated; titles (ti) and journal names (jn) were corrected; likewise volume (vol), issue (no), pages (pg) and publication year (py) were standardized. Notice, many of these journal publications did not contain all this bibliographic information. For example, some publications were not published at the time of the reporting and were not validated in the survey; hence we were left with incomplete information for the matching procedures, for example a suggested tentative title and first author that in the end could have changed considerably.
- The set of cleaned journal publications was subjected to two matching procedures: 1) all publications from all councils are subjected to matching in the CI-WoS database; and also

matched in the CFA in-house version of the national Danish bibliometric indicator database (BFI).

- Re 1. We try to match all publications from all councils in order to estimate the coverage in the citation database for FSE and FKK publications. If the coverage is satisfactory grants from these councils will be included in the impact analyses.
- Re 1. The 6963 unique matched journal articles constitute the set of grant journal publications eligible for impact analyses (coming from 1042 grants out of 1322). Notice, of the 9590 journal publications initially subjected to matching in the CI-WoS database 7973 publications were actually matched (i.e., an 83 percent match rate). However, several of these matches turned out to be: 1) duplicates, 2) other journal publication types than research articles and reviews, and 3) were published before 2005. As stated, eventually 6963 unique journal publications were eligible for performance analyses; but when distributed among the grants the number of journal publications is 7660 meaning that there are 1169 duplicates in the set (i.e., publications linked to several grants). Also, 284 of the journal publications are linked to the 79 postdoc-grants from 2006 that eventually were eligible for the impact analyses.
- Re 2 (marked in red). In order to be able to do more than just counting the number and type of publications coming out of FKK and FSE grants, we examine the distribution of level 1 and level 2 journal publications from 2009 to 2012 in the BFI-database and compare this to the corresponding publication profiles for FNU, FSS and FTP and national trends for main fields. Notice, the matching between the set of reported journal publications and the BFI-database is only carried out using title matching.
- Re 2 (marked in red). From the set of 9590 reported journal articles, some 4695 publications were eventually matched in the BFI database, notice a match rate is difficult to establish because we do not know how many of 9590 potential publications are published before 2009 and therefore not included in the DBI database. After removing duplicates, 3946 unique journal publications from all five councils remain for analysis.

Consequently, three data sets come out of these cleaning and matching procedures of the reported and validated grant publication set:

1. A publication set of 19,958 reported and potentially validated publications coming out of the 1322 eligible grants; these publications have been coded for specific publication types enabling analyses of publication activity and behaviour.

2. A publication set of 6963 unique journal publications indexed in CI-WoS coming from 1042 grants out of the 1322 eligible grants; these publications are qualified for impact analyses.
    a. Of these 6963 journal publications, 284 come from 79 postdoc grants, which will be treated separately in many of the following analyses.
3. A set of 3946 reported journal publications from 2009-2012 matched to the national BFI database; this set enable further analyses of journal publication behaviour among FKK and FSE grantees.

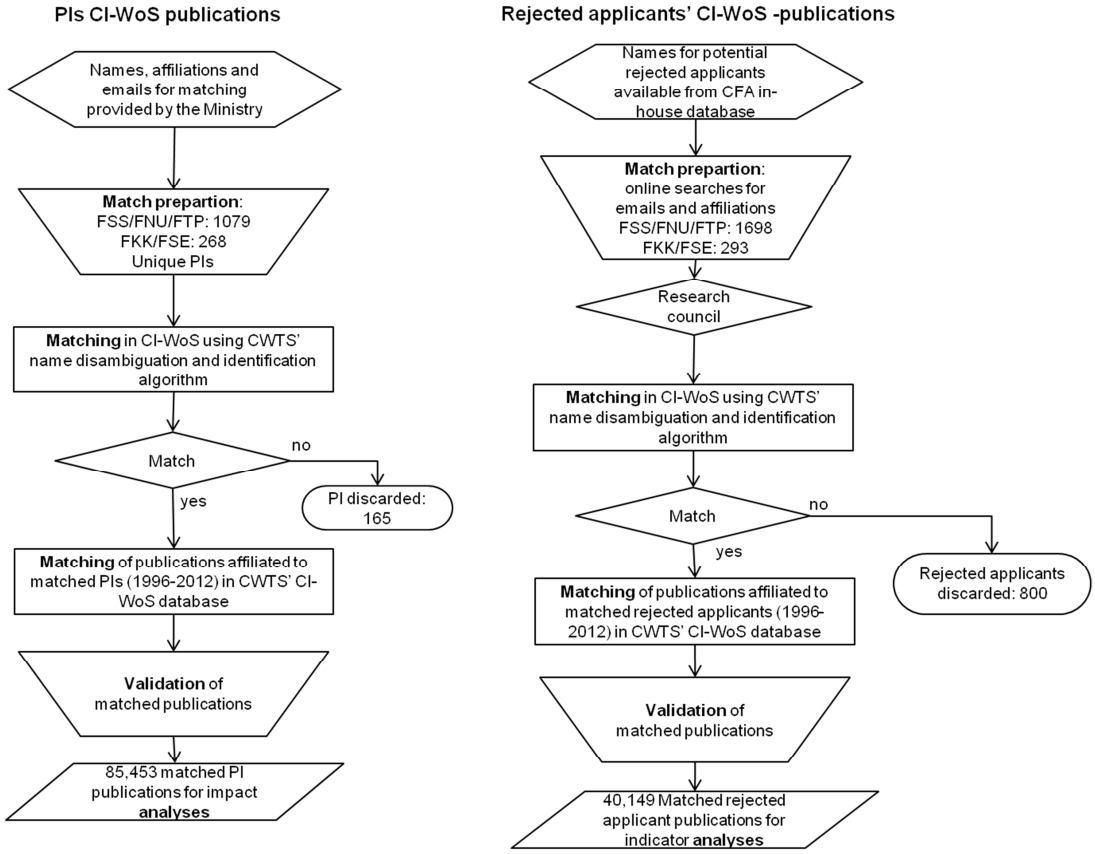
Collection, cleaning and matching: Sets of CI-WoS publications for PIs and rejected applicants

The flow chart in Figure 3.2 below shows the collection, cleaning and matching procedures carried out in order to create CI-WoS publication portfolios for PIs and rejected applicants. Two parallel flow charts are shown because the processes are very similar, albeit with some important differences as we will point out. We outline the two flow charts separately starting with the PIs (the left-hand flow chart).

- The Ministry provided a list of names, affiliations and emails for the successfully funded PIs in the period 2005 to 2008. Name, affiliations and emails are the primary parameters in the matching process in CWTS CI-WoS database. Notice, affiliations and emails are extracted from information related to the specific grant and could therefore be different in the period before or after the funding period. An initial set of 1347 PI names for all five councils was provided (128 of them are postdocs). Notice that there are 143 PIs who have more than one successfully funded project in the period examined (one PI has five grants). Of the 1347, 268 PIs were linked to grants from the FKK or FSE.
- Lists of names, affiliations and emails are cleaned, standardized and prepared for matching. All PIs from all councils go into the matching, despite the expected coverage limitations for the arts and humanities (FKK) and the social sciences (FSE).
- The matching procedure is done in CWTS' CI-WoS database and we apply CWTS' specially constructed name disambiguation and clustering method for this purpose (Caron & van Eck, forthcoming). CWTS has developed a general author disambiguation method using rule-based scoring and clustering. The method is capable of disambiguating complete bibliographic databases such as the WoS. The method is considered to be highly efficient

with average precision rates around 97% and recall rates between 90 and 95%; for methodologicall and experimental details see (Caron & van Eck, forthcoming).

Figure 3.2. Flow chart outlining the data collection, cleaning and matching procedures carried out in order to create CI-WoS publication portfolios for PIs and rejected applicants.



- Some 1213 unique PIs were matched in the CI-WoS database, 57 of those were funded by FKK and 119 by FSE; 165 PIs were discarded.
- Subsequently, for each of the 1213 matched PIs, portfolios of potential publications linked to these authors and published between 1996 and 2012 were created.
- The portfolios of potential publications were placed in an online evaluation tool created by CWTS and each publication was validated manually by members of the CFA team. Basically, the validation strategy was focused on detecting false positives, i.e., publications in the portfolio not affiliated with the PI. As stated above, identification of missing publications was not feasible in this study.

- The validated publications, some 85,453 in total of which 32,076 are duplicates and 53,377 are unique, constitute the overall set of publications for PIs and obviously, distributed among the 1213 PIs, i.e., the individual portfolio of these units.

Next we outline the almost similar process for the rejected applicants, the right-hand flow chart in Figure 3.2.

- A pool of potential rejected applicants suitable for the comparative performance analyses was constructed from the CFA in-house database of DFF applicants from 2001 to 2009. The general criterion for initial inclusion was application but no successful DFF-funding from 2003 to 2008; a somewhat large pool was selected knowing that later steps in identification and matching procedure would probably cause attrition. See also the description of the selection procedure above.
- Some 1506 unique rejected applicants were matched in the CI-WoS database, 127 of those were funded by FKK and 167 by FSE; 800 rejected applicants were discarded.
- Subsequently, for each of the 1506 matched rejected applicants, portfolios of potential publications linked to these authors and published between 1996 and 2012 were created.
- The portfolios of potential publications were placed in an online evaluation tool created by CWTS and each publication was validated manually by members of the CFA team. Basically, the validation strategy was again focused on detecting false positives, i.e., publications in the portfolio not affiliated with the rejected applicants. As stated above, identification of missing publications were not feasible in this study.
- The validated publications, some 40,149 in total of which 4412 are duplicates and 35,737 are unique, constitute the overall set of publications for the rejected applicants and obviously, distributed among the 1506 of them, i.e., the individual portfolio of these units.

Consequently, two general comparable CI-WoS publication sets come out of these matching procedures, one for the PIs and one for the rejected applicants and these general publication sets can then be disaggregated to the individual level of publication portfolios:

- A set of 85,453 publications distributed among 1213 PIs, i.e., the individual portfolio of these units; the individual publication portfolios can be separated into pre and post application year subsets and the post application subset can further be separated into grant and non-grant publications. In Chapter 5 we discuss the inclusion criteria for the

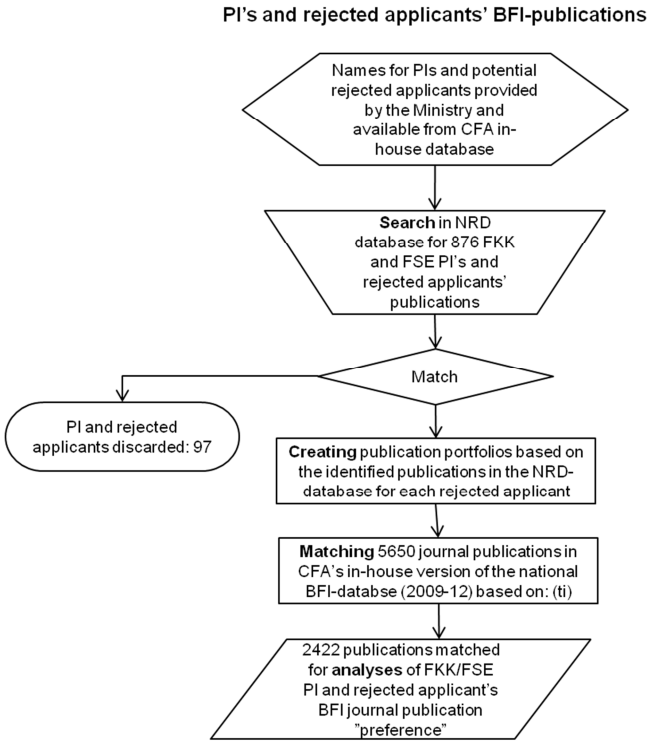
comparison analyses between PIs and rejected applicants, i.e., not all of the 1213 PIs go into the final analyses.

- A set of 40,149 publications distributed among 1506 rejected applicants, i.e., the individual portfolio of these units. The individual publication portfolios can be separated into pre and post application year subsets; notice, for obvious reasons the portfolios for the rejected applicants cannot be further separated into grant and non-grant publications. In Chapter 5 we discuss the inclusion criteria for the comparison analyses between PIs and rejected applicants, i.e., not all of the 1506 rejected applicants go into the final analyses.

Collection, cleaning and matching: Sets of BFI publications for FKK and FSE PIs and rejected applicants

The flow chart in Figure 3.3 below shows the collection, cleaning and matching procedures carried out in order to create restricted publication portfolios for FKK and FSE PIs and rejected applicants.

Figure 3.3. Flow chart outlining the data collection, cleaning and matching procedures carried out in order to create BFI publication portfolios for PIs and rejected applicants.



The restricted publication portfolios comprise matched journal publications from 2009 to 2012. As stated above, this analysis is a supplement to the impact analyses because we suspect that

coverage in CI-WoS is meagre for these two councils rendering impact analyses problematic. The two publication sets constructed will be used for a specific comparative analysis of publication behaviour between FKK/FSE PIs and rejected applicants (the analysis is described further below in this chapter).

- Similar to the matching procedures outlined in Figure 3.2 above, the basis for this procedure is 1) the names for PIs provided by the Ministry and the names for the rejected applicants available from the CFA in-house database.
- To be able to match these names with publication data from the BFI-database, we first need to identify the researchers in the National Research Database (NRD) because comprehensive searching for unique names and affiliations in the BFI database is not possible. The NRD database, while certainly deficient in many respects, has better searching facilities. The NRD is basically a repository of bibliographic information of all sorts harvested from the local bibliographic information systems at the individual research intuitions. Supposedly the NRD covers bibliographic information going back to 1998 but the actual coverage is much less. The research institutions in Denmark were rather slow to implement bibliographic information systems and incentives for researchers to register their publications were low until 2008. However, with the implementation of the national Danish bibliometric research indicator (BFI) around 2008, coverage is expected to be good as it contains all bibliographic information going into the indicator plus other publications.
- Manual searchers for 876 individual researchers (both PIs and rejected applicants) were carried out; eventually we were able to find publications for 779 of them and 97 were therefore discarded.
- Subsequently, publication portfolios were created based on the NRD data for 138 FSE PIs and 270 FSE rejected applicants, and 115 FKK PIs and 256 FKK rejected applicants.
- The publications comprising these portfolios were then matched to the BFI database based on their titles. Title string matching is attractive in this case because the bibliographic data indexed in both the NRD and BFI databases (at least from 2008 onwards) come from the same source namely local bibliographic information systems at the universities.
- In all we identified 5650 potential journal publications in the NRD database for the 779 researchers; these publications were then matched to the CFA's in-house version of the national BFI-database (2009-12). Notice, the quality of the NRD bibliographic data varies substantially, there are many duplicates and the assignment of publication types can be very

problematic, i.e., what appears to be journal articles turns out be news or magazine articles, therefore among the 5650 potential journal publications we expect some noise.

- Eventually, some 2422 unique and validated journal publications came out of this procedure. Initially, for the 138 FSE PIs, out of 1116 journal articles, 611 were matched and after data cleaning 508 remained for analysis. For the 270 FSE rejected applicants, out of 2000 journal articles, 858 were matched and after data cleaning 831 remained for analysis. For the 115 FKK PIs, out of 1207 journal articles, 817 were matched and after data cleaning 635 remained for analysis. Finally, For the 256 FKK rejected applicants, out of 1327 journal articles, 464 were matched and after data cleaning 421 remained for analysis.

Consequently, two publication sets come out of these searching and matching procedures for FKK and FSE PIs and rejected applicants to be used for journal publication profile analysis. A FSE set comprising 508 PI journal publications from 2009-2012 and 858 journal publications from FSE rejected applicants for the same time period. Also, a FKK set comprising 635 PI journal publications from 2009-2012 and 421 journal publications from FKK rejected applicants for the same time period.

Final data sets, their potentials and the benchmark units

Despite the challenges in data collection and matching, what we have is comprehensive and unique datasets highly qualified for advanced bibliometric analyses. As outlined above, the data collection procedures provide a number of different and to some extent intertwining publication sets which can be analyzed alone or for some of them in combination with each other. The report will contain two basic bibliometric methods: Publication analyses and citation analyses. In principle publication analyses can and will be performed on all the data sets created whereas citation analyses are restricted to the publication sets constructed from the CI-WoS database. To reiterate we have created the following publication sets:

1. All reported publication output from DFF grants from 2005 to 2008, where publications from the 2006 postdoc grants can be treated as a subset and used as such in all other publication sets. This publication set is coded for publication and will be used for publication analyses mainly in Chapter 4, but secondary also in Chapter 5 and 7. Publication analyses comprise publication activity and profile analyses.
2. A subset of journal publications from the reported grants published between 2009 and 2012 and matched to the BFI database. The BFI "status" of the journals in which these publications are published is linked to this this restricted publication set enabling publication analyses where journal publication behaviour can be examined. This subset is used in Chapter 4 to support the general publication profile analyses.
3. A subset of journal publications from the reported grants published between 2005 and 2012 and matched to the CI-WoS database. Citation data, but also subject, collaboration and funding data is linked to this publication set enabling citation impact analyses, but also publication analyses where collaboration and funding patterns are examined. This publication set will be used in Chapter 4 and in a reduced form also in Chapter 7.
4. A grant PI publication set containing portfolios of journal publications from CI-WoS potentially published from 1996 to 2012. This publication set can be split into pre-application and post-application subsets and due the specifically constructed CI-WoS grant publication set (#3 above) we have the possibility to also isolate DFF-grant or non-DFF grant post-application publications. As the PI publication set is linked to CI-WoS citation data is linked to the publications making impact analyses possible. This publication set is

used in conjunction with a corresponding publication set described below (#5) for rejected applicants in a comparative citation performance analysis of these two units in Chapter 5.

5. A rejected applicant (i.e., DFF applicants with no funding between 2003 and 2008) publication set containing portfolios of journal publications from CI-WoS potentially published from 1996 to 2012. This publication set can also be split into pre-application and post-application subsets. As the rejected applicant publication set is linked to CI-WoS citation data is linked to the publications making impact analyses possible. This publication set is used in conjunction with a corresponding publication set described above (#4) for PIs in a comparative citation performance analysis of these two units in Chapter 5.
6. An FKK and FSE PI subset of potentially all journal publications published between 2009 and 2012 and matched to the BFI database. The publication set potentially contains both grant and non-grant publications. The BFI "status" of the journals in which these publications are published is linked to this restricted publication set enabling publication analyses where journal publication behaviour can be examined. This publication set is used in conjunction with a corresponding publication set described below (#7) for rejected applicants in a comparative analysis of publication behaviour for these two units in Chapter 5.
7. An FKK and FSE rejected applicant subset of potentially all journal publications published between 2009 and 2012 and matched to the BFI database. The BFI "status" of the journals in which these publications are published is linked to this restricted publication set enabling publication analyses where journal publication behaviour can be examined. This publication set is used in conjunction with a corresponding publication set described above (#6) for rejected applicants in a comparative analysis of publication behaviour for these two units in Chapter 5.

The performance analyses indicated above, i.e., citation impact analyses, will be carried out using four benchmark units (the suitability of these units is discussed in Chapter 4 and 5). The following benchmark units are used:

1. Standard CI-WoS references values. The main performance indicators used, MNCS, PPtop10% and MNJS all have reference values calculated on the whole CI-WoS database within the same publication and citation windows as applied in the analyses. As discussed in the next section, the reference value for MNCS and MNJS is one corresponding to the average performance across fields in the database. Likewise, the reference value for

PPtop10% is 10 percent which corresponds to the expected proportion of publications from a unit that should be highly cited. As a basis, all indicators calculated in this are compared to their reference values. Notice, generally, Denmark performs above the reference values in impact analyses, therefore we can expect DFF-performance to also generally be above these reference values.

2. Consequently, to be able to assess the degree to which the DFF units perform above the reference values, we use two benchmark units: Denmark and a specially constructed set of Danish publications from 2005 to 2010 linked to Centres of Excellence funded by the Danish National Research Foundation.
    a. Denmark: We examine the potential drop in performance for Denmark by calculating national indicators including and excluding the different DFF publication sets (overall for DFF and the individual councils). Notice, whether potential drops in indicator values can be considered important should be based on informed judgment and not statistical significance test; the latter are not appropriate for such decisions and particularly not in the present case as we in principle are examining the total population and certainly not a probability sample from it (see Schneider, 2013; 2014).
    b. Danish National Research Foundation (DNRF): To make informed judgements on the DFF sets of publications, we also compare what happens to the Danish indicator values when we include and exclude a set of publications linked to the DNRF. This publication set is constructed based on validated publication data from our recent bibliometric evaluation of the DNRF[5]. Notice, this benchmark unit (DNRF) is also a Danish funding institution and as such is somewhat comparable to DFF, but as we discuss in Chapter 4 funding institutions are somewhat arbitrary units of analyses in bibliometric analyses, and it is very difficult, if not impossible, to find or construct good comparable benchmark units to such funding units. In that respect, there are some important differences between DNRF and DFF which should be taken into consideration. Up front, we expect the DNRF set of publications to perform above the DFF set, simply because in principle the conditions given to CoEs, and the cumulative effects this creates, generally favours conditions that may yield high performance. We know from the previous bibliometric evaluation of the DNRF that

[5] http://dg.dk/filer/Publikationer/Evaluering2013/Appendiks%205_bibliometrisk_report_03122013.pdf.

the level of publication performance is very high, what we are interested in in this report is to see to how close the DFF sets comes to the DNRF set of publications when it comes to performance, knowing that the DNRF to some extent has some intrinsic advantages towards performance. We discuss this further in Chapter 4. Finally, we do not use the DNRF set of publications at the disaggregate level of research councils as we do not consider them suitable to comparison at that level.

3. Finally, the set of rejected applicants can also be considered a benchmark unit in relation the set of PI publications.

Bibliometric indicators

A basic assumption behind bibliometric analyses (i.e., the quantitative study of scientific literature) is that scientific domains develop at an international research frontier (Price, 1963). Research results are communicated in publications that are submitted to evaluation by peers. In the references of their publications, researchers acknowledge (i.e., they cite) relevant publications by others, as they build on previous work. Therefore, the number of times a publication is referred to (i.e., cited) gives a partial indication of the "impact" of a publication, its reception and use by researchers at the research frontier. In many fields, journals are the most important medium of communication. When scholarly and scientific journals are indexed in controlled citation databases like WoS or Scopus, a large variety of bibliometric analyses, including citation analysis, becomes possible. Currently, international journal literature is the only reliable publication type on which impact analyses can be made and this in fact only goes for fields and countries where the journal coverage is sufficient in the citation databases.

In the present study we use CWTS' in-house version of Thompson Reuter's WoS citation database. WoS covers publications from about 12,000 journals in the sciences, the social sciences, and the arts and humanities. Each journal in WoS is assigned to one or more "subject categories". The CWTS in-house version of the WoS database includes a number of improvements over the original WoS database. Most importantly, compared to Thompson Reuters' WoS, the CWTS database uses a more advanced citation matching algorithm and an extensive system for address unification. The database also supports a hierarchically organized field classification system on top of the WoS "subject categories" constructed by Thompson Reuters.

When examining impact, raw citation and publication counts are flawed indicators. Both statistical requirements and imperfections in the citation process make it desirable to aggregate across individuals, publications, and citations. Another reason for computing indicators on the oeuvre of a unit rather than on individual papers is that within an oeuvre, later papers or review papers may draw citations that otherwise would have gone to earlier papers. The oeuvre approach prevents that such a transfer of citations within an oeuvre is treated as a statistical error in the assessment of single papers. Also, as scientific (sub)fields differ in publication and citation patterns (as visible in differences in, for example, length of reference lists or age of cited literature), it is usually not meaningful to compare directly the raw impact of publications from one (sub)field with those of a different (sub)field. Therefore, we normalize citation scores so that they are comparable across fields.

To determine the appropriateness of our indicators for assessing a particular unit of analysis, the internal WoS coverage of the unit is examined. The internal WoS coverage of a unit is defined as the proportion of the references in its oeuvre that points to publications (also) covered by WoS. The lower the internal WoS coverage of a unit's output, the more careful one should be in the interpretation of our indicators. What follows in the next section is an in-depth discussion of the main bibliometric indicators that we use in this report.

Output and impact indicators

Indicators are calculated based upon the oeuvre of the unit of analysis. Obviously, publications and citations are the two basic entities of indicators. We provide a number of simple indicators to support the more advanced indicators described in the next subsection. **P** is the total number of publications for a unit of analysis during the time period examined. It is a very simple indicator and it is only used to provide insights into the journal publication volume of the unit and as input for more sophisticated relative indicators. Only articles and reviews are included and in the present analysis we use full counting of publications primarily because we have different units of analysis and different levels of aggregation, thus a unit is credited with a full P if at least one author from the unit under investigation is mentioned in the author by line of a publication. **TCS** is a unit's total number of citations excluding self-citations. A self-citation to a publication is a citation given in a later publication of which at least one author (either first author or co-author) is also an author of the cited paper (either first author or co-author). As an indication of the self-citation rate we present the percentage of self-citations (**Scit**), relative to the total number of citations (including self-citations) received. We disregard self-citations in indicator calculations because they have a somewhat different nature than ordinary citations. Many self-citations are given for good reasons, in particular to indicate how different publications of a researcher build on each other. However, sometimes self-citations can serve as a mechanism for self-promotion rather than as a mechanism for indicating relevant related work. This is why we consider it preferable to exclude self-citations from the calculation of our impact indicators. By disregarding self-citations, the sensitivity of our impact indicators to manipulation is reduced. Disregarding self-citations means that our impact indicators focus on measuring the impact of a work on other members of the scientific community. Finally, **Pnc** is the percentage of papers not cited during the time period excluding self-citations.

Indicators of impact

A number of indicators are available for measuring the average impact of the publications of a unit. These indicators are all based on the idea of counting the number of times the publications of a unit have been cited. Citations can be counted using either a fixed-length citation window or a variable-length citation window. In the case of a fixed-length citation window, only citations received within a fixed time period (e.g., three years) after the appearance of a publication are counted. In the case of a variable-length citation window, all citations received by a publication up to a fixed point in time are counted, which means that older publications have a longer citation window than more recent publications. In this study we apply fixed-length three year citation windows including the publication year, except for some publications in 2011 and all publications from 2012, here the citation window is shorter. This means that citation counts to these later publications are less robust than the full three year windows. The latter is expected to lead to more reliable impact measurements.

Each journal in WoS is assigned to one or more "subject categories". These categories are interpreted as "scientific fields". There are about 250 "subject categories" in WoS and they can serve different functions in bibliometric analyses. One of them is to establish the mean citation activity of these "scientific fields" which is needed to normalize a unit's local citation activity and establish general reference values. Notice, the WoS "subject categories" are problematic but at the time of writing this report they are the only feasible mean to normalize citation activity across time and fields (we discuss the problems of WoS subject categories further in Chapter 4).

Publications in so-called "multidisciplinary" journals such as Nature, Proceedings of the National Academy of Sciences, and Science are, if possible, individually re-assigned to subject fields on the basis of their references. The reassignment is done proportionally to the number of references pointing to a "subject category". It is important to emphasize that the overall impact indicators are calculated based on this assignment.

The most straightforward indicator is the mean citation score, denoted **MCS**. This indicator simply equals the average number of citations of the publications of a unit. Only citations within the relevant citation window are counted, and self-citations are excluded. A major shortcoming of the MCS indicator is that it cannot be used to make comparisons between scientific fields. This is because different fields have very different citation characteristics. For instance, using a three-year fixed-length citation window, the average number of citations of a publication of the document type article equals 2.0 in mathematics and 19.6 in cell biology. So it clearly makes no sense to make

comparisons between these two fields using the MCS indicator. Also the MCS, and this in fact is true for all indicators based on mean values, is calculated as a central tendency whose validity assumes adherence to the Central Limit Theorem. However complex citation networks often have power law characteristics where the scaling exponent, α, is lower than 3.0 and in these instances the variance is infinite, the domain of attraction is no longer the Gaussian distribution and the population average no longer characterizes it.

MNCS is the mean normalized citation score, which provides a more sophisticated alternative to the MCS indicator. The MNCS indicator is similar to MCS except that it performs a normalization that aims to correct for differences in citation characteristics between publications from different fields, between publications of different ages (in the case of a variable-length citation window), and between publications of different document types (i.e., article and review[6]). To calculate the MNCS indicator for a unit, we first calculate the normalized citation score of each publication of the unit. The normalized citation score of a publication equals the ratio of the actual and the expected number of citations of the publication, where the expected number of citations is defined as the mean number of citations of all publications in WoS that belong to the same field and that have the same publication year and the same document type. The field (or the fields) to which a publication belongs is determined by the WoS "subject categories" of the journal in which the publication has appeared. The MNCS indicator is obtained by averaging the normalized citation scores of all publications of a unit. If a unit has an MNCS indicator of one, this means that on average the actual number of citations of the publications of the unit equals the expected number of citations. In other words, on average the publications of the unit have been cited on par with similar publications in terms of field, publication year, and document type. An MNCS indicator of, for instance, two means that on average the publications of a unit have been cited twice as frequently as would be expected based on their field, publication year, and document type. We refer to Waltman, Van Eck, Van Leeuwen, Visser, and Van Raan (2011a; 2001b) for more details on the MNCS indicator. To illustrate the calculation of the MNCS indicator, we consider a hypothetical unit that has only five publications. Table 3.3 provides some bibliometric data for these five publications. For each publication, the table shows the "subject category", to which the publication belongs, the

[6] We note that the distinction between the different document types is sometimes based on somewhat arbitrary criteria. This is especially the case for the distinction between the document types *article* and *review*. One of the main criteria used by WoS to distinguish between these two document types is the number of references of a publication. In general, a publication with fewer than 100 references is classified as *article* while a publication with at least 100 references is classified as *review*. It is clear that this criterion does not yield a very accurate distinction between ordinary articles and review articles.

year in which the publication appeared, and the actual and the expected number of citations of the publication (for the moment, the last column of the table can be ignored). All publications are of the document type article. Citations are counted using a variable-length citation window. As can be seen in the table, publications 1 and 2 have the same expected number of citations. This is because these two publications belong to the same field and have the same publication year and the same document type. Publication 5 also belongs to the same field and has the same document type. However, this publication has a more recent publication year, and it therefore has a smaller expected number of citations. It can further be seen that publications 3 and 4 have the same publication year and the same document type. The fact that publication 4 has a larger expected number of citations than publication 3 indicates that publication 4 belongs to a field with a higher citation density than the field in which publication 3 was published. The MNCS indicator equals the average of the ratios of actual and expected citation scores of the five publications. Based on Table 3.3, we obtain:

$$\text{MNCS} = \frac{1}{5}\left(\frac{7}{6.13} + \frac{37}{6.13} + \frac{4}{5.66} + \frac{23}{9.10} + \frac{0}{1.80}\right) = 2.08$$

Hence, on average the publications of our hypothetical unit have been cited more than twice as frequently as would be expected based on their fields, publication years, and document type.

Table 3.3. Bibliometric data for the publications of a hypothetical research group.

Publication	*Subject category*	*Year*	*Actual citations*	*Expected citations*	*Top 10% threshold*
1	Surgery	2007	7	6.13	15
2	Surgery	2007	37	6.13	15
3	Clinical neurology	2008	4	5.66	13
4	Hematology	2008	23	9.10	21
5	Surgery	2009	0	1.80	5

Perhaps the most important impact indicator is the proportion of highly cited publications, in this analysis the proportion of publications among the 10% most cited in the database denoted **PPtop10%**. For each publication of a unit, this indicator determines whether, based on its number of citations, the publication belongs to the top 10 percent cited publications among 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. In other words, the non-parametric indicator determines whether the publication is placed on or above the 90^{th} percentile of the citation distribution. PPtop10%

indicator equals the proportion of the publications of a research unit that belong to the top 10%. If a research unit has a PPtop10% indicator of 10%, this means that the actual number of top 10% publications of the unit equals the expected number, which is 10% (i.e. the citation distribution of a unit's publications is expected to follow the reference standard, thus it is expected that its 10% most highly cited publications are also among the 10% most highly cited in the global distribution, if the PPtop is set to 10%). A PPtop10% indicator of, for instance, 20% means that a group has twice as many top 10% publications as expected. Of course, the choice to focus on top 10% publications is somewhat arbitrary. Instead of the PPtop10% indicator, we can also calculate for instance a PPtop1%, PPtop5%, or PPtop20% indicator. In this study, however, we use the PPtop10% indicator. On the one hand, this indicator has a clear focus on high impact publications, while on the other hand the indicator is more stable than for instance the PPtop1% indicator.

To illustrate the calculation of the PPtop10% indicator, we use the same example as we did for the MNCS indicator. Table 3.3 shows the bibliometric data for the five publications of the hypothetical research group that we consider. The last column of the table indicates for each publication the minimum number of citations needed to belong to the top 10% of all publications in the same field and the same publication year and of the same document type.[7] Of the five publications, there are two (i.e., publications 2 and 4) whose number of citations is above the top 10% threshold. These two publications are top 10% publications. It follows that the PPtop10% indicator equals

$$PP_{top\,10\%} = \frac{2}{5} = 0.4 = 40\%$$

In other words, top 10% publications are four times overrepresented in the set of publications of our hypothetical research unit.

To assess the impact of the publications of a unit, our general recommendation is to rely on a combination of the MNCS indicator and the PPtop10% indicator. The MCS indicator does not correct for field differences and should therefore be used only for comparisons of groups that are active in the same field. An important weakness of the MNCS indicator is its strong sensitivity to publications with a very large number of citations. If a unit has one very highly cited publication, this is usually sufficient for a high score on the MNCS indicator, even if the other publications of the group have received only a small number of citations. Because of this, the MNCS indicator

[7] If the number of citations of a publication is exactly equal to the top 10% threshold, the publication is partly classified as a top 10% publication and partly classified as a non-top-10% publication. This is done in order to ensure that for each combination of a field, a publication year, and a document type we end up with exactly 10% top 10% publications.

may sometimes seem to significantly overestimate the actual scientific impact of the publications of a unit. The PPtop10% indicator is much less sensitive to publications with a very large number of citations, and therefore does not suffer from the same problem as the MNCS indicator. A disadvantage of the PPtop10% indicator is the artificial dichotomy it creates between publications that belong to the top 10% and publications that do not belong to the top 10%. A publication whose number of citations is just below the top 10% threshold does not contribute to the PPtop10% indicator, while a publication with one or two additional citations does contribute to the indicator. Because the MNCS indicator and the PPtop10% indicator have more or less opposite strengths and weaknesses, the indicators are strongly complementary to each other. This is why we usually recommend taking into account both indicators when assessing the impact of a unit's publications.

Within this report however our primary focus is upon the PPtop10% because we are interested in "excellence" and the proportion of highly cited publications is considered to be a better indicator of this than average based citation indicators such as MNCS; further we also use PPtop10% because of its robustness, i.e., few missing publications will not influence the indicator, this provides us with a steady and sturdy measure that is very well geared towards benchmarking over a longer period of time.

It is important to emphasize that the correction for field differences that is performed by the MNCS and PPtop10% indicators is only a partial correction. As already mentioned, the field definitions on which these indicators are based on are the WoS subject categories. It is clear that, unlike these subject categories, fields in reality do not have well-defined boundaries. The boundaries of fields tend to be fuzzy, fields may be partly overlapping, and fields may consist of multiple subfields that each have their own characteristics. From the point of view of citation analysis, the most important shortcoming of the WoS subject categories seems to be their heterogeneity in terms of citation characteristics. Many subject categories consist of research areas that differ substantially in their density of citations. For instance, within a single subject category, the average number of citations per publication may be 50% larger in one research area than in another. The MNCS and PPtop10% indicators do not correct for this within-subject-category heterogeneity. This can be a problem especially when using these indicators at lower levels of aggregation.

Finally, we use **MNJS**, the mean normalized journal score indicator, to measure the impact of the journals in which a unit has published. To calculate the MNJS indicator for a unit, we first calculate the normalized journal score of each publication of the unit. 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 (i.e., the same WoS subject category). Only publications in the same year and of the same document type are considered. The MNJS indicator is obtained by averaging the normalized journal scores of all publications of a unit. 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. The interpretation of the MNJS indicator is analogous to the interpretation of the MNCS indicator. If a unit has an MNJS indicator of one, this

Table 3.4. Overview of standard CWTS bibliometric indicators.

Indicator	Dimension	Definition
P	Output	Total number of publications of a unit.
Coverage	Output	Internal coverage. Proxy of oeuvre being covered by Web of Science. Measured by the proportion of cited references in the oeuvre linking to other WoS publications.
MCS	Impact	Mean number of citations of the publications of a unit (self-citations not included).
TCS	Overall	Total number of citations.
MNCS	Impact	Mean normalized number of citations of the publications of a unit (self-citations not included).
TNCS	Overall	Total average normalized number of citations.
MNJS	Journal impact	Mean normalized citation score of the journals in which a research unit has published.
Ptop 10%	Overall	Number of publications belonging to the top 10% highly cited publications in the database.
PPtop 10%	Impact	Proportion of papers that belong to the top10% highly cited publications in the database.
Pnc	Overall	Percent of papers uncited
Scit	Overall	Proportion of self-citations

means that on average the group has published in journals that are cited equally frequently as would be expected based on their field. An MNJS indicator of, for instance, two means that on average a unit has published in journals that are cited twice as frequently as would be expected based on their field citation activity. The use of Thomson Reuters' Journal Impact Factor and the MNJS indicator

seems to be similar in the sense that in both cases publications are assessed based on the journal in which they have appeared. However, among several deficiencies, journal impact factors have the important disadvantage that they do not correct for differences in citation characteristics between scientific fields. Because of this disadvantage, impact factors should not be used to make comparisons between fields. The MNJS indicator, on the other hand, does to a large extent correct for field differences. When between-field comparisons need to be made, the use of the MNJS indicator can therefore be expected to yield significantly more accurate journal impact measurements than the use of impact factors. Table 3.4 below summarizes the CWTS indicators.

Journal level indicators from the Danish national performance-based indicator

Usually in bibliometric analyses, performance analyses are focused upon citation impact and publication behaviour, i.e., how much is published and where is it published, is usually supplemental analyses used to contextualize impact. However, as outlined above, impact analyses are usually restricted to units that publish in international journals indexed in an appropriate citation database such as WoS. This often means that the humanities and several fields in social science, but also fields in technological fields such as computer science, is left out of such analyses due to poor coverage in the citation databases.

In the present report there has been a wish to also include "performance analyses" for the humanities and social sciences. Hence, to the extent that FKK and FSE can be seen as representing the humanities and the social sciences, we have first tried to examine the actual coverage of the publications coming out of the grants (and correspondingly the PIs of these grants) in the WoS in order to determine whether they could be applied in aggregate citation impact analyses. In the event of a poor coverage, and to be able to examine non-indexed WoS journal publications, we have decided to apply an analysis that may convey something about the journal publication behaviour of PIs and rejected applicants. We rule out a simple publication activity comparison as it is a poor indicator that cannot be compared across fields, between positions etc. What we can do is to match the journal publications coming out of the grants/PIs (and rejected applicants) to the national Danish bibliometric indicator (BFI) database. CFA has an in-house version of this database with valid publication information from 2009 to 2012. The reason this database can be used for a profile analysis of journal publication behaviour is that journals in the BFI-indicator are ranked in two categories where the more "exclusive" level 2 category yields more publication points (and thus are "worth" more in the national funding model). Notice, other publication channels such as publishers

in the case of books or conference proceedings have only recently been graded, thus only journals are feasible for the present analysis. Level 1 comprises in principle all scholarly eligible journals, where eligibility criteria are some basic norms such as a standard external peer review process. Level 2, is an "exclusive" number of journals which are deemed to be leading in a field and preferably with an international audience. Level 2 is exclusive in as much as the number of journals designated at any given time to this level should produce roughly one-fifth of the publications produced in a field. Journals can be nominated by all researchers but their status is decided annually by 68 subject committees. Notice journals are only treated by one committee and thus have one classification. Hence, the basic idea behind this two-tiered classification system is that publications on level two receive more publication points than publications on level one.

The model is supposed to affect researchers' and scholars' publication behaviour in the direction of level 2 publications. In that respect, we can examine the publication profile of those funded and not-funded. Analyses based on journal rankings are always problematic. While such rankings may say something about the social status of journals, they say less about the actual quality of a specific publication. Nevertheless, on an aggregate level of oeuvres such analyses can be informative when it comes to publication preferences and weak indications of performance.

4. Analyses of the reported scholarly and scientific output from the DFF-grants (2005 – 2008)

In this chapter we examine the sets of publications constructed from the reported DFF-grants. Based on the 1322 grants, we first examine the general publication behaviour and profiles for the five research councils. Next, we specifically examine the journal publication behaviour in relation the BFI journal status for FKK and FSE grants. Finally, the main focus of this chapter is the impact analyses on the DFF and council levels of analysis based on the matched CI-WoS journal publications coming from 1042 grants (including 79 postdoc grants).

Analysis of publication behaviour based on *all* reported and validated publications from eligible grants between 2005 and 2008

First we examine the overall output from the 1322 eligible grants initially reported of which 805 also validated in the survey. Notice, we include all reported publications and treat them equally. Data source is the set of 19,958 reported grant publications and we split the set in two, publications reported from all types of grants except postdoc-grants from 2006 and publications reported from the 2006 postdoc-grants.

Table 4.1. Reported publication output for all grants except postdoc-grants from 2006.

	FKK	FNU	FSE	FSS	FTP	Total
Books	57	34	37	1	11	140
Book chapters	398	287	291	98	55	1129
Conference papers	438	978	363	322	1151	3252
Journal articles	391	4463	667	2707	1362	9590
Book/journal editor	44	12	20	4	7	87
Other journal publications	3	20	3	17	2	45
Theses	32	174	32	313	187	738
Scientific reports	40	152	52	25	42	311
Working papers	62	48	157	38	44	349
Patents	0	2	0	0	1	3
Popular communication	354	287	160	137	134	1072
Manuscripts	12	61	12	13	9	107
Other	82	84	24	73	47	310
Unknown	216	527	215	601	330	1889
Total	2129	7129	2033	4349	3382	19022

Table 4.1 above shows the total publication outputs for the five research councils distributed among different publication types. We have standardized the initially used publication categories and devised the above listed publication types and recoded the whole set of publications. Table 4.1 is divided into several categories marked by grid lines. From the top, the first four publication types: Books, book chapters, conference papers and journal articles (research articles and reviews) are the main (peer reviewed) publication types included in the BFI indicator. The next category include reported editorial activities, such as editing anthologies or special journal issues related to the project, as well as other journal publications such as letters, notes, editorials etc. These activities are not credited in the BFI-indicator. Next is a separate category representing reported theses. Theses in fact cover more than PhD-theses. In these numbers are also for certain 43 master theses (FNU: 23, FSS: 9 and FTP: 11) as well as 11 bachelor projects (FNU: 2, FSS: 4 and FTP: 5). The subsequent category comprises two publication types typically considered so-called "grey literature" but vital for some research domains: Scientific reports and working papers. In order to be coded as a scientific report or working paper, we required that the status should be published with information on availability such as report series, url etc. The next category is patents, we include them here as we encountered these in the publication lists, but we will address patents and patent applications more closely below and exclude them for the profile analysis below. The next category is named popular communication; this includes various forms of public science communication in newspapers, magazines, radio, television, blogs etc. The final category is a mixed bag of reported but unfinished manuscripts, publications where the information quality was so poor that their type could not be established and so-called "other" types which could be teaching material, software or datasets.

It is clear from Table 4.1 that journal articles is by far the most prevalent reported publication type. For all councils combined, half of all the reported publications are journal articles. Also, 90 percent of the eligible grants with reported publications (excluding postdoc grants) come from the three research councils FNU, FSS and FTP. Correspondingly, 78 percent of all reported publication types come from grants from these three councils. Notice that close to 10 percent of the reported publications are classified as "unknown"; we cannot establish the status of these publications, even though some of them belong to grants that seem to have been validated. Notice also that there is considerable variation among the councils when it comes to "unknown" publications, for FNU, FSS and FTP the proportion of "unknown" publications constitute between three and four percent of their total reported output, whereas the proportion for FSE is eight percent

and the proportion for FKK is close to 17 percent of their total reported output. We presume that among the "unknown" there are many planned publications, some of which will probably never materialize.

Conference papers are the second largest publication type reported with some 17 percent of the total. Conference papers are one of the four main publication types included in the national bibliometric indicator and together they constitute 74 percent of the total reported output. From Table 4.1 we can start to discern the publication behaviour shown by the different research councils. We will go deeper into these profiles below in Table 4.3, but first we show the reported output for the 2006 funded postdoc grants.

Table 4.2 present the reported output from the postdoc grants from 2006 included in the analysis.

Table 4.2. Reported publication output from the 2006 postdoc-grants.

	FKK	FNU	FSE	FSS	FTP	Total
Book	5	2	5	0	0	12
Book chapters	27	3	19	11	5	65
Conference papers	28	7	10	11	54	110
Journal articles	29	55	14	195	85	378
Book/journal editor	5	0	0	0	0	5
Other journal publications	0	0	0	0	1	1
Theses	2	0	0	5	3	10
Scientific reports	1	0	2	2	9	14
Working papers	1	0	0	0	4	5
Popular communication	44	3	8	18	14	87
Manuscripts	0	0	0	0	3	3
Other	21	0	0	5	9	35
Unknown	38	62	23	49	39	211
Total	201	132	81	296	226	936

Originally, the eligible postdoc grants constituted some 8 percent of the 1322 grants with reported output and the total output from 108 postdoc grants constitute some 5 percent of the total output for all grants. We can see that not all of the publication types introduced above are included in Table 4.2. Journal articles are still the most prevalent publication type comprising some 40 percent of the total reported output for the postdoc grants. The number of publications classified as "unknown" constitutes some 23 percent of the total and similar to Table 4.1 there is considerable variation among the councils, for example 47 percent of the FNU output is classified as "unknown".

We should emphasise that the actual numbers are considerably lower than in Table 4.1 which makes the proportions more vulnerable and less robust.

We also notice that the publication type "theses" are reported for the postdoc grants but we have not been able to clarify why they are reported. We will examine the publication profiles for the individual councils' postdoc grants below in Table 4.4.

In Table 4.3 below we examine the publication profiles for the five research councils and thus the aggregated publication behaviour inherent in the individual grants and their constituent research domains; to complement this we also examine the actual subject fields assigned to the grants at the time of funding in Figures 4.1 and 4.2.

In order to give a more balanced portrait of the council's aggregated behaviour we have excluded the publication types "manuscripts", "other" and "unknown". Also, in bibliometric output analyses it is common to weight books so that the effort of writing books somehow is comparable to journal articles and conference papers when we count output. In the present case we have weighted books as five publication equivalents (i.e., five journal articles); the number five is based on what others have done (e.g., Piro et al. 2013), but the number is arbitrary, in principle books should have individual weights as their size and contribution varies, but for a simple aggregate analysis as the one presented here we find it reasonable to use the common arbitrary weight of five.

Table 4.3. Publication profiles for the five research councils based on the reported outputs coming from grants funded between 2005 and 2008 (excluding the 2006 postdoc grants).

	FKK	FNU	FSE	FSS	FTP
Book	13.9%	2.6%	9.6%	0.1%	1.8%
Book chapters	19.4%	4.4%	15.1%	2.7%	1.8%
Conference papers	21.4%	14.8%	18.8%	8.8%	37.9%
Journal articles	19.1%	67.7%	34.6%	73.8%	44.8%
Book/journal editor	2.1%	0.2%	1.0%	0.1%	0.2%
Other journal publications	0.1%	0.3%	0.2%	0.5%	0.1%
Theses	1.6%	2.6%	1.7%	8.5%	6.2%
Scientific reports	2.0%	2.3%	2.7%	0.7%	1.4%
Working papers	3.0%	0.7%	8.1%	1.0%	1.4%
Popular communication	17.3%	4.4%	8.3%	3.7%	4.4%

Table 4.4 clearly shows some distinct but well-known differences in publication behaviour between the five research councils. It is very clear that the main publication activity reported for grants funded by FNU and FSS is journal articles. Obviously, this is well-known, and FNU and FSS also comprise the fields which are most suitable for citation analyses due to the international

journal publication behaviour. Perhaps more surprising is the emphasis on theses in the reported outputs from the FSS grants; this indicates considerable collaborative work in embedded projects where PhD-students play an important role. Notice also, that close to 15 percent of the total output from FNU comes from conference papers. The status of conference papers varies considerably within research domains subsumed under FNU. In many science domains conferences have secondary communicative functions compared to communication in journals; however, as we show below, computer science projects seem to a large extent (at least in principle) to be subsumed under FNU and their publication activity is primarily in conference proceedings.

The publication profile for FTP is also well-known; here we see that while journal publication is still the main publication activity with close to 45 percent of the total output, conference papers are almost as prevalent with 38 percent. In some of the research domains under FTP, the reliance on conference papers is much higher, making citation analyses less reliable both for these research domains and for FTP as a whole due to the coverage problems for conference proceedings in the citation databases. As with FSS, we also see a relatively large proportion of "theses" reported in connection with FTP grants. Again we believe that this can partly be explained by a larger share of embedded projects.

The publication profile for FSE grants also shows some well-known characteristics, a much more heterogenic profile where journal publication is the most common publication activity with some 35 percent of the total output, but also a considerable relative activity when it comes to conference papers and book chapters, and even books (given the five publication equivalent weighting). Also, working papers constitute some eight percent of the total output. Working papers are an important publication channel in economics and as we show below, grants subject coded as economics are numerous among the FSE grants. "Theses" play a less important role in the reported output for FSE grants (and FKK as well), probably because FSE and FKK grants are less embedded and more focused on individuals. Clearly, the lesser importance of journal publication compared to the previously mentioned councils also makes citation analyses less valid and reliable for FSE, although there is considerable variation among social science fields in this respect; for example, it is generally acknowledged that economics is a field where citation analysis in principle is valid.

Clearly the most heterogenic and perhaps most surprising publication profile is that of FKK. We see more or less equal activity when it comes to the main BFI publication types: Books, book chapters, conference papers and journal articles, close to 20 percent, though books are lower but this is obviously an artefact of the weighting. Books are still important in many research domains

subsumed under FKK, at least in the period examined in this analysis. Some evidence indicates that most recently book and conference paper publication activity is dropping and journal publication is increasing in many humanities fields[8]. Perhaps most interesting and surprising is the considerable emphasis PIs give to "popular communication" in the reported output of the grants. Nevertheless, in many domains in the humanities (and to a lesser extent in the social sciences) participation in the public debate is seen as a research activity, but this is seldom acknowledged in cross-disciplinary research assessments. Notice, "popular communication" can be anything from radio and television appearances to feature articles in newspapers and blog contributions. We can also see that editorial activities play a larger role in domains subsumed under FKK (and to a lesser extent under FSE); for FKK this activity mainly refers to editing anthologies. Obviously, at face value, most humanistic fields are generally not suitable for citation analyses in international journal databases, their publication behaviour is too heterogenic and often in national languages, but there are exceptions such as linguistics, philosophy and psychology (in as much as psychology is classified under FKK).

Table 4.4 shows the corresponding publication profiles for the five councils based on the substantially smaller set of the 2006 postdoc grant publication output.

Table 4.4. Publication profiles for the five research councils based on the reported outputs coming from the 2006 postdoc grants.

	FKK	FNU	FSE	FSS	FTP
Book	15.4%	12.8%	32.1%	0.0%	0.0%
Book chapters	16.7%	3.8%	24.4%	4.5%	2.9%
Conference papers	17.3%	9.0%	12.8%	4.5%	30.9%
Journal articles	17.9%	70.5%	17.9%	80.6%	48.6%
Book/journal editor	3.1%	0.0%	0.0%	0.0%	0.0%
Other journal publications	0.0%	0.0%	0.0%	0.0%	0.6%
Theses	1.2%	0.0%	0.0%	2.1%	1.7%
Scientific reports	0.6%	0.0%	2.6%	0.8%	5.1%
Working papers	0.6%	0.0%	0.0%	0.0%	2.3%
Popular communication	27.2%	3.8%	10.3%	7.4%	8.0%

The overall profiles resemble those depicted in Table 4.3. Publication behaviour for FNU and FSS postdoc grants are primarily oriented towards journal articles. While journal articles are the most dominant output for FTP postdoc grants, conference papers also play a substantial role. Similar to the overall publication set depicted in Table 4.3, the publication behaviours for FSE and FKK

[8] http://www.uhr.no/documents/Evaluering_af_den_norske_publiceringsindikator.pdf

postdoc grants clearly show a more heterogenic pattern, where books, book chapters, conference papers and journal articles all play substantial roles. For FSE postdoc grants, book publication seems to be the most prevalent activity, but here we need to use caution because numbers are low and publication equivalent weighting undoubtedly enhances the effect. Nevertheless, books and book chapters do play an important role. Also similar to Table 4.3, "popular communication" is a prevalent output reported by postdoc grantees funded by FKK.

The reported output from the funded grants displays some well-known patterns, which in fact is comfortable as it testifies to the validity of the relative patterns inherent in the reported outputs. The publication behaviour discernible for the five research councils provides a picture of what is prioritized and what is considered a scholarly or scientific output in the respective areas. Using 10 different publication types gives a much more nuanced pictured of the different albeit aggregated publication behaviours compared to the usual main types often reported (books, book chapter, conference papers and journal articles). These results remind us that comparisons between different fields should be carried out with sensibility to these legitimate differences. We cannot weight all fields on the same scale.

When granted, projects are provided with a subject classification which is distinct for a specific research council (i.e., a grant has one subject classification and the classification is linked to one research council). In order to provide more detailed information of the publication profiles we have also mapped the reported grant outputs according to the assigned subject fields of their respective parent grants. Figure 4.1 shows total output for each subject category based on Table 4.1 and the subject categories are ranked ordered from highest to lowest.

Not surprisingly we see a number of subject areas under FSS and FNU among those with the largest reported output. Together, FSS and FNU contribute with 65 percent of the eligible grants in the analysis. Areas with known high publication activity also come out on top in this analysis, primarily bio- and life sciences, but also "physics" and "mathematics and computer sciences" have outputs on or above 1000. For FTP the category with largest output is the broadly defined "information, communication and technology". Noticeably, FTP also has a number of categories with relatively small outputs, but this is also an artefact of the classification as it seems to be finer grained for FTP than say FSS; as such biomedicine covers a large variety of subfields.

"Economics" is the category within FSE with most reported outputs; likewise, "film and media studies" is the category with most reported outputs for FKK. Figure 4.1 gives an impression of the general cognitive orientation of the funded projects, but obviously, Figure 4.1 is also a

reflection of the classification scheme used. Clearly some areas are covered under broad categories while others have very specific categories.

Figure 4.1. Total reported output distributed by subject codes assigned to grants at the time of funding (all outputs are weighted as 1 and the publication types "manuscripts", "other" and "unknown" are excluded).

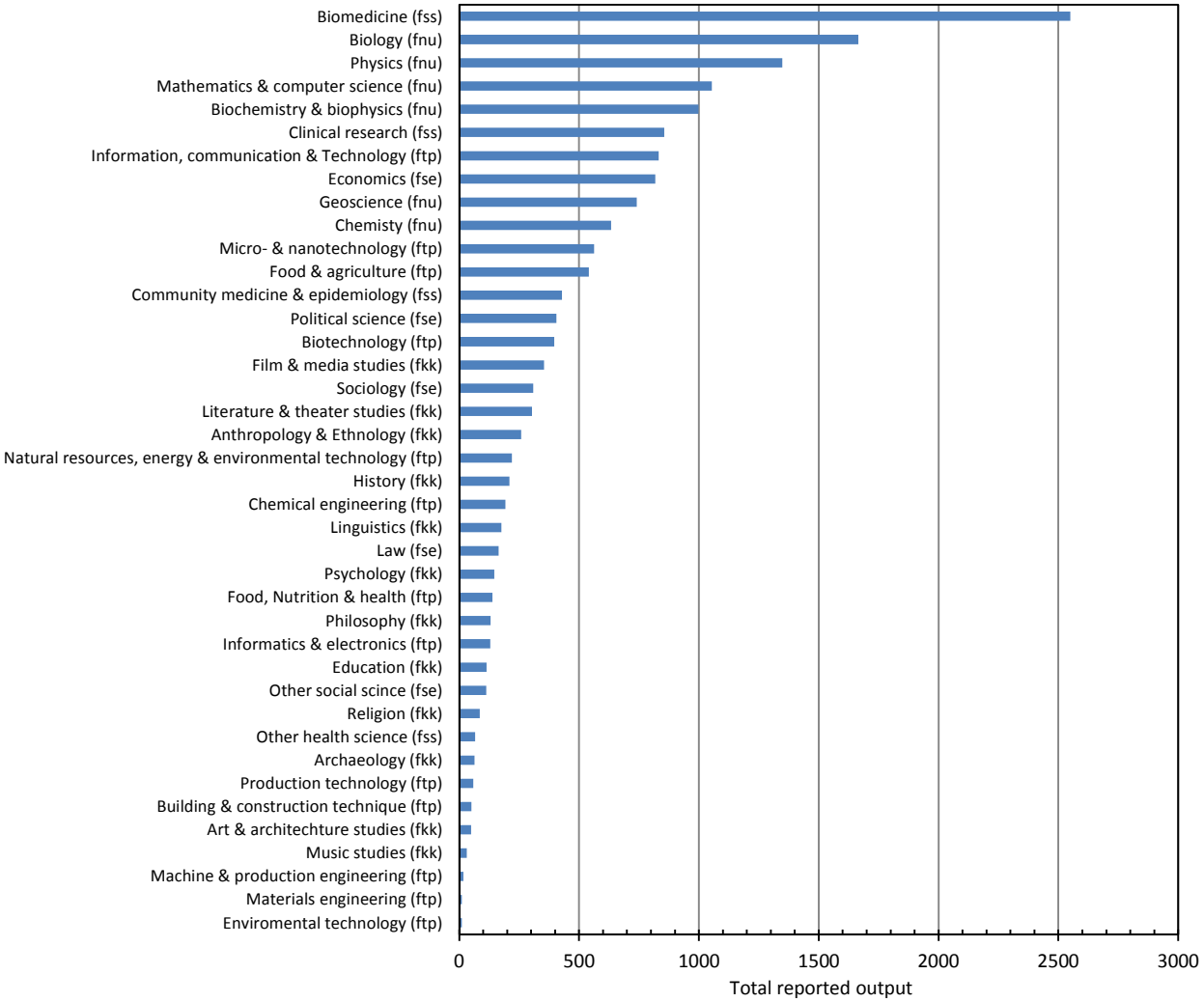
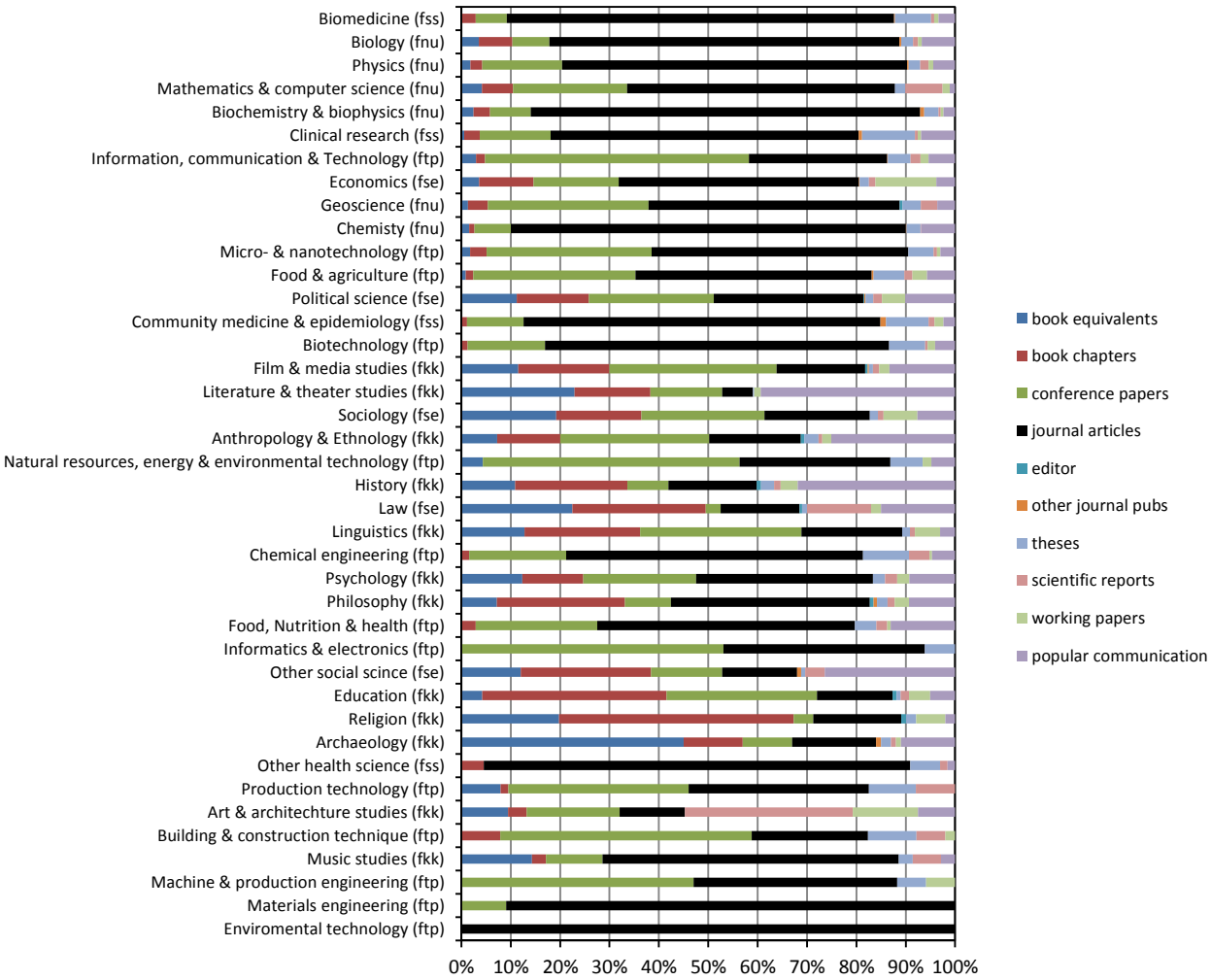


Figure 4.2 below shows the relative publication profiles for the different subject categories assigned to the parent grants of the reported outputs. We use the same rank order for the subject categories as in Figure 4.1 so that "biomedicine" is on top because this category contains the highest output and correspondingly "environmental technology" is at the bottom due to the lowest reported output. For each subject category, we have calculated the relative distribution of publication types and colour coded the outcome. Notice we have also ranked the publication types so that the four publication types included in the national Danish bibliometric indicator comes first

when reading from left to right. The demarcation between these four publication types and the rest is "journal articles" which has received the perceptible black colour bar. Journal publication constitutes around 50 percent of the reported output and journal publication is the major premise in the rest of the bibliometric analyses in this report, hence with this colour coding we want to give a more visible impression of the different subject areas' preference for journal publication and thereby somehow indicate where such analyses give meaning and where not.

Figure 4.2. Publication profiles for the subject categories subsumed under the five research councils (books are weighted as five publication equivalents and publication types "manuscripts", "other" and "unknown" are excluded).



Notice, that the subsequent bibliometric analyses based on journal publications are done at the aggregate level of councils. As is discernible from Figure 4.2, there is considerable variation between subject categories within the same research councils in the general publication profiles and

specifically in their reliance on journal publication activity. Among the highest ranked categories, journal publication seems to be the important activity but there are some noticeable exceptions. For example, publication behaviour in "information, communication and technology" from FTP and "political science" from FSE is clearly more heterogenic with less emphasis on journal publication. In relation to the impact analysis reported below, we estimate the specific councils' coverage in the citation databases in order to judge the validity of such analyses.

What has been presented above is the publication profiles of the five research councils based on the reported outputs of the individual grants. In that respect, it is the aggregated behaviours of different research domains that are displayed at the council level. What we see is the reported activities as well as the preferences for publication channels. This is informative as it demonstrates the major differences between fields which are especially important to remember in a bibliometric analysis. As stated several times, such publication analyses cannot be used for comparable performance analyses, for this we need citation analyses. However, to supplement the existing publication analyses, we have also tried to match the reported journal articles to the BFI database for articles published between 2009 and 2012. We do this to further examine publication behaviour; in this case the potential preferences for which journals to publish in. Such an analysis is possible due to the two-tiered classification of journals in the national Danish bibliometric indicator. Again we caution this is not a performance analysis, in principle an article's eventual influence on the scholarly community cannot be deduced from where it is published.

As outlined in Chapter 3 we managed to match 3946 journal articles out of the originally 9590 reported ones. Remember that the total number in principle covers several other publication years than the ones included here and also numerous duplicates and publications that did get published or have not yet been published. It is therefore impossible to estimate the actual coverage; however, we can loosely compare the results below for journal articles to the relative total reported for BFI journal output for main fields to get some impressions of where journal publications funded by DFF are published[9].

Remember, the BFI-indicator differentiates between journals on two levels, where level 2 is seen as the more exclusive containing a restricted set of journals; Table 4.5 provides the results. The results are interesting in as much as the share of level 2 publications is larger than one would expect given the official BFI-statistics. In the latter statistics, the natural sciences and technology, which constitute FNU and FTP in this analysis, are treated as one category. Nevertheless, level 2

[9] http://ufm.dk/forskning-og-innovation/statistik-og-analyser/den-bibliometriske-forskningsindikator/indikatorstatistik

publication activities for the natural sciences and technology is around 40 percent, health sciences 37 percent, social sciences 35 percent and the humanities around 30 percent. In that respect, publication activity in journal status level 2 for the five research councils, based on the reported matched articles in the BFI-database, is generally considerably higher than one would expect based on the official statistics. Obviously, we cannot rule out biases in the publication data and systematic bias in the matching process, so the results should be interpreted in the light of the subsequently presented analyses and here there is some evidence that journal publication activity for grants funded by DFF is generally more concentrated in higher impact journals compared to other Danish journal articles in the same period.

Table 4.5. Distribution of matched reported journal articles published between 2009 and 2012 according to journal status in the national Danish bibliometric indicator (BFI).

	Journal status level 1	Journal status level 2	Total n
FKK	58% (n = 55)	42% (n = 40)	95
FNU	49% (n =858)	51% (n =892)	1750
FSE	43% (n = 73)	57% (n = 96)	169
FSS	50% (n =594)	50% (n = 596)	1190
FTP	49% (n = 363)	51% (n = 378)	741
Total n	1944	2002	3946

Summary

In this section we have examined publication profiles emerging from the set of publications reported as output from the 2005 to 2008 grants. Some 90 percent of the grants (excluding postdoc grants) come from three research councils FNU, FSS and FTP and together they have reported 78 percent of all publication types. In the total set, journal articles constitute some 50 percent of the reported output, but at the disaggregate level the analyses clearly show some distinct but well-known differences in publication behaviour between the five research councils. It is very clear that the main publication activity reported for grants funded by FNU and FSS is journal articles, whereas publication behaviour is much more heterogenic for grants funded by FKK and FSE. The publication behaviour analyses also reveal some interesting differences in priorities in what the domains considered as legitimate outputs of their funded research activity. In that respect it is interesting that only some of these output types are acknowledged in the national bibliometric

indicator although we should emphasize that these reported outputs are based on grants belonging to a previous funding model revised in 2009 and in place before the national bibliometric indicator was implemented. We should point out that in principle research councils, or DFF for that matter, obviously have no publication behavior themselves, what has been presented above is the aggregated behaviours of different research domains that eventual come to light at the aggregate council level. The analyses of publication behavior also provide some early indication of the appropriateness of applying citation analyses to certain councils and the research areas subsumed under them, and more generally the appropriateness of using journals as the primary means of evaluation. Nevertheless, due to a perceived lack of good coverage in the citation databases for FKK and FSE journal publications, and thereby also problems in relation to doing citation analyses, we ended this section by comparing the proportion of level two journal publications from the reported output for each of the five councils in the national bibliometric indicator (BFI) and the result is distinctive. Publication activity in journal status level two (the most distinct outlets in the BFI indicator) for the five research councils, based on the reported matched articles in the BFI-database, is generally considerably higher than the national trends in BFI journal publication behaviour from 2009 to 2012. Consequently, journal publications linked to DFF grants are generally published to a larger extent in journals considered to have "higher status". The latter is of course debatable, and certainly not the accepted view in all fields, but the pattern is clear.

Where you publish is one thing, the impact of what you publish is another. The former belongs to publication analyses and the latter to citation analyses and citation analyses should be the principle means for performance analyses. The next section presents different performance analyses based on the reported grant journal publications both for the overall DFF set and for the individual council sets of publications.

Performance analysis: Citation impact of the matched WoS-indexed journal publications from eligible grants between 2005 and 2008

This section presents the citation impact analyses of the matched international journal publications from the reported output. As outlined in Chapter 3, initially 9590 reported journal articles were subjected to matching in the CI-WoS database; 7973 were identified, a matching rate of 83 percent. Among the 7973 were journal publications published before 2005, publications of other types than articles and reviews and duplicates. The final set of unique journal articles going into the analyses constitute 6963 publications and when distributed among grants 7660 as duplicate publications emerge (i.e., publications linked to several grants).

In this section we first outline the grant types included in the citation analyses. Next we examine the publication sets' coverage and output in order to establish the validity of the citation analyses. We then continue with the actual impact analyses, first for the overall DFF-set of publications and subsequently for the disaggregated council sets of publications. Subsequently we examine impact according to subject fields, as well as collaboration and impact for both the DFF and council sets of publications, and we end the chapter with an advanced citation analysis in order to examine the share of potential 'breakthrough' articles in the DFF set of publications. Where appropriate, the performance of the DFF and council sets are compared to benchmark units, i.e., comparable sets of publications from the same time period for Denmark and the DNRF. Also, separate analyses are presented for the 2006 postdoc grant publications.

Table 4.6. Number of grant types distributed among councils with at least one CI-WoS journal publication matched.

	FKK	FNU	FSE	FSS	FTP	Total
Larger research projects	20	52	5	86	12	175
Ole Rømer-grants		3				3
Postdoc-grants	5	21	5	33	19	83
Research centre	1	6	1			8
Research projects	12	180	57	293	158	700
Skou-grants		26				26
Steno-grants		47				47
Total	38	335	68	412	189	1042

Table 4.6 above shows the number and different grant types going into the citation performance analyses. Compared to Table 3.2 (eligible grants for the overall output analyses), the attrition rate is some 21 percent, not surprisingly the largest attrition is among FKK and FSE grants,

an attrition rate of 67 and 47 percent respectively. Obviously, this is due to publication behaviour where we now focus on international journal publication.

Publication performance, especially output, for a unit of analysis obviously depends upon the number of researchers participating. However, it is very difficult to establish not only the number of researchers participating but also the actual research time equivalents they spend on the research evaluated. To compensate for this, monetary input is often used as a loose proxy for the size of research projects; thus depending on the fields' general publication behaviour, larger monetary inputs should, other things being equal, lead to larger outputs. So in order to provide some context for the present performance analyses, in the Appendix we have provided some basic statistics concerning grant size and the distribution of grants by research councils; below we will discuss performance in relation to grant types and grant sizes.

Coverage of CI-WoS publications in the DFF publication sets

It is important to examine the journal publication coverage in the CI-WoS citation database for the units of analysis going into the analyses. Obviously, coverage can be examined in various ways; for example, the publication profiles presented in the previous section gives one indication of what coverage we can expect in a journal citation databases. To determine the CI-WoS coverage, we use an indirect approach where we estimate the importance of journal publications indexed in the CI-WoS citation database for the units of analysis. We do this by determining, from the DFF and council sets of publications, the extent to which researchers cite other CI-WoS journal publications in their articles linked to the DFF grants. Hence, the internal CI-WoS coverage of a unit is defined as the proportion of the references in its oeuvre that points to publications (also) covered by CI-WoS. While not perfect, this approach to estimating coverage provides a good indication of a unit's reliance on CI-WoS journal publications versus non-CI-WoS publications such as books, book chapters and conference papers. The lower the internal CI-WoS coverage of a unit's output, the more careful one should be in the interpretation of indicators, or if the coverage is too low, the unit should simply be excluded. As a rule of thumb, CWTS considers coverage below 50 percent as poor CI-WoS coverage, meaning that impact analyses are based on a minority of a unit's publications, making them unreliable.

It is important to notice that we can estimate coverage at different levels, grants, subject fields, research councils and the DFF. Obviously, a particular grant can have low coverage for various reasons, but when aggregated to the council level, where different publication behaviours

are subsumed, the coverage can go up. And in the case of the DFF we can expect a relatively higher coverage rate due to the aggregation level. Finally, as mentioned in Chapter 3, the actual output of a unit is important when calculating indicators; hence we also examine the actual output for the individual grants before pooling them at aggregated levels of analysis.

Table 4.7 below shows the coverage of the two main levels of analysis, the overall DFF set of publications and the individual research councils. As expected, the coverage for DFF is "excellent" according to Moed's (2005) categorization; including the relatively few publications (some 6 percent of the total) from FKK and FSE, known to have poorer coverage, changes little. However, coverage varies considerably more at the council level.

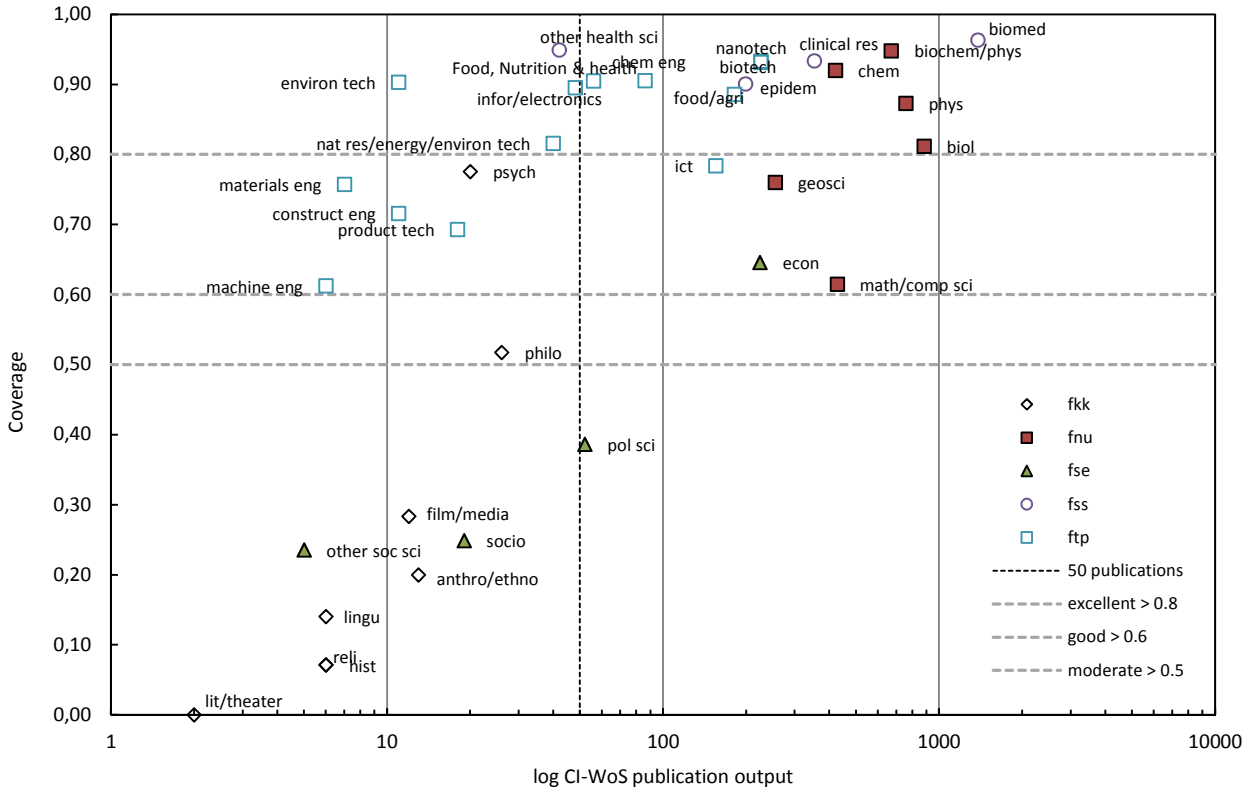
Table 4.7. Internal coverage for the matched DFF-publications from 2005-2012, postdoc publications included.

	No. of publications	Internal coverage
DFF all councils	6963	87%
DFF all councils except FKK	6871	88%
DFF all councils except FKK and FSE	6559	89%
FKK	100	43%
FNU	3454	85%
FSE	312	55%
FSS	2139	95%
FTP	1106	89%

FSS, FTP and FNU all have "excellent" coverage. Notice that FNU has the "lowest" coverage of the three; we speculate that the inclusion of computer science projects under FNU may be due to this? FSE has "moderate" coverage, 55 percent of the references given in the 305 articles are to other CI-WoS indexed journal articles. Finally, and not surprisingly, FKK have poor coverage with 43 percent. In fact, it is surprising that the percentage is "so high"; usually the humanities as a collective domain show an even poorer coverage. This relatively larger than expected coverage, should not immediately be interpreted as an indication of a more international oriented journal publication behaviour for the humanities in the DFF set. Rather it is probably more a function of the research areas that constitute the FKK in this analysis. We examine this below.

In Figure 4.3 below, publications have been coded with the subject classification originally assigned to their parent grants (like Figures 4.1 and 4.2 above). Subsequently, we have estimated the CI-WoS coverage for the different subject areas and plotted this as a function of output. Finally, different markers indicate the research councils to which the different subject areas are subsumed.

Figure 4.3. CI-WoS coverage for subject fields subsumed under the five research council as a function of journal publication output (log-scale).



The aim with this figure is not only to examine the variation of coverage within FKK and FSE, but also to examine the respective size of the subject fields constituting the individual councils, where size is matched CI-WoS journal publications. The latter is important as the robustness of indicators is dependent on the size of the analyzed unit; often a size of ≥ 50 full publication counts is given as a threshold for calculating robust indicators, yet this is merely a rule of thumb. As can be seen from Table 4.7, when using the five research councils as units of analysis, publication counts is well above 50 per unit. However, when disaggregating the individual council sets into subject areas based on the (uneven) classification codes for grants, then we can see that all subject areas covered by FNU are above 50, most of FSS are also above, some of FTP and a few of FSE are above, but no subject areas alone from FKK are above 50 publications per unit. While this to some extent is an effect of the classification codes and their varying degree of broadness, it is interesting to notice that "psychology" in fact has "good" coverage, close to "excellent" and that "philosophy" has "moderate" coverage.

These fields are known to have some preference for publication in international journals, indeed "psychology" is often characterized using C. P. Snow's notion of "Two Cultures", where

one of these is behavioural or social scientific and oriented towards journal publication. Together, the subject areas "psychology" and "philosophy" have 46 publications which corresponds 46 percent of the output for FKK. In that sense it may be somewhat interesting to examine the performance of FKK, given the visibility of these two areas, but on the other hand, the dispersion among the other fields subsumed under FKK with low coverage and few publications, raises the question to what extent indicators for FKK are valid. Below we examine and discuss some of these indicators.

While units of analyses are the sets of publications for DFF and the five research councils, it is also important to examine the underlying coverage pattern for the individual grants.

Figure 4.4. Matched grant output (publications) compared to the overall internal coverage of the grants.

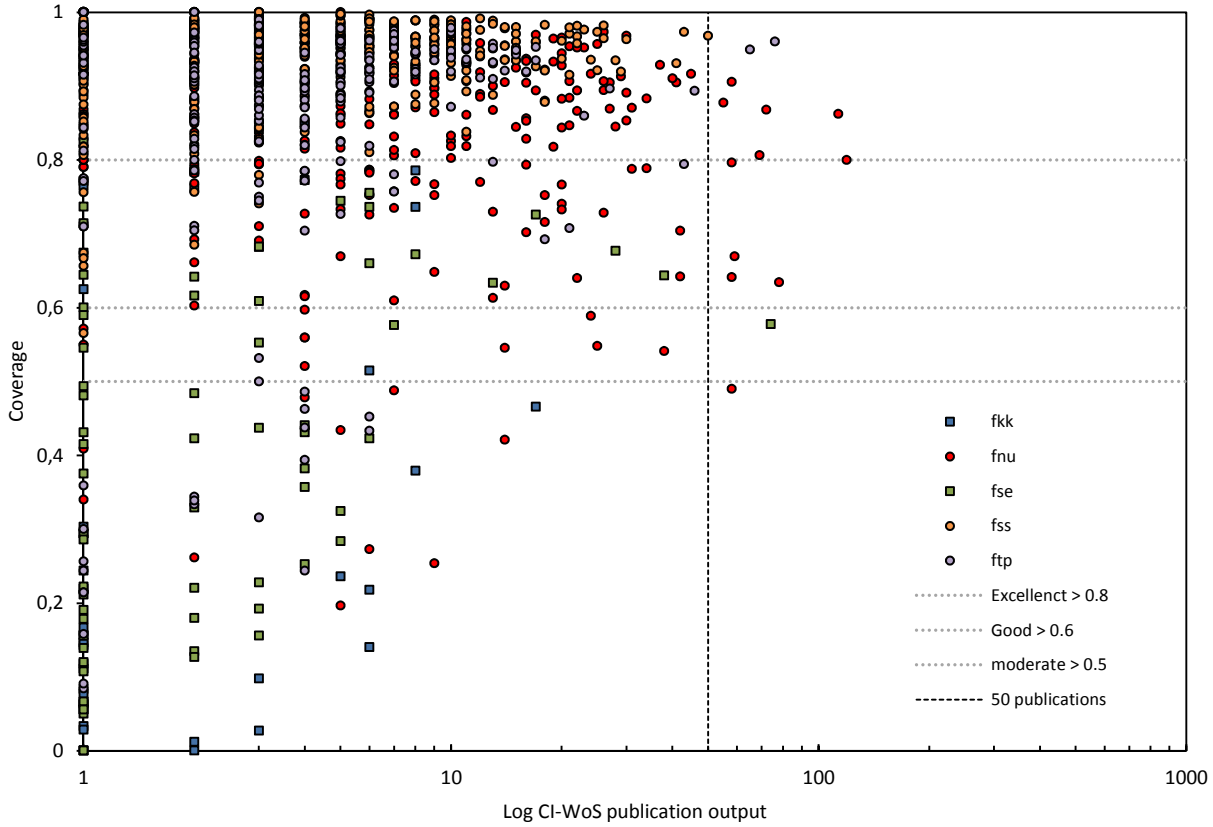
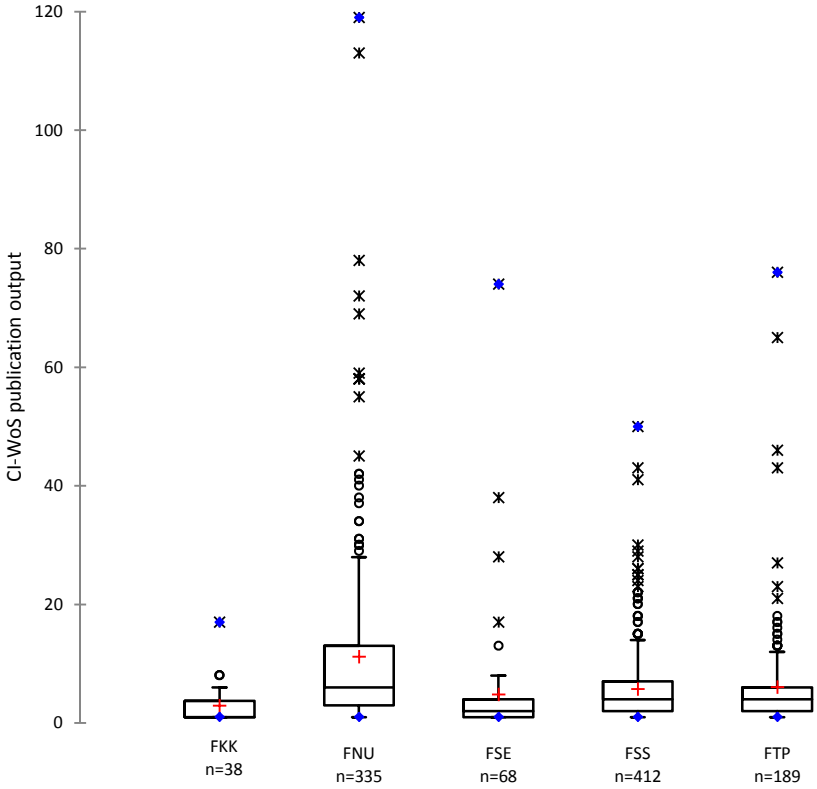


Figure 4.4 above shows this distribution. Again coverage is plotted as a function of output and the individual research councils are marked differently. It is evident that the majority of grants have coverage above 0.5 and it is also evident from Figure 4.4 that numerous grants are only represented by one journal publication. The majority of grants with only one publication seem to come from FKK and FSE, but the other councils also have grants with this minimum size. Finally, few grants have more than 50 publications, indeed the mean number of publications is 7.3 (sd: 10.7) and the

median is 4. Hence, we not only have the usually much skewed scientometric distributions we also generally have low publication counts for most grants. To substantiate the variation in the grants' publication output, Figure 4.5 shows a box plot where the distributions of grant output are shown for each of the five research councils. Notice, publication output is merely what is matched and cannot be taken as measure of the publication activity for the individual grants.

Figure 4.5. Distribution of total number of matched publications for the individual grants distributed among the five research councils.



The skewness is apparent for all distributions; all councils have grants represented with one publication and the maximum number is 17 for FKK, 119 for FNU, 74 for FSE, 50 for FSS and 76 for FTP. Means and medians are 2.9 (1) for FKK, 11.5 (6) for FNU, 4.8 (2) for FSE, 5.7 (4) for FSS and 8.9 (4) for FTP.

Overall, this makes it clear that impact analyses would be defective if they were carried out on the grant level and we refrain from doing this in the present report. Consequently, the DFF set of publications have "excellent" coverage and excluding publications linked to FSE and FKK will not change much due to the small numbers involved. As expected, FNU, FSS and FTP also have "excellent" coverage and these councils are suitable for impact analyses. FSE have moderate

coverage and can be included, though we should examine the robustness of the calculated indicators and be careful when interpreting the results. Coverage for FKK is poor and as such the council should be excluded. However, when disaggregating the council's grants into subject categories, publication patterns emerge that gives some inclination to examine performance for the FKK set of publications, albeit with extreme caution; we will do that for some impact analyses presented in the following subsections. First we present performance indicators for the DFF set of publications and subsequently we present indicators for the council sets of publications.

Overall impact results for the DFF-publication set

In this subsection we present performance indicators for the overall set of DFF CI-WoS journal publications. We present indicators with and without the small subset of publications from postdoc grants funded in 2006 and we also present indictors for this restricted postdoc set of publications. We also present indicators with and without FKK and FSE publications. The basic citation window is three years except for articles published in 2011 and 2012. We experiment with two publication windows, one for the whole period 2005 to 2012 and a more restricted one from 2005 to 2010. We do that to examine the effects of the shorter citation windows in the former set for articles published in 2011 and 2012. We do not provide time series data due to the relatively short period under investigation and keeping publications in larger blocks ensures greater robustness of indicators. The individual indicators are presented and discussed in Chapter 3, but it is important to emphasise that relying on one indicator is highly problematic. Performance should always be established based on a number of indicators in order to contextualize results. Nevertheless, the proportion of highly cited articles is by many considered to be the most important bibliometric performance indicator at the moment for two reasons: a statistical reason, since percentile indicators are more robust than average-based indicators, and a conceptual reason, focusing on the ability of a unit to produce the most highly cited articles in the much skewed citation distributions is more telling in relation to performance than "mere" average citation rates which are vulnerable to outliers; often the PPtop10% indicator is linked to a unit's ability to produce "excellent research". Subsequently, after presenting the overall indicators for the DFF set of publications, we examine them in relation to two benchmark units. Remember that the reference value for MNCS indicator is one, i.e., the average citation activity in the database and 10 percent for PPtop10%, i.e., the expected proportion of a unit's articles at or above the 90th percentile of the database's normalized citation distribution.

The subsection ends with a table where we present indicators calculated for the various different grant types included in this report.

Table 4.8 presents indicators for the DFF set of publications excluding publications from the 2006 postdoc grants; Table 4.9 presents the indicators for the restricted postdoc set of publications; and finally Table 4.10 presents the indicators for the whole DFF set of publications including the postdoc publications. We will discuss Table 4.8 and 4.9 more closely and then only address the potential differences appearing in Table 4.10 when the postdoc publications are included. As noticed above, we present indicators for two publication window blocks and for three different (sub)sets of the DFF set of publications: A subset containing only FNU, FSS and FTP publications; a subset including these councils plus FSE publications; and finally the whole set of DFF publication including all councils.

From Table 4.8 we can see that the difference between the two publication window blocks is roughly some 1500 publications.

Table 4.8. Bibliometric indicators for the DFF set of publications: All grants *except* postdoc-grants from 2006.

Council pubs included	FNU, FSS and FTP	FNU, FSS and FTP	FNU, FSS, FTP and FSE	FNU, FSS, FTP and FSE	All councils	All councils
Pub-window:	2005-2012	2005-2010	2005-2012	2005-2010	2005-2012	2005-2010
P	6291	4706	6596	4917	6679	4961
Coverage	89%	89%	87%	88%	87%	87%
TCS	53818	43362	54647	43909	54827	44005
MCS	8.55	9.21	8.28	8.93	8.21	8.87
TNCS	11202.9	8559.8	11709.3	8874.1	11812.2	8932.1
MNCS	1.78	1.82	1.78	1.80	1.77	1.80
Ptop10%	1193.2	905.2	1247.2	939.6	1258.0	946.1
PPtop10%	19.0%	19.2%	18.9%	19.1%	18.8%	19.1%
NPPtop10%	1.90	1.92	1.89	1.91	1.88	1.91
Pnc	13.8%	13.0%	14.5%	13.7%	14.8%	13.9%
Scit	27.7%	26.4%	27.5%	26.3%	27.5%	26.2%
MNJS	1.48	1.51	1.48	1.50	1.47	1.50

Overall coverage is excellent; it drops one to two percentage points when FSE and FKK are included, but remains overall “excellent”. The self-citation rate (Scit) is somewhere between 26 to 28 percent which is expected. Overall self-citation rates for units of this size is somewhere between 25 to 28 percent. More remarkable is the proportion of non-cited publications (Pnc). The proportion is somewhat lower, perhaps two to three percentage points, than expected for units of the same size, as well as publication and citation windows. Self-citation rates are slightly higher in the

2005-2012 set of publications. This is no doubt due to the fact that there is an overrepresentation of self-citations to articles in the period immediately after the publication. This number stabilizes after a few years.

Likewise, the proportion of non-cited publications is also generally highest for the 2005-2012 sets of publications. This is an effect of the shorter citation windows for the 2011 and 2012 articles, which essentially gives them a shorter exposure time to receive citations. As a consequence, relative indicators calculated for the 2005-2010 sets of publications will, everything else equal, be somewhat larger than the 2005-2012 sets of publications. The MNJS indicator measures the average citation impact of the journals in which a set of publications has appeared, where the citation impact has been normalized for the fields to which the journals belong. An MNJS above one means that on average the journals have been cited more frequently than would be expected based on their fields. The stable MNJS indicators around 1.47 to 1.51 can be considered high; in other words, the sets of DFF publications are on average published in journals with relatively high impact in their respective fields. Finally, the main indicators for the overall performance of the articles in a set are PPtop10% and MNCS; i.e., the proportion of relatively highly cited publications in the sets where the expected proportion is 10 percent; and the mean normalized citation scores for the sets. Undoubtedly, the DFF sets of publications perform at a very high level both when it comes to the proportion of highly cited publications (PPtop10%) and the mean normalized citation scores. The performance is roughly 90 percent higher than expected for PPtop10% and 80 percent for MNCS. Compared to other units of this size and composition, the performance is considerably above the international level. The indicators are very stable across the different sets and publication window blocks. As stated above, the indicators for the 2005-2010 sets are slightly higher, which is an effect of the equal sized citation windows.

Table 4.9 presents the same set of indicators calculated for the restricted set of publications linked to the 2006 postdoc grants[10]. We should emphasize that going from 5-6000 publications to 280 means that the indicators for the latter set of publications are clearly less robust. Nevertheless, coverage is slightly higher for the postdoc set compared to the DFF set above. Self-citation rates are considerably lower and so is the proportion of non-cited publications. It is difficult to assess the factors influencing these rates, but albeit to some extent they are less robust, the set of postdoc grants funded in 2006 performs remarkably well, not only above the overall set of DFF-publications, but well above. The articles are published on average in journals with very high

[10] Notice, as indicated in the introduction, it is the Ministry's wish to specifically examine the set of publications; postdoc grants from 2005, 2007 and 2008 are not included in this report.

impact, and the actual impact of the articles is between 160 to 180 percent above the expected reference value for PPtop10% and 127 to 145 percent above the expected average database citation rate for MNCS. Noticeably, as with the DFF set examined in Table 4.8 above, the postdoc set of publications also succeeds in producing a considerable number of the highest cited publications in the database given the time period and citation windows.

Table 4.9. Bibliometric indicators for the DFF set of publications: Postdoc-grants from 2006.

Council pubs included	FNU, FSS and FTP	FNU, FSS and FTP	FNU, FSS, FTP and FSE	FNU, FSS, FTP and FSE	All councils	All councils
Pub-window:	2005-2012	2005-2010	2005-2012	2005-2010	2005-2012	2005-2010
P	268	226	275	232	284	239
Coverage	93%	93%	92%	92%	91%	90%
TCS	3923	3639	3955	3670	3982	3682
MCS	14.64	16.10	14.38	15.82	14.02	15.41
TNCS	622.5	553.3	639.1	569.1	643.4	571.2
MNCS	2.32	2.45	2.32	2.45	2.27	2.39
Ptop10%	72.3	63.5	74.4	65.6	74.4	65.6
PPtop10%	27.0%	28.1%	27.1%	28.3%	26.2%	27.5%
NPPtop10%	2.70	2.81	2.71	2.71	2.62	2.75
Pnc	8.2%	6.2%	8.0%	6.0%	8.8%	7.1%
Scit	18.5%	18.2%	18.4%	18.1%	18.4%	18.1%
MNJS	1.87	1.92	1.87	1.93	1.85	1.90

So far the performance of the two sets of DFF publications show very high performance and a strong ability to produce “excellent” research articles, in so far as the 10 percent most cited articles in the database can be considered as such. Obviously when combining the two publication sets, given that the postdoc set is much smaller, if something, we would expect some small positive changes in the relative indicators in the overall DFF set of publications. Indeed this is also what is discernible from Table 4.10 below. The postdoc set of publications constitute some 4 percent of the total DFF output, yet the slight increase in publications when merging the two sets leads to a general increase in the main performance indicators of some 0.2 or 0.3 percentage points.

Whether we exclude FKK and FSE or not is not an issue as the indicators are so stable, therefore we only focus on the combined set of all DFF publications in the benchmark comparisons below. We do however also briefly examine the postdoc set.

Table 4.10. Bibliometric indicators for the DFF set of publications: All grants combined.

Council pubs included	FNU, FSS and FTP	FNU, FSS and FTP	FNU, FSS, FTP and FSE	FNU, FSS, FTP and FSE	All councils	All councils
Pub-window:	2005-2012	2005-2010	2005-2012	2005-2010	2005-2012	2005-2010
P	6559	4932	6871	5149	6963	5200
Coverage	89%	89%	88%	88%	87%	87%
TCS	57741	47001	58602	47579	58809	47687
MCS	8.80	9.53	8.53	9.24	8.45	9.17
TNCS	11825.3	9113.1	12348.4	9443.3	12455.7	9503.3
MNCS	1.80	1.85	1.80	1.83	1.79	1.83
Ptop10%	1265.5	968.7	1321.7	1005.3	1332.5	1011.7
PPtop10%	19.3%	19.6%	19.2%	19.5%	19.1%	19.5%
NPPtop10%	1.93	1.96	1.92	1.95	1.91	1.95
Pnc	13.6%	12.7%	14.3%	13.4%	14.6%	13.6%
Scit	27.1%	25.8%	27.0%	25.7%	27.0%	25.7%
MNJS	1.50	1.53	1.49	1.52	1.49	1.52

In scientometric studies we usually compare like with like such as research institution with other research institutions or countries with countries. If possible, units of correspondingly similar size should be compared as it is generally so that with larger units, be it institutions, indicator values will tend to move closer towards the reference value, a sort of "regression towards the mean" (noticeable exceptions are very high performing large-sized units such as Harvard University in the USA). As stated in the introduction and emphasised above, it is difficult to find or construct benchmark units suitable for comparison with a unit of analysis like the DFF which is a funding institution. In the present report we credit publications which are supposedly the direct, indirect or partial result of a grant to the funder of the grant namely DFF. Obviously, publications as discrete units primarily "belong" to authors and institutions, funders, and there are often several of them, are given an acknowledgement, but otherwise not credited. Nevertheless, we use the funding institution as our unit of analysis and link publications to it. An ideal benchmark unit would obviously be a very similar funding institution but such do probably not exist.

In a recent report we evaluated the bibliometric performance for another Danish funding institution the Danish National Research Foundation (DNRF). In that analysis we had similar problems identifying suitable benchmark units. At that time we did not have the resources to construct more suitable benchmark units so we ended up comparing the DNRF performance with high performing international research institutions as well as the performance of Denmark. The

former is questionable as the units of analysis are clearly different in aim, purpose and size. The latter is also not without problems especially when it comes to difference in size and coverage, but at least the DNRF set of publications could be seen as a subset of the national output. As we now have a set of articles which are credited to another Danish funding institution, it seems more appropriate to compare the DFF set of publications with this DNRF set of publications. But such a comparison is also not ideal because, while both units are funding institutions, and of approximately similar size when it comes to publications from 2005 to 2010, the two have quite different objectives, modes and funding instruments. Briefly, the DNRF is set up to fund Danish Centres of Excellence (CoE). Approximately 100 CoEs have been funded since 1993, the selection process is hard, rejection rates high, but the eventual funding of the CoEs is very large and long-termed - up to 10 years - compared to other funding instruments. The DFF on the other hand has several different funding instruments (as documented above). Compared to the DNRF, a much higher number of projects are funded by DFF with lower amounts and typically for shorter periods and in principle funded projects are of a different nature than those designated for a CoE. In fact, as we will explore in Chapter 9, several DFF grants form parts of CoEs. So in that respect, even though we have two sets of publications we can link to two Danish funding institutions, the comparison has intrinsic weaknesses. Up front, we can expect the DNRF set of publications to perform above the DFF set, simply because in principle the conditions given to CoEs, and the cumulative effects this creates, generally favours conditions that may yield high performance. With these caveats in mind, we still think it can be informative to compare the two different funding institutions remembering that they play different roles in the Danish research funding ecology. Similar to the previous examination of the DNRF, we examine what happens to the main performance indicators when we exclude the DFF set, the DNRF set or both sets from the overall set of Danish publications from the period 2005 to 2010. We also compare performance of the two funding sets. We expect the DNRF set to perform above the DFF set and that both sets perform above the national set, the question is to what extent?

Finally, in the next chapter we compare the performance between PIs and rejected applicants. Given the data available, as well as the premises and resources for the present analysis, this is as close as we can get to measuring potential performance benefits from being funded. As such, the analysis presented in the next chapter can also be seen as a comparison of DFF with some benchmark unit, in this case rejected applicants, i.e., researchers not funded by DFF from 2003 to 2008.

Table 4.11 presents the indicator comparisons between the DFF and DNRF sets of publications the Danish sets of publications for the same period, as well as comparisons between the DFF and DNRF sets of publications. The publication window is 2005 to 2010. We use this window for two reasons: 1) the specially constructed set of publications linked to the DNRF only includes publications to 2010, and 2) restricting to 2010 means that we can have full three year citation windows for all publications.

Table 4.11. Indicator comparison of the DFF set of publications to benchmark units: Denmark with and without the DFF set of publications and the specially constructed DNRF set of publications.

Publication sets	P	MNCS	PPtop10%	Pnc	MNJS
Denmark (2005-2010)	63687	1.45	15.4%	20.4%	1.23
Denmark **excluding** the **DFF** set of publications (2005-2010)	58726	1.42	15.1%	20.9%	1.21
Denmark **excluding** 4961 randomly chosen articles in 1000 resamples*	63687	1.45 (1.439-1.452)	15.4% (0.153-0.154		
Denmark **excluding** the **DNRF** set of publications (2005-2010)	58543	1.41	14.8%	21.2%	1.20
Denmark **excluding** the **DFF** and **DNRF** set of publications (2005-2010)	54403	1.39	14.6%	21.7%	1.18
DFF set of publications (2005-2010)	4961	1.80	19.1%	13.9%	1.50
DNRF set of publications (2005-2010)	5144	1.88	21.6%	11.3%	1.58
DNRF set of publications **excluding** the **DFF** set of publications (2005-2010)	4385	1.79	20.2%	12.1%	1.54
DFF set of publications **excluding** the **DNRF** set of publications (2005-2010)	4140	1.68	17.5%	14.6%	1.44
The combined set of DFF and DNRF publications (2005-2010)	759	2.41	29.4%	6.9%	1.81

*Simple upper and lower bound percentile intervals in brackets.

The set "Denmark (2005-2010)" is marked in grey as this is the main reference set for the first comparisons. Overall, the performance of Danish publications is considered to be very high compared to other countries. For more than a decade Denmark has been among the five highest performing countries in the world measured by PPtop10% and MNCS[11]. Clearly, from Table 4.11 we can see a drop in indicator values for Denmark when we exclude the DFF, DNRF and the combined DFF and DNRF sets of publications from the overall Danish set. The DFF set forms 7.8 percent of the Danish set, however it contributes with 9.7 percent of the total normalized citations

[11] http://www.nordforsk.org/en/publications/bibliometric-research-performance-indicators-for-the-nordic-countries.

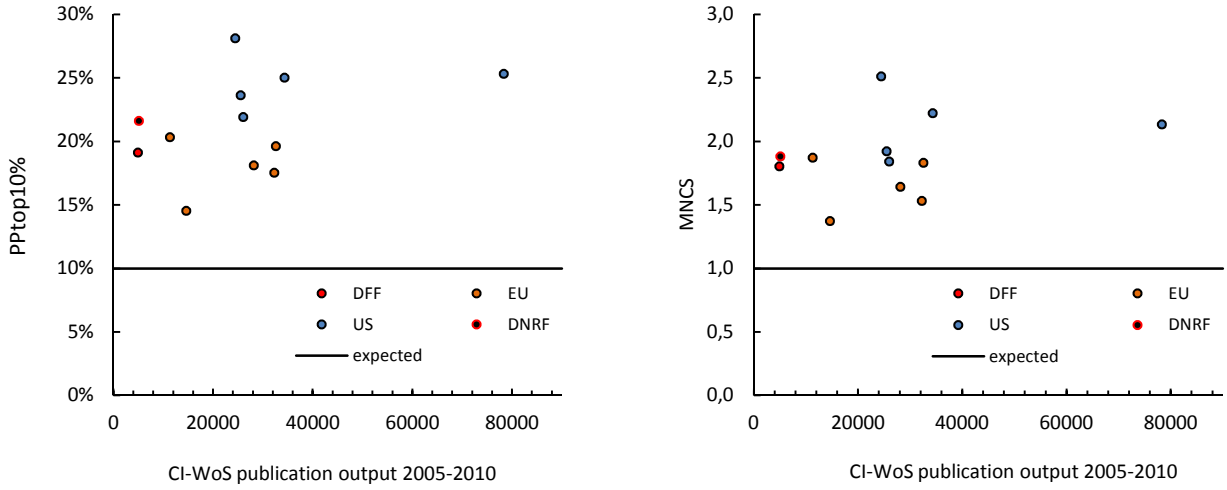
(TNCS) (a ratio of 1.25) and likewise 9.7 percent of the highly cited articles (Ptop10%) (a ratio of 1.24). Hence, as a unit the DFF set of publications provide a positive surplus in citations and highly cited articles compared to the size of their input (articles); e.g., the publication/citation ratio is that for every DFF publication there is a net gain of 1.25 normalized citations. If we look at the relative performance indicators there are drops of 0.3 percentage points in the MNCS and PPtop10%. The MNJS drops 0.2 percentage points and the Pnc goes up with 0.5 percentage points. Is this a marked drop in performance? For what it is worth, several statistical tests for the difference between including and excluding the set of DFF publications are statistical significant but judging the standardized effect sizes according to Cohen's (1988) often (ab)used thresholds suggest marginal effects. However, we do not find statistical significance tests meaningful or useful in such situations where sample sizes most likely guarantee statistical significant findings, and more problematic, where the sample at hand is not a probability sample as in this case (see Schneider, 2013; 2014). It is difficult to see what random sampling error we are addressing. Statistical significance does not address the importance of findings and effect sizes must be judged in context as small effects can also be important. We claim that the present findings are important. Removing the set of DFF publications generally reduces the national Danish performance because generally DFF publications are cited more and there are more of them among the highest cited in the database. To validate this we have randomly excluded a set of articles from the total set of Danish publications from 2005-2010 corresponding in size to the DFF set and done this for 1000 iterations and calculated PPtop10% and MNCS indicators. As shown in Table 4.11, the results are clear and very stable; we see the same overall indicators as for Denmark meaning that removing a random set of articles of similar size to the DFF set does not make a difference for overall Danish impact whereas removing the DFF set does.

Turning to the DNRF set, it forms 8.1 percent of the Danish set but contributes with 10.5 percent of the normalized citations (TNCS) (a ratio of 1.30) and 11.3 percent of the highly cited articles (Ptop10%) (a ratio of 1.40). As expected, the effect of excluding the DNRF set from the overall Danish set is slightly larger compared to the effects of excluding the DFF set. The MNCS drops 0.4 points, the MNJS drops 0.3 points, the Pnc goes up 0.8 percentage points, but most interestingly, the PPtop10% drops 0.6 points which is twice as much as the DFF effect for highly cited articles. Consequently, DNRF publications accrue slightly more normalized citations and more of them end up as highly cited compared to the DFF set. Bypassing the effects of removing both sets for the time being, the differences in performance between DFF and DNRF are expressed

in the middle of the table. What is important to emphasise here is not that the DNRF set performs above the DFF set, this was expected; instead what is the important point is that fact that the DFF set performs at a very high level too. Hence, Denmark performs at high level compared to other countries; 14.6 percent of the Danish publications are funded by DFF and/or DNRF. These publications accrue 18.1 percent of the total normalized citations (TNCS) (a ratio of 1.24) and even more of the highly cited articles (Ptop10%) (a ratio 1.28). What seems to be the major differences between the DFF and DNRF sets? From the last part of Table 4.14 we can see that it seems to be the publication profile, where a larger number of publications in the DNRF set are published in the highest impact journals in the respective fields, and the "ability" to produce even more highly cited articles. The larger MNCS indicator should be seen as an effect of having more highly cited articles. The latter results are somewhat expected given the presumable advantages under which the DNRF publications in principle have come about. Leaving the performance of DNRF aside, the DFF set can be considered as high performing as well. Finally, and very interesting, 759 of the publications credited to the DFF set is also credited to the DNRF, we thus have an overlap between the two sets of 15 percent.

As we have discussed above, we generally think that performance comparisons between funding units is somewhat arbitrary and questionable between funding institutions and research institutions. Basically we have different units with different purposes and often widely different sizes measured in publications. Nevertheless, in the previous evaluation of the Danish National Research Foundation a number of high performing international research institutions were included as benchmark units, e.g., American universities such as Harvard, Stanford, Yale, UC San Francisco, MIT and European universities such as Cambridge, University College and Imperial College in London, Leeds and École Polytechnique Fédérale De Lausanne. As we discussed in the previous report, such comparisons are certainly not without its problems, but in the absence of something better and in order to contextualize the overall high impact findings for the DFF a brief comparison to these benchmark units can be informative even though these units were chosen for another evaluation. Figure 4.6 below contextualizes the performance of the overall set of DFF publications from 2005 to 2010 by plotting it together with the DNRF set and the five American and five European research institutions chosen for the DNRF evaluation.

Figure 4.6. Contextualizing the performance of the overall set of DFF publications by comparison to American and European research institutions used in the DNRF evaluation.



The DFF set of publications is clearly the smallest unit if Figure 4.6. However, it is also clear that when it comes to the proportion of highly cited articles (PPtop10%) and mean citation scores (MNCS), then the performance of the DFF set is comparable to some of the highest performing European universities and a couple of the American ones. As outlined above, the largest gap between DFF and DNRF is when it comes to the proportion of highly cited articles, but both are high performing units. Essentially, we are comparing apples and oranges in Figure 4.6, but to a certain extent it testifies to the high impact level of the DFF set of publications.

Finally, it is not appropriate to compare the restricted set of publications linked to the postdoc grants to the total set of DNRF publications, the differences are simply too large. However, it is somewhat possible to compare the performance of the postdoc set to the individual performance of the CoEs included in the DNRF analysis. Figure 6.6 on page 60 in the report[12] shows the individual performances (MNCS and PPtop10%) as a function of publication output for the CoEs included in the analysis. The postdoc set constitutes 239 publications for 2005-2010 with performances of 2.39 for MNCS and 28 percent for PPtop10%. Comparing this to Figure 6.6 in the DNRF report clearly indicates that the postdoc set has comparable performance to the CoEs in the top quartiles. Likewise, 15 percent of the publications linked to the postdoc set are also linked to the DNRF set. Removing these reduces the postdoc set to 203 publications, the MNCS to 1.95 and PPtop10% to 23 percent; still very high performances also in comparison to the individual CoEs in Figure 6.6.

[12] http://dg.dk/filer/Publikationer/Evaluering2013/Appendiks%205_bibliometrisk_report_03122013.pdf.

We can conclude that the DFF sets of publications generally show high bibliometric performance levels, far above the international reference values of one for MNCS and 10 percent for PPtop10% meaning that publications linked to a DFF grant on average have much high citation rates than expected, and a considerably larger number of articles than expected end up being highly cited after three years. We end this section by examining the bibliometric performance according to the different grant types that eventually form the overall DFF set. Similar to the principle differences between DFF and DNRF as funding institutions, so are there within differences between the DFF grant types which eventually could lead to potential performance advantages for some and in that respect the size of grants may be a proxy of such cumulative advantages?

Table 4.12 below outlines the same basic set of indicators as the previous tables but here we disaggregate the indicators to the level of grant types (see Table 11.1 and Figure 11.1 in the Appendix for further information on grant types; here it is noticeable that the grant size distributions are skewed). Some interesting but perhaps evident patterns emerge. On average "research centres" receive the largest funding. Indeed to some degree they can be compared to CoEs, with a longer duration and more researchers involved. In this analysis "research centres" perform at a very high level only surpassed by the performance of the "Ole Rømer grants"[13]. Interestingly, the proportion of non-cited (Pnc) articles is 29.8 percent which is the largest proportion among the grants. The reason for this is that one of the eight "research centres" are funded by FKK and have a very low output with extremely low citation rates. Removing this particular grant lowers Pnc to 21 percent.

Another clear pattern is the "postdoc grants", on average they receive the lowest amounts indicating the scale of the projects, few involved and short duration and this is visible in the relatively low average output per grant. But again, the performance of the articles is very high indeed (notice, among the other grant types there may be embedded postdoc positions). Clearly the most frequent grant type is "research projects". Next after the postdoc grant types, "research projects" on average receive the lowest amount of funding (i.e., the median is in fact slightly below the postdoc grants at 1.2 million Danish kroner). Interestingly, while still performing in the higher end, together with the "Skou-grants", "research projects" have the "lowest" impact of the grant types considered. Also, interesting, the journal publication behaviour as expressed by the MNJS is clearly below the other grant types.

[13] We have included the three "Ole Rømer" grants despite that there only is three of them because they have an extraordinary high impact which is also robust.

Table 4.12. Bibliometric indicators calculated for grant types; all matched WoS publications are included for all five councils, and publication window is 2005 to 2012.

	Larger research projects	Ole Rømer-grants	Postdoc-grants	Research centres	Research projects	Skou-grants	Steno-grants
No. of grants	175	3	83	8	700	26	47
Mean grant size (rounded)	2,851 mill	5,853 mill	1,426 mill	6,767 mill	1,665 mill	2,421 mill	2,522 mill
P	1725	33	300	234	4763	262	315
P/no. grants	9.8	11	3.6	29.2	6.8	10.1	6.7
Coverage	87%	89%	91%	79%	87%	89%	90%
TCS	17700	2475	4144	2075	34995	2098	2498
MCS	10.3	75.0	13.8	8.9	7.3	8.0	7.9
TNCS	3411.2	396.0	667.7	591.3	7752.6	418.1	563.4
MNCS	1.98	12.00	2.23	2.53	1.63	1.60	1.79
Ptop10%	378.0	20.5	76.4	67.5	817.8	52.0	70.5
PPtop10%	21.9%	62.2%	25.5%	28.8%	17.2%	19.8%	22.9%
NPPtop10%	2.19	6.22	2.55	2.88	1.72	1.98	2.24
Pnc	10.8%	6.1%	9.0%	21.4%	15.8%	13.0%	11.4%
Scit	25.6%	11.0%	18.7%	29.8%	28.8%	27.1%	29.0%
MNJS	1.54	5.08	1.82	2.16	1.42	1.55	1.48

Finally, the three “Ole Rømer grants” given to “excellent younger researchers” receive on average the second largest funding amount, but their performance level is no less than outstanding. In fact, 75 percent of the publications come from one grant and this grant’s performance alone is even higher than the MNCS and PPtop10% scores indicated in Table 4.16, i.e., 12 and 62.2 percent respectively. The performance is comparable to best performing CoEs in the DNRF report. In fact, below in the subsection on identification of potential ‘breakthrough’ research papers we examine this one particular grant further as it turns out that no less than three of its 25 included articles can be considered as potential ‘breakthrough’ articles; truly remarkable as very few articles candidate as such ‘breakthroughs’. We do acknowledge that it is somewhat inappropriate to discuss the results of three grants given to individuals and then considering them to be representative for a specific but rare grant type. Nevertheless, we think the outstanding performance should be noticeable and discussed. This analysis demonstrates that in some crude way grant sizes are a proxy of research capacity and output, but performance is in generally high over the whole spectre, though the most lavishly funded seem to perform at a slightly higher level (perhaps the reason why they were funded in the first place?). Funding and other potential benefits for the latter groups are undoubtedly enhanced by the well-known phenomenon of preferential attachment, also popularly known as the

'Matthew effect', i.e., successful funding often leads to another essentially resulting in cumulative effects. In Chapter 6, the surveys and interviews indicate that grantees in general are very successful in getting other grants and funding, in a sense "money breeds money".

Overall impact results for publication sets at the disaggregated level of councils

In this subsection we examine the performance indicators at the disaggregate level of research councils. We do not report individual indicators for the postdoc set of publications distributed among research councils as publication numbers become too small and indicators essentially unreliable. Instead we present two tables with indicators, Table 4.13 where all publications except the postdoc publications are included and Table 4.14 where all publications are included.

In this disaggregate performance analysis we do not use the DNRF set of publications as a benchmark unit. We only use a specifically constructed Danish set of publications with and without the specific council sets of publications. The specifically constructed Danish publication sets are subsets of publications coming from the same CI-WoS subject categories where the different research councils have published from 2005 to 2012. In this way we can construct a benchmark unit that is comparable to the overall publication activity for the specific councils in a given time period.

Table 4.13. Bibliometric indicators for publication sets at the council level from 2005-2012: All grants *except* postdoc-grants from 2006.

	FKK	FNU	FSE	FSS	FTP
P	91	3413	305	1971	1047
Coverage	42%	85%	55%	95%	89%
TCS	233	26632	829	21754	7675
MCS	2.56	7.80	2.72	11.04	7.33
TNCS	132.9	6098.3	506.4	3639.6	1821.3
MNCS	1.46	1.79	1.66	1.85	1.74
Ptop10%	12.8	648.1	54.0	374.0	201.1
PPtop10%	14.1%	19.0%	17.7%	19.0%	19.2%
NPPtop10%	1.41	1.90	1.77	1.90	1.92
Pnc	36.3%	16.8%	28.5%	7.3%	16.3%
Scit	22.8%	32.2%	17.2%	20.5%	26.4%
MNJS	1.09	1.48	1.42	1.51	1.49

Table 4.13 provides the indicators for the council sets without the postdoc publications. It is apparent that the size of the councils measured in number of publications varies substantially and as already indicated above, coverage is "poor" for FKK and "moderate" for FSE. We should therefore

be careful when we interpret indicators especially for FKK. Here international journal publication is clearly not a primary publication activity and the relatively low publication numbers and skewed distribution results in indicators which are not robust (see Figure 4.6 below for an example of robustness).

While not particularly useful for performance comparisons, as discussed in Chapter 3, the mean citation score (MCS) is useful as an indication of a field's citation density. It is clear that fields subsumed under FKK and FSE have relatively low citation densities compared to FNU, FSS and FTP (i.e., this roughly means that one citation in say sociology corresponds to four citations in a clinical field). When we combine field information on the MCS with information on the proportion of articles not cited after three years (Pnc) then we get further knowledge on publication behaviour. While in general citation density is lower in the humanities and social sciences and more articles receive few or no citations, having a longer citation window would undoubtedly reduce the Pnc for FKK and FSE simply because the lag between publishing and receiving citations is longer in these fields due to lower publication activity.

All councils (also FKK despite the lack of robustness) perform well above the database reference values and performance can be considered high for all councils.

Table 4.14. Bibliometric indicators for publication sets at the council level from 2005 to 2012: All grants *including* postdoc-grants from 2006.

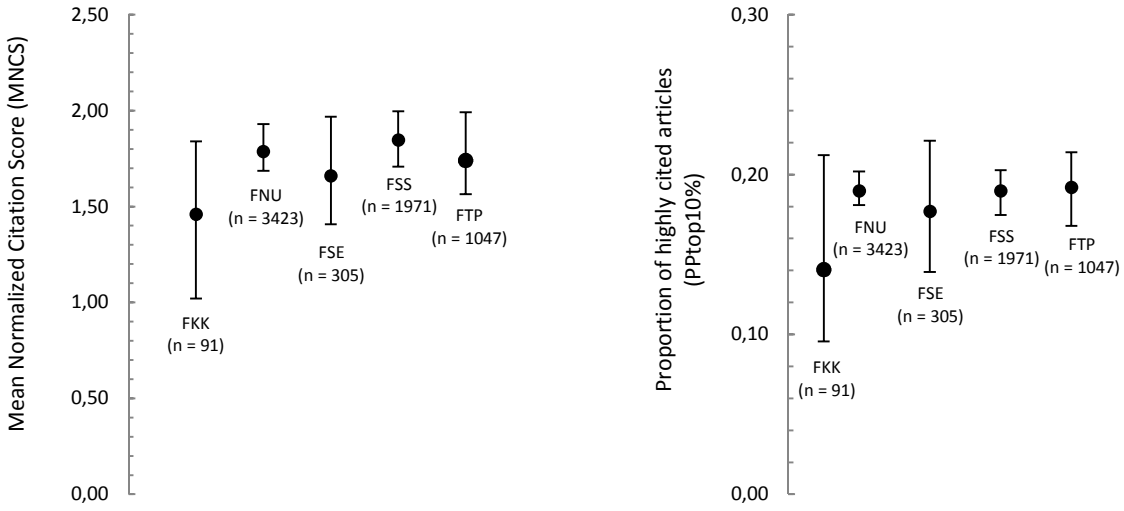
	FKK	FNU	FSE	FSS	FTP
P	100	3454	312	2139	1106
Coverage	43%	85%	55%	95%	89%
TCS	260	27015	861	24967	8002
MCS	2.60	7.82	2.76	11.67	7.24
TNCS	137.2	6175.1	523.0	4093.0	1913.6
MNCS	1.37	1.79	1.68	1.91	1.73
Ptop10%	12.8	657.3	56.1	427.4	210.8
PPtop10%	12.8%	19.0%	18.0%	20.0%	19.1%
NPPtop10%	1.28	1.90	1.80	2.00	1.91
Pnc	36.0%	16.8%	27.9%	7.1%	16.3%
Scit	22.2%	32.1%	17.0%	20.0%	26.5%
MNJS	1.08	1.47	1.44	1.56	1.50

The influence of the publications linked to the 2006 postdoc grants can be deduced by comparing Table 4.13 to 4.14 below. Overall, the postdoc set distributed among councils does not change the indicators in any significant way, perhaps with the exception of MNCS for FKK which

goes from 1.85 to 1.91 when the postdocs are included. FSS is also the council with most postdoc publications in the present analysis.

Before we compare the performance of the individual councils to the specifically constructed benchmark units we will address the issue of robustness of the indicators further. In Figure 4.7 below we demonstrate the challenges of calculating robust indicators on skewed distributions.

Figure 4.7. Robustness of performance indicators: Bootstrapped 95% stability intervals.



As we have stressed several times, publication and citation statistics are based on highly skewed distributions. Essentially this means that outliers play a crucial role. Outliers in the top quartile of the distributions are extremely interesting but they also influence the central tendencies calculated for such distributions, especially when sample sizes (i.e., publication numbers) are relatively low. In fact, citation distributions are often so skewed that the Central Limit Theorem does not work properly. The basic rule of thumb in scientometrics is to use units of analysis with a "solid" number of publications linked to it, the more the better. In this way, to a certain extent, we can make the indicators less reliable upon a few outliers and we can therefore enhance the robustness of the indicators we calculate. Obviously, average-based indicators such as MNCS are more vulnerable than percentile-based indicators such as PPtop10%, but small publication numbers also makes relative percentile indicators such as the PPtop10% less robust (i.e., a denominator ensures more robustness).

As an example, Figure 4.7 shows the indicators for the individual research councils based on Table 4.14. Surrounding the indicators are so-called asymmetric stability intervals. A stability interval indicates a range of values of an indicator that are likely to be observed when the underlying set of publications changes. For instance, the MNCS indicator may be equal to 1.50 for a particular unit, with a stability interval from 1.40 to 1.65. This means that the *true* value of the MNCS indicator equals 1.50 for this unit, but that changes in the set of publications of the unit analysed may relatively easily lead to MNCS values in the range from 1.40 to 1.65. The Leiden Ranking employs 95% stability intervals constructed using bootstrapping methods (Waltman et al., 2012; Schneider & van Leeuwen, forthcoming). Notice, stability intervals are not confidence intervals and cannot be interpreted as such; we have a true value for the indicator; what we then do is to resample the publication set numerous times to see what happens to the indicators when we randomly remove publications from the set. As can be inferred from Figure 4.7, the more publications the shorter the whiskers of the stability intervals and the more robust indicators you get; indicators less reliant on single or few outliers in the sample.

We only demonstrate this to emphasise the point about robustness and the size of the units of analysis. We do not provide stability intervals for all the calculated indicators. But from this it is evident that the FKK set of publications as a unit, considering its poor coverage and the lack of robustness due to relatively few publications where outliers seem to influence quite substantially, is generally not suitable for impact analysis in its given state.

Table 4.15 below presents the comparison between the sets of council publications and the specifically constructed benchmark units of other Danish articles published in the same period and in the same subject categories as the specific councils' publications. Notice, for reasons given above, we have excluded FKK for this analysis. For each council we provide the council's main performance indicators and subsequently indicators for the benchmark set of publications with and without the council set of publications. We should warn that a direct comparison of indicators between the generally much smaller council sets and the much larger benchmark sets can deceive, again numbers are crucial. We are comparing two widely different sizes of output. All councils perform considerably better than their benchmarks and this is a valid conclusion. The counterfactual question, however, is how the councils would perform if their publication numbers rose considerably? Often units of analysis actually show a pattern of "regression towards the mean", but this is certainly not always the case, some units manage to have a very high output and

correspondingly high impact, we actually see cumulative effects (exponential growth between output and impact) for some large units.

Table 4.15. Indicator comparison for the individual research council publication sets compared to benchmark units: Other Danish journal articles published in the same research areas as the council sets in the same time period, 2005 to 2012 (notice, numbers for benchmarks in this table do not sum up to Table 4.19 due to duplicates and fractional counting needed when constructing specific sets across subject categories).

	P	MNCS	PPtop10%	MNJS
FNU	3433	1.79	19.0%	1.47
Denmark	72499.4	1.44	15.4%	1.24
Denmark excluding FNU	69066.4	1.42	15.2%	1.23
FSS	2038	1.90	19.8%	1.55
Denmark	64118.	1.50	16.0%	1.28
Denmark excluding FSS	62080.9	1.49	15.9%	1.27
FTP	1095	1.73	19.0%	1.50
Denmark	71264.6	1.45	15.7%	1.25
Denmark excluding FTP	70169.6	1.45	15.6%	1.25
FSE	312	1.68	18.0%	1.44
Denmark	7171.5	1.33	14.2%	1.14
Denmark excluding FSE	6859.5	1.32	14.1%	1.13

From Table 4.15 we can see that the largest drop in indicator values happen in the case of FNU where both MNCS and PPtop10% drops by 0.2 percentage points. The FNU set forms 6.5 percent of the publications in the Danish benchmark set and it contributes with 7.8 percent of the total normalized citations (TNCS) and likewise 7.9 percent of the highly cited articles (Ptop10%). The difference between the performance with and without the FSS publications is 0.1 percentage points. The FSS set forms 4.1 percent of the publications in the Danish benchmark set and it contributes with 5.1 of the total normalized citations (TNCS) and likewise 4.9 percent of the highly cited articles (Ptop10%). A drop in PPtop10% of 0.1 is the only visible difference for FTP. The FTP set forms 2 percent of the publications in the Danish benchmark set and it contributes with 2.4 of the total normalized citations (TNCS) and likewise 2.5 percent of the highly cited articles (Ptop10%). We should draw attention to the fact that the FTP set publications is scattered among many different subject categories in the CI-WoS, this is indirectly visible when one looks at the publication numbers for the FNU and FTP benchmark units, they are about equal size. There is a large overlap between these two benchmark units and it may be that for FTP the constructed benchmark unit is actually not very good. Finally, the difference between the performance with and without the FSE publications is 0.1 percentage points. The FSE set forms 4.3 percent of the

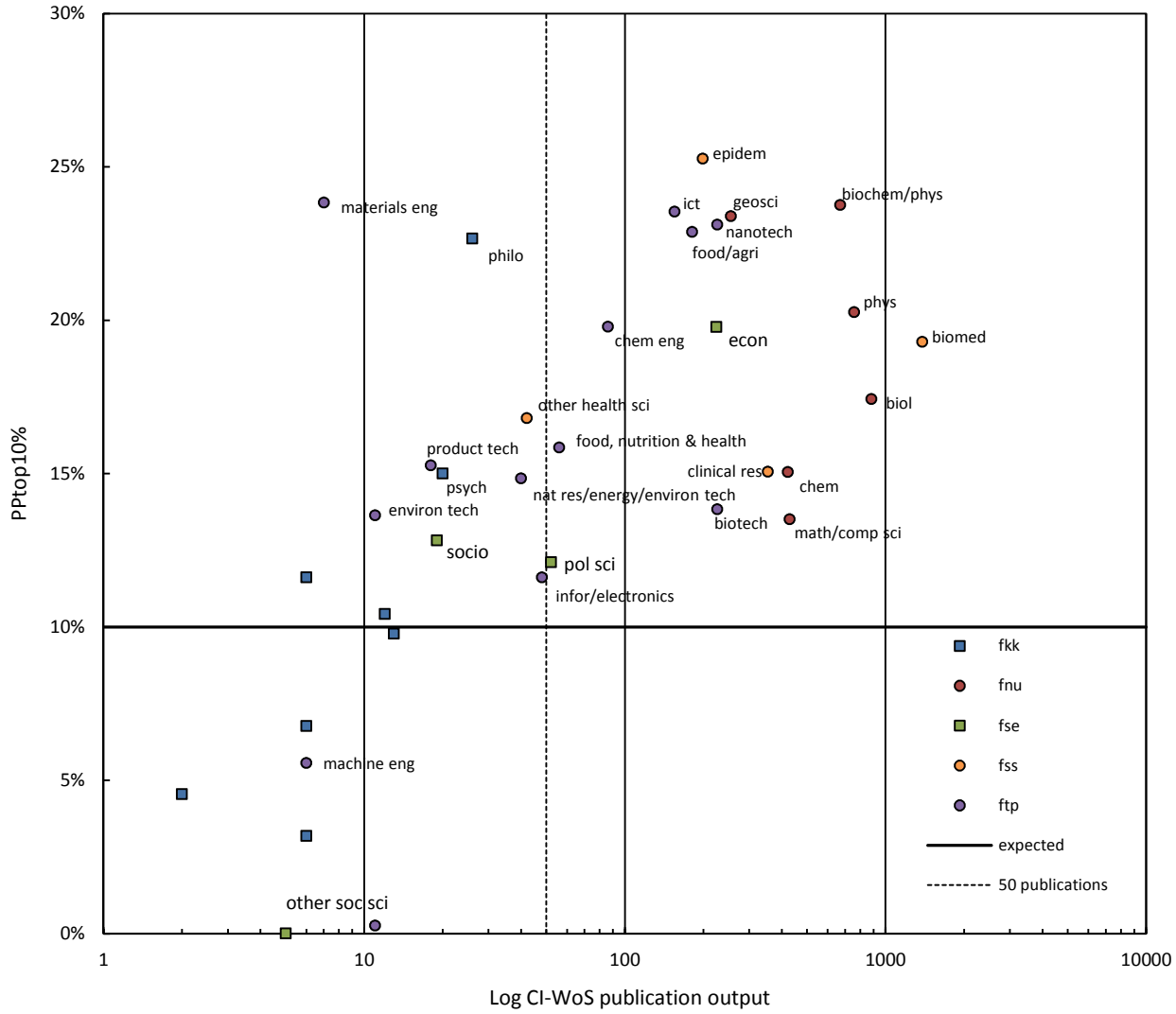
publications in the Danish benchmark set and it contributes with 5.4 of the total normalized citations (TNCS) and likewise 5.3 percent of the highly cited articles (Ptop10%).

While 0.1 and 0.2 percentage point drops may seem as a small effect, one should remember the inherent workings of publication and citation statistics. All sets of councils perform at a high level and the net gain of publication to citation is positive for all councils. Removing their relative small publication sets is indeed visible in the overall Danish impact for specifically constructed research areas. Notice, it is not so that removing more and more publications from a set automatically means that the indicator values drop in a similar way; they are just recalculated on the remaining publications. In principle changes begin to happen when highly cited papers are disproportionately removed compared to lower cited papers. The fact that the council sets (and the overall DFF set) have relatively more highly cited publications than expected means that when they are removed it becomes noticeable in the benchmark units' indicator values.

Citation impact according to subject categories

In this section we try to contextualize the indicator findings in the previous subsections by mapping performance to output using subject categories as units of analysis instead of the overall DFF set or the individual councils. We use two different subject classifications: 1) the subject classification assigned to grants at the time of funding; this is the same classification used above in Figures 4.1, 4.2 and 4.3; and 2) the CI-WoS subject categories assigned to journals. None of these classifications are ideal since they both focus on other units than the actual publications. The first classification distinctively classifies a grant into one category. Hence, when we use this as a proxy all publications linked to the grant will be classified under the same subject. Further, this classification scheme is highly uneven; some areas are exhaustively indexed while others are subsumed under few broad headings. This is why we bring in a second classification in order to get more exhaustiveness. However, the CI-WoS subject categories are also known for their problems. First, what is indexed is journals and not the actual articles and journals can be indexed with more than one category and the categories themselves can have large overlaps in journals between them.

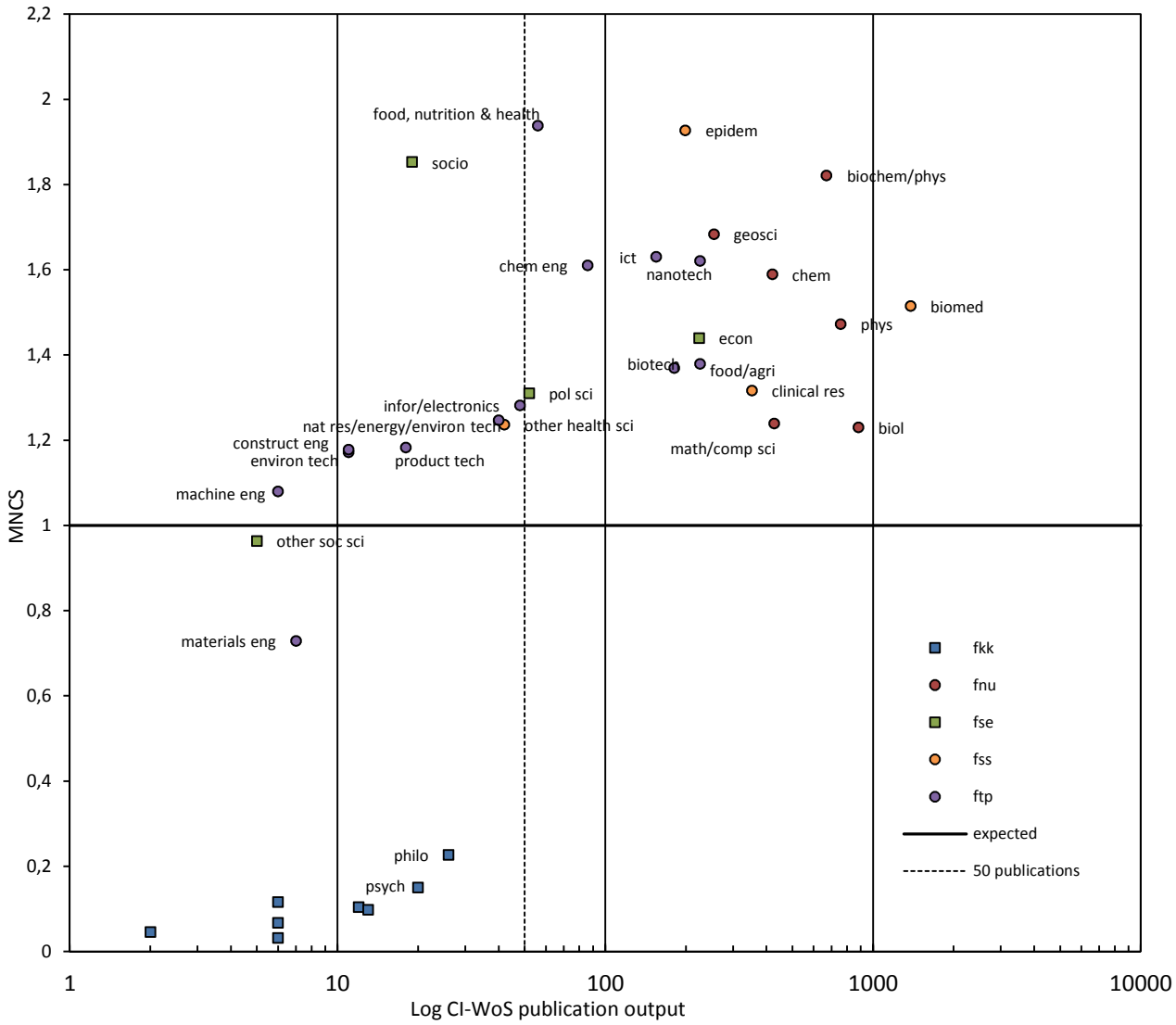
Figure 4.8. Proportion of highly cited articles (PPtop10%) as a function of output for subject fields used to index funded grants; output is shown on a log-scale.



Hence, in mapping exercises as the one below, an article receives the same subjects as the journal in which it is published. To avoid double counting, articles are fractionalized so that if an article appears in a journal classified in three subject categories, the article will weigh one third in all categories. A consequence of this is that the actual number of subject categories where a unit of analysis is seemingly active quickly approaches the maximum of 252, i.e., the total number of CI-WoS categories. In order to avoid this, we have enforced a threshold so that 85 percent of all publications are represented in the map which corresponds to the 68 subject categories with the highest number of DFF publications. The remaining 15 percent of the publications are scattered among 153 other subject categories. The actual threshold for exclusion is 23.5 publications in the

excluded category, 61 categories have publication numbers less than three (the total set with indicators is outlined in Table 11.2 in the Appendix).

Figure 4.9. Mean normalized citation score (MNCS) as a function of output for subject fields used to index funded grants; output is shown on a log-scale.



Basically, the two mappings support each other. The first two plots based on the grant classifications contextualize the main topics subsumed by the research councils.

The third and fourth plots dissolve the grant and council structures and basically show where the DFF set of publications have been published in the CI-WoS universe across the councils. The first two plots have subject labels in the plots, whereas in the third and fourth plots' labels are numbers which refer to subject labels in Table 4.16. As the plots are essentially twin plots

(PPtop10% and MNCS), we make some general comments at the end of this subsection. Notice, in the first two plots we have left out the labels referring to FKK subject areas with the poor coverage

Figure 4.10. Proportion of highly cited articles (PPtop10%) as a function of output for CI-WoS subject categories used to index journals; output is shown on a log-scale.

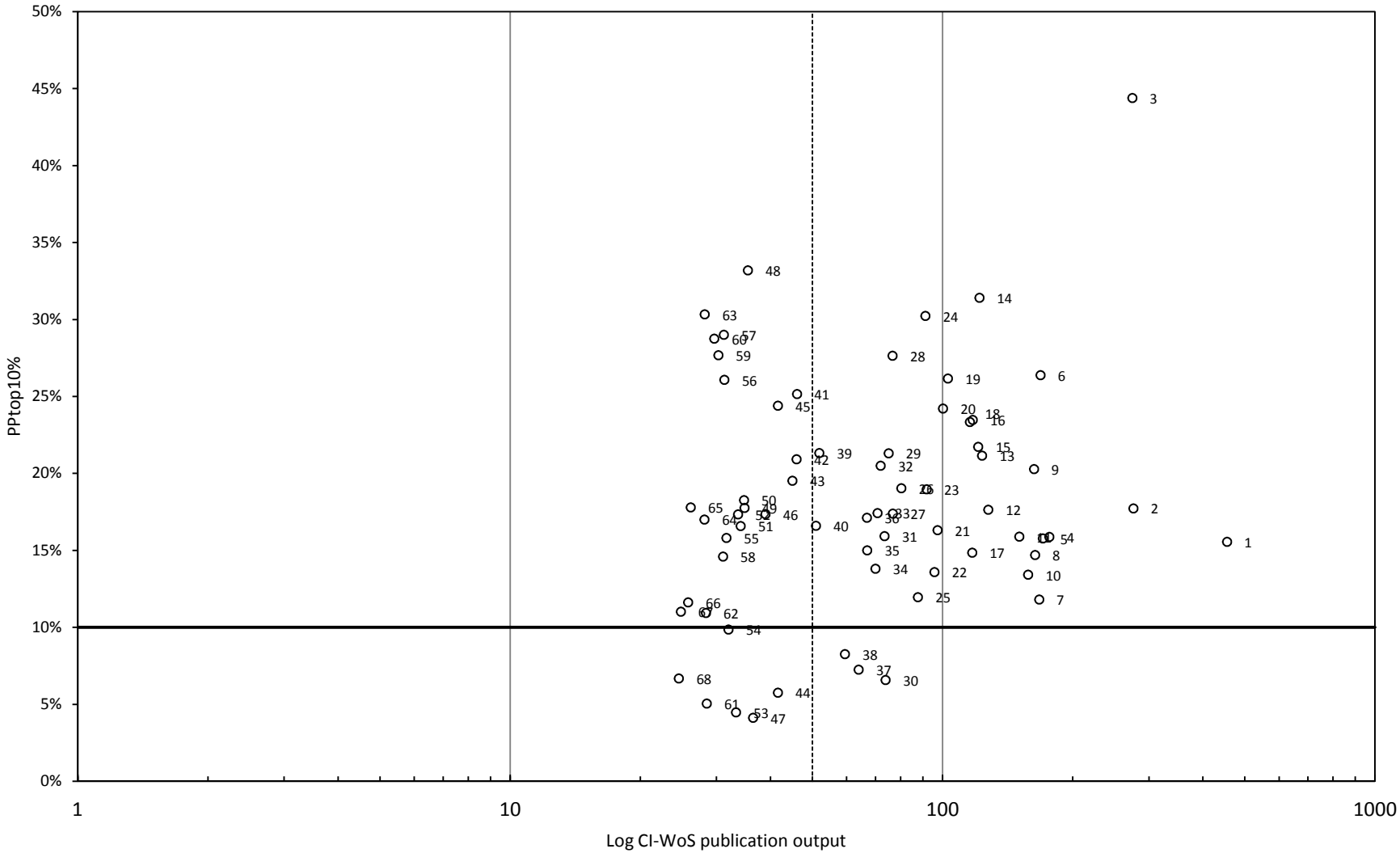


Figure 4.11. Mean normalized citation score (MNCS) as a function of output for CI-WoS subject categories used to index journals; output is shown on a log-scale.

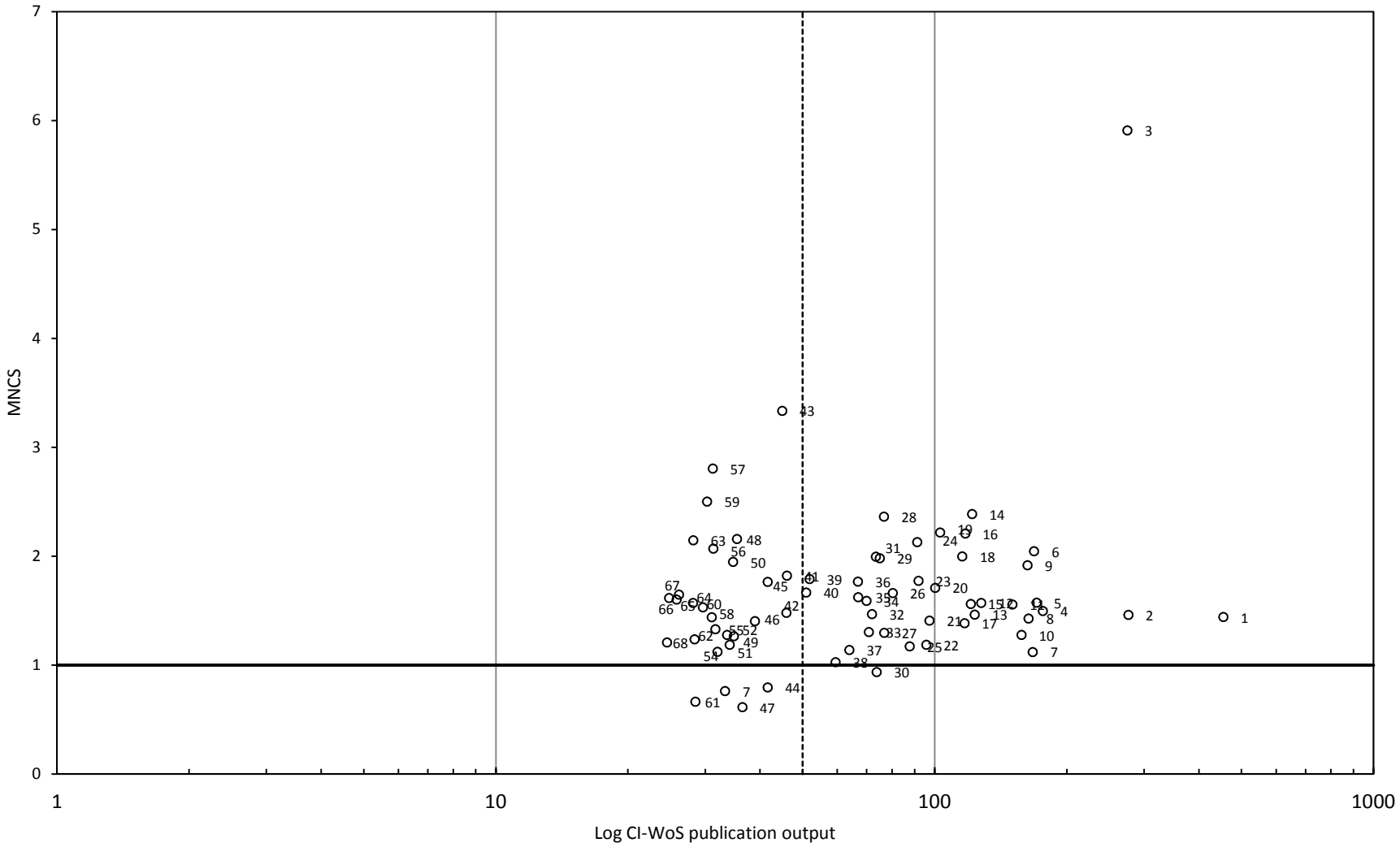


Table 4.16. CI-WoS labels for Figures 4.10 and 4.11.

CI-WoS subject category	Labels	CI-WoS subject category	Labels	CI-WoS subject category	Labels
BIOCHEMISTRY & MOLECULAR BIOLOGY	1	PHYSICS, APPLIED	31	COMPUTER SCIENCE, THEORY & METHODS	61
ASTRONOMY & ASTROPHYSICS	2	GEOCHEMISTRY & GEOPHYSICS	32	MECHANICS	62
MULTIDISCIPLINARY SCIENCES	3	EVOLUTIONARY BIOLOGY	33	MEDICINE, RESEARCH & EXPERIMENTAL	63
PHYSIOLOGY	4	ENVIRONMENTAL SCIENCES	34	RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING	64
MATHEMATICS	5	BIOLOGY	35	POLITICAL SCIENCE	65
CELL BIOLOGY	6	MATERIALS SCIENCE, MULTIDISCIPLINARY	36	DERMATOLOGY	66
NEUROSCIENCES	7	CHEMISTRY, ORGANIC	37	INFECTIOUS DISEASES	67
ENDOCRINOLOGY & METABOLISM	8	HEMATOLOGY	38	CHEMISTRY, INORGANIC & NUCLEAR	68
GENETICS & HEREDITY	9	OCEANOGRAPHY	39		
CHEMISTRY, PHYSICAL	10	UROLOGY & NEPHROLOGY	40		
CHEMISTRY, MULTIDISCIPLINARY	11	PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH	41		
ECOLOGY	12	CARDIAC & CARDIOVASCULAR SYSTEMS	42		
PHYSICS, ATOMIC, MOLECULAR & CHEMICAL	13	PHYSICS, MATHEMATICAL	43		
PHYSICS, MULTIDISCIPLINARY	14	MATHEMATICS, APPLIED	44		
ONCOLOGY	15	SPORT SCIENCES	45		
OPTICS	16	CLINICAL NEUROLOGY	46		
MICROBIOLOGY	17	MINERALOGY	47		
PHARMACOLOGY & PHARMACY	18	ENTOMOLOGY	48		
PLANT SCIENCES	19	ENGINEERING, ELECTRICAL & ELECTRONIC	49		
PHYSICS, CONDENSED MATTER	20	BUSINESS, FINANCE	50		
MARINE & FRESHWATER BIOLOGY	21	PERIPHERAL VASCULAR DISEASE	51		
IMMUNOLOGY	22	VIROLOGY	52		
ECONOMICS	23	SOIL SCIENCE	53		
BIOCHEMICAL RESEARCH METHODS	24	CHEMISTRY, ANALYTICAL	54		
ZOOLOGY	25	CHEMISTRY, MEDICINAL	55		
PHYSICS, PARTICLES & FIELDS	26	NANOSCIENCE & NANOTECHNOLOGY	56		
STATISTICS & PROBABILITY	27	GEOGRAPHY, PHYSICAL	57		
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	28	TOXICOLOGY	58		
GEOSCIENCES, MULTIDISCIPLINARY	29	VETERINARY SCIENCES	59		
BIOPHYSICS	30	NUTRITION & DIETETICS	60		

The four figures present different perspectives on what research areas are behind the analysed publication sets. We will not go into detailed analyses, this can be pursued using maps and Table 11.2 in the Appendix, but we will highlight some interesting findings. First, the double twin-plots illustrate why it is a good idea to use several performance indicators rather than having to rely on only one. For example, in the first twin-plots the subject area "food, nutrition & health" come out quite differently depending on the indicators plotted. In Figure 4.8 "food, nutrition & health", while performing well, is not among the highest performing units with its PPtop10% at 15.8 for 56 publications. However, in Figure 4.9, "food, nutrition & health" rises to the top with an MNCS of 1.9 for 56 publications. Similar, in the same figures, and for sake of the example we disregard the low publication numbers, "philosophy" and "psychology" perform very well on the PPtop10% indicator but very poorly on the MNCS indicator. In the case of "food, nutrition & health", the unit has a substantial number of publications with good normalized citation scores, albeit many of them does not research the 90th percentile of the citation distribution needed to be included in the PPtop10% indicator. Conversely, the relatively small sets of publications linked to "philosophy" and "psychology" have something like a bimodal citation distribution. A number of highly cited articles, few or no articles in the inter quartile range, and a number of articles with few or no citations at all. This is reflected in the high performance when it comes to the percentile indicator and low performance when it comes to the average-based indicator.

Perhaps the most robust units in Figures 4.8 and 4.9 among the highest performing are "community medicine & epidemiology (epidem)" and "biochemistry & biophysics (biochem/phys)". While there is a CI-WoS subject category named "biochemistry & molecular biology" (label 1), which in fact is the largest subject category measured in publications, some 455, the overlap of articles is somewhat different and the performance is significantly lower. A corresponding subject category to "community medicine & epidemiology" is not readily apparent in Figures 4.10 and 4.11 and looking at the articles that constitute this category reverses publication in 142 different medical and biomedical journals, some of them general high impact journals such as JAMA, New England Journal of Medicine, but also the multidisciplinary journal Science. Likewise, if we examine where the articles from the "biochemistry & biophysics" category in Figures 4.8 and 4.9 are published, no less than 286 journals are used for the 702 articles. Among the frequently used outlets are subject specific journals such as Molecular and Cellular Proteomics and Journal of Biological Chemistry, but interestingly also three multidisciplinary journals Science, Nature and the Proceedings of the National Academy of Sciences of the United States of America

(PNAS) are present. These multidisciplinary (not to be mistaken as interdisciplinary) journals have their own mixed-bag category in CI-WoS named "multidisciplinary sciences". In Figures 4.10 and 4.11, where these journals and their articles are kept together in their own arbitrary group, the performance is exceptional with a PPtop10% of 44 percent and an MNCS of 6. If we scrutinize the "biochemistry & biophysics" category in Figures 4.7 and 4.8, then we discover that articles published in Science, Nature and PNAS constitute 6.3 percent of the total number of publications, but together these articles attract 29.2 percent of the total number of normalized citations (TNCS) received by the group and 17 percent of the highly cited publications (Ptop10%). A somewhat similar pattern is visible in the "community medicine & epidemiology". Here the articles from the two general medical journals JAMA and New England Journal of Medicine together with Science constitute 4 percent of the total number of publications but the articles published in these journals attract some 28.2 percent of the total number of normalized citations (TNCS). Consequently, assignment of multidisciplinary journals and general biomedical journals with known high impact to specifically constructed subject categories in principle can make a huge difference when it comes to calculating impact measures.

Indicators of collaboration

The purpose of this collaboration analysis is to show the main patterns of collaborations for the overall set of DFF publications and for the sets of publications linked to the individual research councils. Further we present the main performance indicators for the different collaboration patterns. Three patterns are examined: No collaboration, national collaboration and international collaboration. Collaboration is detected in the address fields of the CI-WoS indexed publications. Publications referring to only one research institution in the address field are classified as "no collaboration". Publications referring to multiple institutions all from the same country are classified as "national collaborations" and publications with at least one reference to an international institution is classified as "international collaboration". It is well-known in scientometrics that international co-authored journal articles on average receive more citations than national authored articles, but individual fields' publication behaviour plays a crucial role here; some fields are per definition more international than others.

Table 4.17 presents the collaboration patterns for the overall DFF set of publications and in the subsequent Table 4.18 we present the corresponding collaboration patterns for the sets of publications linked to the individual research councils. In Table 4.18 we examine the overall DFF

set with and without the publications linked to the postdoc grants, as well as the postdoc grants themselves.

Table 4.17. Collaboration and impact (PPtop10%, MNCS and MNJS) for the DFF set of publications with no collaboration, national cross-institutional collaboration and international collaboration.

2005-2012	All grant types excluding postdoc	Only postdoc grants	All grant types combined
Total P	6679	284	6963
p no collaboration	1798	92	1890
p national collaboration	1084	54	1138
p international collaboration	3797	138	3935
% no collaboration of total P	26.9%	32.4%	27.1%
% national collaboration of total P	16.2%	19.0%	16.3%
% international collaboration of total P	56.8%	48.6%	56.5%
MNCS: no collaboration	1.44	2.06	1.47
MNCS: national collaboration	1.47	1.47	1.47
MNCS: international collaboration	2.01	2.71	2.04
PPtop10% no collaboration	16.3%	28.1%	16.9%
PPtop10% national collaboration	16.8%	24.1%	17.2%
PPtop10% international collaboration	20.6%	25.8%	20.8%
MNJS no collaboration	1.29	1.43	1.30
MNJS national collaboration	1.33	1.47	1.34
MNJS international collaboration	1.60	2.27	1.62

The collaboration patterns are quite distinct. With small variations for the postdoc set, around half or slightly more of all publications are a result of international collaboration. Also, exclusive national collaboration is the least frequent collaboration activity with somewhere between 16 to 19 percent of the publications. Finally, more than one in four articles are a result of "no collaboration" meaning that the articles are either single authored or co-authored with colleagues from the same institution. Turning to performance for these collaboration types for the overall set of DFF publications, excluding the postdoc publications, we see that there is only minor difference between no collaboration and national collaboration when it comes to MNCS and PPtop10% as well as MNJS. But the difference between these two patterns and international collaboration is notable. Fully as expected internationally co-authored articles have on average a markedly higher citation impact. Nevertheless, performance levels for the other two groups are still high. The patterns in the postdoc set are more extreme. Here the no collaboration articles have a very high average citation rate (MNCS), clearly larger than the national collaboration group. The international publication pattern shows preference for publication in very high impact journals and

excellent MNCS and PPtop10% scores. Lumping the two sets together gives about equal high performance for no collaboration and national collaboration and very high impact for international co-authored articles and the latter constitute some 56.5 percent of all publications testifying that researchers involved with DFF grants contribute substantially to the international scientific networks and this international orientation is an important factor in explaining the general high impact observed for the DFF set of publications.

The distinct patterns for the overall DFF set presented in Table 4.17 are obviously influenced most by the publication behaviours in the fields that contribute with most publications in the analysis, e.g., FNU and FSE. Smaller fields' publication behaviour may disappear in such overall results.

Table 4.18. Collaboration and impact (PPtop10%, MNCS and MNJS) for the five individual council set of publications with no collaboration, national cross-institutional collaboration and international collaboration.

2005-2012	FKK	FNU	FSE	FSS	FTP
Total P	100	3454	312	2139	1106
Coverage	43%	85%	55%	95%	89%
p no collaboration	63	820	133	498	412
p national collaboration	13	375	35	591	171
p international collaboration	24	2259	144	1050	523
% no collaboration of total P	63%	24%	43%	23%	37%
% national collaboration of total P	13%	11%	11%	28%	15%
% international collaboration of total P	24%	65%	46%	49%	47%
MNCS: no collaboration	1.16	1.37	1.17	1.69	1.55
MNCS: national collaboration	1.09	1.36	1.40	1.56	1.57
MNCS: international collaboration	2.09	2.01	2.21	2.24	1.93
PPtop10% no collaboration	12.3%	15.6%	9.7%	20.7%	17.1%
PPtop10% national collaboration	2.7%	15.4%	17.3%	19.1%	16.2%
PPtop10% international collaboration	19.5%	20.9%	25.8%	20.4%	21.5%
MNJS no collaboration	0.98	1.29	1.20	1.40	1.32
MNJS national collaboration	1.12	1.29	1.52	1.36	1.37
MNJS international collaboration	1.30	1.57	1.64	1.74	1.68

Table 4.18 presents patterns of collaboration disaggregated to the council levels in order to better examine variations in publication behaviour and especially preferences for international publishing. We see marked differences in publication behaviour. With international collaboration in 65 percent of the articles, FNU is more internationally oriented compared to the 56 percent in the overall DFF set. On the other hand, both FSS and FTP have a somewhat lower share of articles

with international collaboration, 49 and 47 percent respectively, compared to the overall DFF set presented in Table 4.17. Also, FSS and FNU show other differences in publication behaviour between them, compared to FNU and compared to the overall DFF set. With 28 percent, FSS has a relatively larger share of national collaboration, in fact the largest among all councils. With 37 percent, FTP has relatively large share of its publications with no collaboration. In that respect publication behaviour for FTP resembles more that of FSE and FKK, than FNU or FSS. The publication pattern for FSE is also distinct. FSE is as internationally oriented in its collaborations as FSS and FTP. The main difference is between no collaboration and national collaboration. Clearly, with 43 percent, FSE researchers have preferences for working alone or together with colleagues from the same institution, compared colleagues from other Danish research institutions (mean number of authors per article for FSE is 2.2 and the median is 2, see Figure 11.2 in the Appendix). Finally, and not surprisingly, the publication behaviour for FKK is just as distinct as FNU, though basically reversed with 63 percent of the publications with no collaboration (mean number of authors per paper is 2 and the median is 1), whereas only 24 percent of the articles have international collaboration. The publication numbers involved for FKK are markedly lower compared to the other councils and this may influence the percentages but the pattern that emerges is also the one we would expect also if we disregard the fact that we only examine international journal publication behaviour.

Turning to impact patterns, here coverage is an issue especially for FKK. Uncertainty, lack of robustness and validity are linked to the FKK performance indicators. It is highly questionable whether the internal journal publication can be seen as the focal publication behaviour for FKK as a unit. There may be fields or part of fields subsumed under FKK where such behaviour is central, but not for FKK as a whole. Nevertheless, for all councils the general pattern is the same as in Table 4.20. When publications are a result of international collaboration citation impact levels are highest and they are indeed high for all councils. Also, generally when collaborating with international colleagues, publication behaviour tends to be directed toward the highest impact journals (interestingly FSE publications resulting from national collaboration, albeit only 35, are also on average published in very high impact journals, the MNJS level for the other councils for this collaboration type is markedly lower). This means that on average publications with international collaboration are more visible (i.e., published in journals that attract greater attention) and are used by more colleagues (they have presumable read the articles, although that is not always the case, and cited them) than publications with no or national collaboration. Consequently, if

international journal publication is the focal publication behaviour for a field or subfield, then international collaboration is a vital factor in achieving high performance.

Advanced citation analysis: Identification of potential 'breakthrough' articles

The final analysis in this chapter is an advanced citation analysis developed in relation to our previous bibliometric evaluation of the Danish National Research Foundation in 2013 and further developed in Schneider and Costas (forthcoming). The notion behind an attempt to detect potential 'breakthrough' research is an interest in identifying those few research results that really make a difference. Until now, the analyses have focused upon overall impact or impact in somewhat arbitrary subject categories using pre-established fields or journal subject categories which is in many ways in conflict with the network of scientific papers, a network that is self-organizing at the article level and across arbitrary field delineations.

'Breakthrough' research is obviously a challenging concept to define, operationalize and detect. Numerous approaches can be taken and eventually what can be considered 'breakthrough' research is a matter to be decided by peers. Hence, it is foolhardy to believe that a quantitative attempt at detecting 'breakthrough' research with one specific approach can be exhaustive or flawless. This is clearly not the case, and we fully acknowledge the limitations of our citation based approach. Nevertheless, as one modest attempt, citation analysis is an interesting approach to explore in this respect. If we assume that in the fields we analyse in this report, research results are mainly reported in international journal articles. If we also assume that within narrower research areas, highly cited publications to a large extent signal impact and use of the content in these papers by the research community, though noise will also be in there, then it would also be reasonable to assume that potential 'breakthrough' research in many instances would be reported in articles that subsequently become highly cited exactly because the research has 'breakthrough' potential.

These are the basic assumptions of this analysis and if they are accepted, two major methodological challenges remain: 1) detecting potential 'breakthrough' papers among the set of (extremely) highly cited papers, and 2) establishing an exhaustive network of research areas in which 'breakthrough' papers can be detected. We think the latter is important because analysing potential 'breakthrough' research should commence in the local context of the research area where such knowledge claims are first proposed. We established such a network of research areas by clustering all research papers in the WoS database according to their citation links. Hence we are able to establish clusters of papers at three levels, where at the disaggregate levels articles are

clustered because they have similar citation preferences, thus it is assumed that they have common research interests.

We should emphasize that distinguishing between potential 'breakthrough' articles and potential 'breakthrough' research is difficult and also depends on the unit of analysis. An article can indeed report what eventually turns out to be 'breakthrough' research, but what eventually turns out to be 'breakthrough' research can also be the sum of knowledge claims in a number of papers, where some of them are perhaps not highly cited. In this analysis, we have chosen a simple approach. We assume that the three different citation analyses explored identify potential 'breakthrough' papers given their respective parameters.

As indicated above, the current approach was developed for our previous bibliometric evaluation of the Danish National Research Foundation in 2013. In the DNRF study the methodology potentials were positively validated. As subset of CoEs was selected by experts judging them to have produced 'breakthrough' research and PIs from the CoEs identified what they considered important articles that disseminated these 'breakthroughs'. The task then was to evaluate to what extent the approach came up with similar results; five out of six CoEs were identified as having produced one or more potential 'breakthrough' articles. In fact the approach is so restrictive that only a handful of the CoEs produced 'breakthrough' articles in all three categories used in the approach. For more information on the validation of the approach we refer to the report[14] and for its theoretical and statistical basis the abovementioned article. Below we briefly explain the approach and how we utilize it in this report.

Our approach for identifying potential breakthrough research starts from the following three assumptions:

- Breakthrough research tends to become highly cited. However, a limitation here is that an article can indeed report 'breakthrough' research, but 'breakthrough' research can also be the sum of knowledge claims in a number of papers, where some of them are perhaps not even highly cited. Initially, we assume that at least one publication should become highly cited.
- A highly cited paper does not per se convey 'breakthrough' research. Therefore focusing on highly cited papers solely is not enough, it is important to identify those that most likely convey 'breakthrough' research and separate them from just highly cited articles that do not report true breakthrough results.

[14] http://dg.dk/filer/Publikationer/Evaluering2013/Appendiks%205_bibliometrisk_report_03122013.pdf.

- Finally, 'breakthrough' research should be identified within its discourse community that is among a set of related and self-organized research articles (i.e. the network of publications).

We propose the following definition of a 'breakthrough paper' for this approach: *a highly cited paper, with an important spread over its own field(s) and also other fields of science, and it must be a paper that is not a mere follower of other highly cited publication(s) but that it has a genuine relevance on its own*. From this definition we focus on highly cited journal articles. Their identification is carried out in the context of the network and clustering of articles worldwide. Review papers are excluded as potential breakthroughs as they mostly condensate and discuss the most recent and important developments in a scientific domain, thus qualifying as 'followers' and not as true breakthroughs.

We approach the detection of breakthrough papers from three different perspectives, thus also providing three different typologies of breakthrough papers. In all three cases we use a classification of all 16.2 million publications indexed in *Web of Science* (WoS) between 1993 and 2012 developed at CWTS (Waltman & van Eck, 2012). This network of publications is created by direct citation links, thus it is assumed that publications in the same cluster have common research interests. Publications are clustered at three levels: there are 21 macro-fields that represent main scientific disciplines. These macro-fields contain 784 different meso-fields, and finally we have a micro-classification composed by 21,167 micro-fields. All these levels have been used in our methodology for detecting breakthroughs in one way or another.

The three approaches explored are characterized as follows:

- *Approach 1* is very simple but also extremely exclusive. It is based on the idea that the most cited paper of every micro-field can most likely be considered as a breakthrough paper because it has the highest impact in it its micro-domain. This is a very restrictive definition of a breakthrough paper, because only one (or occasionally several) papers pass this filter. In fact, only 21,670 out of the 16.2 million publications pass this filter as breakthroughs (i.e., 0.13% of all publications).
- *Approach 2* is based on two advanced citation methods: 1) the 'Characteristics Scores and Scales' method (CSS) (Schubert, Glänzel & Braun, 1987) and 2) a filtering of 'followers'. This approach is relatively less restrictive compared to Approach 1 in as much as 179,349 out of the 16.2 million publications qualify as potential breakthrough papers (i.e., 1.1% of all publications).

- *Approach 3* is also based on the CSS-method and filtering of 'followers', but this approach is more restrictive than Approach 2 because it introduces a knowledge diffusion criterion where it is also required that a potential breakthrough publication has impact beyond its own macro field. Some 59,617 out of 16.2 million publications qualify as potential breakthroughs according to this approach (i.e., 0.37% of all publications).

For a detailed methodological and statistical description of the CSS-method we refer to the DNRF-report. The 'filtering of followers' is a filter we set up so that being highly cited is in itself not sufficient to be considered a breakthrough, because publications should not be "a mere follower of other highly cited publication(s)" – it must have "a genuine relevance on its own". We also refer to the DNRF report for a methodological description of this filtering technique. Finally, the 'knowledge diffusion filter' enforces that breakthroughs also must have impact beyond their own macro-domains (i.e. they must have impact across other major fields of Science). A potential breakthrough according to this third approach is potential breakthrough papers that have an impact in more macro-categories than an average potential breakthrough within the same meso-category. Again we refer to the DNRF-report for methodological details.

From the previous bibliometric evaluation of the DNRF we have identified a set of potential breakthrough articles for the set of DNRF publications. Correspondingly, we have also identified potential breakthrough articles from the set of Danish publications, i.e., publications with at least one Danish address. In order to be able to use these publication sets as benchmarks for the present analysis, we restrict the sets to include only publications from 2005 to 2011. Consequently, we can examine the DFF set of publications for the same period in order to identify potential breakthrough articles and compare the results to the Danish and DNRF sets of publications.

In principle this is just an advanced citation analysis where the focus is on the exclusively few extremely highly cited articles plus some enforced filtering to remove assumed noise. Hence, we can expect somewhat similar performance patterns as presented above where performance was generally high, but the DNRF set of publications had clearly the highest performance in relation to highly cited articles. So even though the 'breakthrough' approach is very restrictive we should expect that the more 'breakthrough' articles are identified in the DNRF set compared to the DFF set.

The results are presented in Table 4.19 below. We repeat, category one is the most restrictive, to be identified as a potential breakthrough article it has to be the highest cited in one of

the 21,670 micro-fields (i.e., an article can only be in one field). Category two is the least restrictive; to be identified as a potential breakthrough article it should be among the one percent most cited in the database and not be a follower of other potential breakthrough articles. Category three is more restrictive than category two, to be identified as a potential breakthrough article the same criteria as in category two applies and then a third knowledge diffusion criterion is introduced stating that the articles should also have impact in other macro fields which reduces the set of potential breakthroughs to 0.37 percent of all articles in the database.

4.19. Proportion of Danish, DFF and DNRF 'breakthrough' articles from 2005 to 2011.

	'Breakthrough' category 1	'Breakthrough' category 2	'Breakthrough' category 3
P 'breakthrough': Database	1369	13997	4326
p 'breakthrough': Denmark	27	292	106
p 'breakthrough': DFF	1	24	10
p 'breakthrough': DNRF	5	48	20
% p 'breakthrough' in own set: Denmark (n = 77571)	0.03%	0.38%	0.14%
% p 'breakthrough' in own set: DFF (n = 6205)	0.02%	0.39%	0.16%
% p 'breakthrough' in own set: DNRF(n = 7108)	0.07%	0.68%	0.28%
% DFF p among Danish 'breakthroughs'	3.7%	8.2%	9.4%
% DNRF p among Danish 'breakthroughs'	18.5%	16.4%	18.9%
% Danish p among database 'breakthroughs'	1.97%	2.09%	2.45%

The first four rows of Table 4.19 present the actual number of identified potential breakthrough articles in the three categories for the database, for the Danish set of publications, for the DFF set of publications and for the DNRF set of publications. Notice, there are duplicates between the categories. Articles identified by a more restrictive method will most probably turn up in one or both of the lesser restrictive categories; there are exceptions. Also notice that the publication window is from 2005 to 2011 and we apply the usual three citation window. The subsequent rows present the proportion of potential breakthrough articles identified.

We benchmark the DFF set to the Danish and DNRF sets in relation to the proportion of potential breakthrough articles they have among their output. It is evident that the approach is very restrictive; proportions are well below one percent. The pattern is clear and somewhat expected.

The DNRF set has a larger proportion of potential breakthrough articles in its set compared to the DFF and Danish proportions. The proportions across the three breakthrough categories are almost identical for the latter two units. Subsequently, we examine the proportion of the DFF and DNRF set of publications in relation to the Danish total. Not surprisingly, the proportion of the DNRF set is again the largest approximately double in size for category two and three and close to five times higher for the restrictive first category. As expected the DNRF set have more potential breakthrough articles in its set. It is expected because the current approach focuses upon extremely highly cited articles and it therefore promotes units producing such rare articles. Apparently, the DNRF is especially well suited for such tasks.

We have identified 24 unique publications linked to DFF grants among the potential 'breakthrough' articles from 2005 to 2011. Eleven of these articles appear in two 'breakthrough' categories. Three of the articles are also included in the DNRF set of publications and two of these appear in two breakthrough categories. The 'breakthrough' articles come from 23 grants, where two grants (geoscience and biochemistry) have three unique 'breakthrough' articles, one of these is aforementioned Ole Rømer grant discussed above. The 24 unique articles are credited 16 times to FNU, 9 times to FSS and 2 times to FTP. The most frequent subjects assigned to the 23 grants are biomedicine (5) and physics (5) and the 24 unique potential 'breakthrough' articles are published in 13 different journals, Nature and Science have published half of them, six each.

5. Comparative citation impact and publication behaviour analyses of grant PIs and rejected applicants

This chapter contains two comparative analyses of grant PIs and rejected applicants: 1) a large impact analysis of the pre and post performance levels for grantees and rejected applicants are examined; and 2) a minor analysis of journal publication behaviour among FKK and FSE grantees and rejected applicants as documented by the national BFI indicator. The latter analysis is included due to the expected poor coverage of especially FKK publications in the CI-WoS database. Notice, the two analyses are distinctively different. The former addresses impact, the latter publication behaviour. The data selection and matching procedures for these analyses are outlined in Chapter 3, the matching of comparable sets of PIs (grantees) and rejected applicants is explained below.

Comparative citation impact analyses of grant PIs and rejected applicants

The purpose of this section is to analyze the effect of receiving a grant from the DFF. The comprehensive dataset that this analysis is based on has a number of strengths in assessing the relative performance of recipients of DFF grants; however, there are also a number of limitations that can bring into question whether we are fully able to isolate the potential effect of DFF grants on citation impact. We discuss these factors in more detail below.

In the analysis, we utilize a non-experimental approach where PIs (grantees) are compared to the control group consisting of comparable applicants that did not receive a grant from the DFF in the period 2003-2008. Both of these groups are described above. Post doc grants are not included in this analysis due to their often limited history prior to grant reception. For each individual, indicators are calculated *ex ante*, *ex post* and in the difference before-after. For PIs, the *ex post* period is from the year of grant award to 2012, and *ex ante* from 1996 to the year prior to grant award. For rejected applicants, the *ex ante* and *ex post* periods are set to 1996-2004 and 2005-2012, respectively. For both groups, before-after differences are simply calculated as *ex post* minus *ex ante* values. The analysis relies in particular on two indicators, the MNCS and the PPtop10%, though we have also examined the MJNS and will discuss these results occasionally. Given that PIs on average have greater citation activity both in the *ex ante* and *ex post* periods, the most appropriate measure in examining effects is the before-after difference, though we will also show *ex post* values (and in cases where there is no significant difference in ex ante values, ex post values can function well as indicators).

We consider two different sets of publications in calculating *ex post* indicators for PIs. The first is based on all publication activity for PIs in the *ex post* period while the second is based on publications that are directly linked to the DFF grant (where the PI is author or co-author). The validation process for these grant publications is described above, where it is also noted that it was not possible to obtain a validated list of grant publications for all PIs.

Before continuing with the description of the analysis, it is important to note its potential strengths and limitations. An important strength is that we have extensive data on publication and citation activity for a relatively large sample of individuals over a long time period. This allows us to compare individuals both before and after grant periods. We are also able to use a variety of indicators which improves robustness and, importantly, these indicators are field normalised which facilitates comparison across disciplines. Furthermore, through the validation process described above, we have been able to identify those publications that are specifically linked to DFF grants for the large majority of individuals in the sample. Finally, rejected applicants are arguably the best possible candidates for a control group to compare with PIs.

There are also a number of limitations that complicate efforts to isolate potential effects. The first concerns the nature of bibliometric data itself. As noted above, bibliometric data is typically highly skewed, which means that individual values (that may be driven by individual specific factors) can greatly influence aggregated results. We attempt to address this by augmenting standard statistical *t*-tests that compare averages with non-parametric tests that compare overall distributions. A second limitation is unobserved factors that may also affect developments in citation impact, and potentially in different ways for PIs and the control group. Possibly the most important among these is alternative funding sources. It is likely that the far majority of individuals from both groups (PIs and rejected applicants) have received external funding from a variety of sources during these *ex ante* and *ex post* periods; this is actually indicated in the survey answers in Chapter 6. Individuals' research activities may often rely on a complex stream of different forms of funding, making it very difficult to isolate the effects of a single source. We are though able to identify whether individuals have received a DFF grant or not over the period, however even here we do not know whether rejected applicants have been involved in other DFF grants as a participant (and not the PI). Nonetheless, we still view the comparison of PIs with rejected applicants to be very valuable in shedding light on the effects of DFF grants, in particular given that we are able to identify those publications that are directly linked to DFF grants. Finally, the number of publications per individual varies greatly, with some having only a few or just a single publication

before or after grant reception. A low number of publications increase the uncertainty for the citation impact measures used in the analysis, as has also been noted above in Chapter 4.

The remainder of this subsection describes the sample in more detail. In order to conduct the analysis some additional restrictions are placed on the data. First, we require that all individuals have at least three years of publication activity in the *ex ante* period in order to produce reasonable indicators. Hence, the first year in which a publication is registered in the CI-WoS data must be 2003 or earlier. Furthermore, we require that there is at least one publication in both the *ex ante* and *ex post* periods. In all, 641 researchers did not have a publication in 2003 or earlier and an additional 34 did not have both an *ex ante* and an *ex post* publication. These were removed from the sample used to conduct the comparative performance analyses. The final sample used consists of 1054 PIs and 999 rejected applicants. Of the 1054 PIs, information on which publications are linked to the grant was not available for 117 PIs. Table 5.1 shows the distribution of individuals across the five research councils, both for the initial and final sample. As can be seen from the table, attrition is greatest among rejected applicants, with roughly around 100 individuals being removed from each research council. While sample size is still quite good for FNU, FSS and FTP, the number of individuals with both an *ex ante* and an *ex post* publication registered in the CI-WoS data is fairly low.

Table 5.1. Distribution of individuals across the five research councils included in the comparative performance analysis.

	FKK	FNU	FSE	FSS	FTP	Total
Initial sample						
Rejected applicants	129	372	170	440	403	1514
PI (grantees)	50	367	114	472	211	1214
Total	179	739	284	912	614	2728
Sample used in matching analysis						
Rejected applicants	25	296	63	317	298	999
PI (grantees)	21	342	55	441	195	1054
Total	46	638	118	758	493	2053

Table 5.2 shows the distribution of individuals according to number of publications, *ex ante*, *ex post* and also for grant publications. In the table, we have categorized individuals into one of four groupings: 1 publication, 2 to 4 publications, 5 to 9 publications, and 10 or more publications. As can be seen below, there are some individuals with as low as a single publication *ex ante* or *ex post*

and a larger number of individuals with only 2 to 4 publications. While a low number of publications may increase uncertainty of the citation based indicators, we have chosen not to impose stricter requirements on the data in order to keep the samples of PIs and rejected applicants as complete as possible.

Table 5.2. Distribution of individuals according to number publications ex ante and ex post.

	1 pub.	2 to 4 pub.	5 to 9 pub.	10 or more pub.	Total
Ex ante publications					
Rejected applicants	39	141	261	558	999
PI (grantees)	7	38	82	927	1054
Total	46	179	343	1485	2053
Ex post publications					
Rejected applicants	25	111	196	667	999
PI (grantees)	14	73	119	848	1054
Total	39	184	315	1515	2053
Grant publications					
PI (grantees)	91	206	269	371	937

As has been noted above, coverage of publications in CI-WoS is typically much lower for the humanities and social sciences. This is also reflected in the large attrition rates from the sample here for FKK and FSE. Calculations shown above indicate that coverage is around 44 to 55 percent for these two research fields which, while much lower than in the other fields, is higher than was expected. In order to be as inclusive as possible, all calculations and statistical tests have been conducted both for the full group including all five councils and for a subgroup where individuals from FKK and FSE are excluded. Differences for the full and subgroups were typically not large, so we have chosen to show the results for the full group in the main text and point out any eventual differences in our discussion of the results. Tables with results for the subgroup are included in the Appendix.

Tables 5.3 and 5.4 present descriptive statistics for the sample, showing both *ex ante* and *ex post* values, along with values for grant publications. As can be seen in comparison of the two tables, values are typically higher for PIs than for rejected applicants, both *ex ante* and *ex post*. At the same time, it should be noted that levels are high for both groups. In most cases mean values are much higher than the median value, indicating the skewness of the data.

Table 5.3. *Ex ante* and *ex post* MNCS indicators for PIs; mean scores, medians and standard deviations.

		Ex ante MNCS	*Ex post* MNCS All pubs	*Ex post* MNCS PI grant pubs	*Ex ante* PPtop10%	*Ex post* PPtop10% All pubs	*Ex post* PPtop10% PI grant pubs
FKK	Mean	0.91	1.30	1.57	13.%	21.8%	33.9%
	Median	(0.92)	(1.07)	(1.81)	(6%)	(20.6%)	(30%)
	S.D.	(0.91)	(1.07)	(1.10)	(16.6%)	(24.6%)	(37.7%)
FNU	Mean	1.77	1.61	1.74	24.4%	22.2%	23.5%
	Median	(1.40)	(1.25)	(1.20)	(21.5%)	(18.7%)	(20%)
	S.D.	(1.31)	(1.38)	(1.89)	(17.0%)	(17.8%)	(23.5%)
FSE	Mean	1.18	1.60	1.68	16.3%	22.7%	27.1%
	Median	(0.75)	(1.41)	(1.50)	(7.1%)	(20%)	(20%)
	S.D.	(1.14)	(1.22)	(1.36)	(23.0%)	(23.8%)	(31.7%)
FSS	Mean	1.43	1.53	1.92	19.8%	20.5%	22.6%
	Median	(1.26)	(1.28)	(1.32)	(17.6%)	(18.4%)	(17.9%)
	S.D.	(0.77)	(1.04)	(2.22)	(13.4%)	(13.3%)	(23.4%)
FTP	Mean	1.70	1.46	1.70	24.9%	21.9%	23.4%
	Median	(1.41)	(1.16)	(1.25)	(23.2%)	(19.5%)	(20%)
	S.D.	(1.13)	(1.10)	(1.81)	(15.1%)	(15.9%)	(23.9%)
Total	Mean	1.57	1.55	1.81	21.9%	21.4%	23.3%
	Median	(1.32)	(1.25)	(1.27)	(19.3%)	(18.7%)	(19%)
	S.D.	(1.08)	(1.18)	(2.01)	(15.9%)	(16.2%)	(24.0%)

		Ex ante P	Ex post P All pubs	Ex post P PI grant pubs
FKK	Mean	11.7	12.5	4.7
	Median	(7.0)	(5.0)	(4.0)
	S.D.	(14.0)	(14.8)	(3.7)
FNU	Mean	34.4	27.9	11.7
	Median	(26.0)	(21.0)	(9.0)
	S.D.	(28.1)	(28.6)	(11.1)
FSE	Mean	7.7	7.2	3.1
	Median	(6.0)	(5.0)	(3.0)
	S.D.	(6.5)	(8.7)	(2.0)
FSS	Mean	59.5	44.2	10.8
	Median	(46.0)	(34.0)	(7.0)
	S.D.	(56.1)	(39.9)	(8.4)
FTP	Mean	42.2	30.4	8.7
	Median	(33.0)	(22.0)	(6.0)
	S.D.	(39.4)	(27.5)	(8.4)
Total	Mean	44.5	33.8	10.4
	Median	(32.0)	(24.0)	(7.0)
	S.D.	(45.6)	(34.4)	(10.4)

Table 5.4. *Ex ante* and *ex post* MNCS indicators for rejected applicants; mean scores, median and standard deviations.

		Ex ante MNCS	*Ex post* MNCS All pubs	*Ex ante* PPtop10%	*Ex post* PPtop10% All pubs	*Ex ante* P	*Ex post* P All pubs
	Mean	0.99	1.49	21.7%	28.3%	4.4	4.8
FKK	Median	(0.59)	(0.99)	(0%)	(14.3%)	(3.0)	(3.0)
	S.D.	(1.25)	(1.50)	(33.1%)	(32.7%)	(5.5)	(4.5)
	Mean	1.63	1.48	21.5%	20.2%	16.7	19.4
FNU	Median	(1.14)	(1.18)	(16.7%)	(18.6%)	(11.0)	(14.0)
	S.D.	(1.67)	(1.45)	(21.2%)	(18.6%)	(19.2)	(21.4)
	Mean	1.15	1.07	19.8%	13.9%	5.4	8.1
FSE	Median	(0.82)	(0.89)	(0%)	(10%)	(3.0)	(6.0)
	S.D.	(1.26)	(1.05)	(27.4%)	(18.0%)	(6.2)	(8.0)
	Mean	1.11	1.19	14.2%	16.1%	20.6	26.8
FSS	Median	(0.93)	(1.04)	(11.1%)	(14.3%)	(15.0)	(21.0)
	S.D.	(0.97)	(1.03)	(14.7%)	(12.6%)	(20.9)	(24.0)
	Mean	1.32	1.20	21.4%	17.2%	16.5	19.1
FTP	Median	(1.13)	(1.03)	(20%)	(14.3%)	(12.0)	(14.0)
	S.D.	(0.94)	(0.97)	(18.2%)	(15.4%)	(15.1)	(17.9)
	Mean	1.32	1.28	19.1%	17.8%	16.9	20.6
Total	Median	(1.04)	(1.06)	(14.3%)	(15.1%)	(11.1)	(14.0)
	S.D.	(1.25)	(1.10)	(19.6%)	(16.6%)	(18.3)	(21.1)

Method

Both in order to examine the robustness of results and to gain a better understanding of where DFF grants may have had the largest impact, we have employed four different approaches in the analysis.

The first is propensity score matching (PSM) that seeks to ensure that the matched groups of PIs and rejected applicants are as comparable as possible prior to the grant period. The specific propensity score matching approach we employ in this analysis, "Nearest-Neighbor Matching", is described in table 5.5. Our main priority was to ensure comparability in terms of *ex ante* publication performance, so we have adopted a fairly simple framework that includes only a limited number of other variables. First we require an exact match according to research council and age group, where age is grouped in three categories: under 40, 40 to 55, and over 55 years of age at time of funding (2005 for rejected applicants). The probit model used to estimate propensity scores is estimated using only *ex ante* bibliometric indicators. Of the three bibliometric measures, MNJS was best able to predict grant reception, however its inclusion in the probit model gave a weaker match according to the two other bibliometric measures, in particular MNCS. As we consider

MNCS and Ptop10% to be more relevant as outcome measures, we have not included MNJS in the probit model.

Table 5.5. Description of the Nearest-Neighbor Matching procedure used in the analysis.

1) Specify and estimate a probit model of the probability of receiving a grant to obtain propensity scores $\hat{P}(X)$:

$$\Pr(Y = 1|X) = G(\beta_0 + \beta_j X_j)$$

2) Restrict the sample to include only individuals within the common support area (where individuals with the same characteristics have a positive probability of being both treated (grantee) or non-treated (rejected applicant))
3) Each treatment (receipt of grant) is paired with the non-treated that has the closest propensity score. We require first, however, exact matches according to research council and age group. The difference between propensity scores for treatments and matched controls must be within 0.001; otherwise they are excluded from the sample, thus eliminating poor matches. Moreover, matching is performed with replacement; i.e. non-treated are not removed after they are matched with a treated individual. Matching without replacement is affected by the sort order and due to the sample size we wish to avoid this.
4) Applying the matched sample, the average treatment effect on the treated is estimated. As matching with replacement biases the *t*-statistics we correct the standard errors for the appearance of repeated observations by bootstrapping.

The second approach is a simple comparison of the full sample of PIs and rejected applicants shown in Tables 5.3 and 5.4, where statistical tests are conducted to assess differences. As can also be seen in Table 5.3, *ex ante* values are much higher for PIs. Hence the most valid approach here is to compare before-after differences, i.e., whether citation impact has increased more for PIs than for rejected applicants.

The third and fourth approaches examine subsamples, excluding outlying *ex ante* values. We first remove the lowest quartile of the entire sample (both PIs and rejected applicants), measured in terms of *ex ante* MNCS, and thereafter examine results after removing both the lowest and highest quartiles. The idea behind the former is that there may be a number of rejected applicants with much lower performance, and their inclusion in the analysis may weaken the comparison between the two groups. However, in order to treat the two groups equally, we have taken the 25th percentile for the entire sample and removed all observations below this level. The latter removes both the top and bottom quartiles for the entire sample. To a partial extent, this approach attempts to follow the idea used in regression continuity approaches that analyze a narrow

group of granted and rejected applicants that are closest to each other in terms of application scores. However, we do not have such application scores, but by focusing on the middle half of the sample, we greatly limit the variation in *ex ante* values for both groups.

Results

In the following we present the results of the four comparative analyses between PIs and rejected applicants; first the results based on the propensity score matching approach; then the simple comparison of the full sample of PIs and rejected applicants focusing on before-after differences in citation impact and comparison of subsamples based on quartiles.

Propensity score matching

Table 5.6 shows the results of the probit model that is used to estimate the propensity score. Of the two citation impact indicators, *ex ante* MNCS is the better predictor of receiving a grant. 287 grantees are outside of the common support (which essentially requires that individuals have a non-negligible estimated probability of both grant reception and rejection) while all rejected applicants are in the common support, resulting in a sample of 1,766 researchers.

Table 5.6. Results of probit regression and comparison of mean values for the matched sample.

	Coeff.	**Std.Err.**	**P-value**
Dependent var.: Receipt of grant (dummy variable)			
Ex ante PPtop10%	0.056	(0.235)	0.812
Ex ante MNCS	0.103	(0.035)	0.003
Constant	-0.128	(0.045)	0.004
Number of obs	2053		
LR chi2(2)	22.01		0.000
Pseudo R2	0.008		

Comparison of means for matched sample

	Mean			t-test	
	Granted	Rejected	% bias	t-stat	p>|t|
Pscore	0.505	0.505	0.0	0.01	0.994
Year of birth	1960	1959.9	1.3	0.26	0.791
Ex ante MNJS	1.272	1.193	13.3	3.46	0.001
Ex ante MNCS	1.255	1.248	0.6	0.20	0.841
Ex ante PPtop10%	0.181	0.192	-6.5	-1.57	0.118

The common support consists of 767 PIs and 999 rejected applicants, though given that the matching procedure selects the rejected applicants closest to the grantee in terms of propensity

score, not all researchers in the common support may be used (and some rejected applicants may be used more than once if they provide the best match). The resulting matched sample that is used to estimate the average treatment effect for the treated (ATT) consists of in all 1201 researchers, 767 PIs and 434 rejected applicants (for comparison with grant publications, the sample is 1097 researchers, 691 PIs and 406 rejected applicants).

Table 5.7 shows the comparison of means for the full (unmatched) sample and for the matched sample. We have also performed Mann-Whitney tests for the matched sample, again given the skewness of many of the bibliometric indicators used here. The Mann-Whitney test is a non-parametric test that examines whether overall distributions for two groups are equal. If we consider first the comparison with PIs' overall CI-WoS publication activity after grant reception, mean values of both MNCS and PPtop10% are greater for PIs both in absolute values and differences, though differences are only weakly significant for *ex post* MNCS (10% level) and insignificant for *ex post* PPtop10%. The Mann-Whitney test however are somewhat stronger, with distributions significantly higher at the 5% level (1% for *ex post* MNCS) for PIs for all 4 indicators.

Table 5.7. Average treatment effects on the treated for MNCS and Ptop10%, all publications.

		PI	Rejected	Difference	S.E.	P-value (t-stat)	P-value (Mann-Whitney)
Ex post MNCS	Unmatched	1.545	1.280	0.266	0.050		
	ATT	1.415	1.317	0.098	0.066	0.067	0.007
Ex post PPtop10%	Unmatched	0.214	0.178	0.036	0.007		
	ATT	0.196	0.189	0.007	0.011	0.258	0.084
Diff MNCS	Unmatched	-0.057	-0.057	-0.000	0.058		
	ATT	0.116	0.080	0.036	0.063	0.074	0.030
Diff PPtop10%	Unmatched	-0.011	-0.011	0.000	0.009		
	ATT	0.010	-0.005	0.015	0.012	0.066	0.094

When considering instead only grant publications instead of all publications for PIs (*ex post*), shown in Table 5.8, differences in means are much larger and the ATT is significant in all four cases, in particular for the *ex post* MNCS (at 1% level). The results from the Mann-Whitney tests are somewhat weaker, where differences are positive and significant for MNCS and PPtop10% in levels but not in differences.

Table 5.8. Average treatment effects on the treated for MNCS and PPtop10%, grant publications.

		PI	Rejected	Difference	S.E.	P-value (t-stat)	P-value (Mann-Whitney)
Ex ante MNCS	Unmatched	1.810	1.280	0.530	0.073		
	ATT	1.640	1.336	0.304	0.093	0.001	0.078
Ex ante PPtop10%	Unmatched	0.233	0.178	0.055	0.009		
	ATT	0.207	0.190	0.017	0.012	0.092	0.925
Diff MNCS	Unmatched	0.246	-0.045	0.291	0.075		
	ATT	0.366	0.068	0.298	0.091	0.001	0.128
Diff PPtop10%	Unmatched	0.013	-0.012	0.026	0.010		
	ATT	0.024	-0.004	0.028	0.014	0.023	0.525

The results above draw on the full sample including all five research councils. When the analysis is limited to the STEM fields where CI-WoS coverage is highest (FNU, FSS and FTP), results are similar though with some differences. For all *ex post* publications, results for the ATT are slightly weaker when FKK and FSE are removed, though given that differences were only weakly significant for all five councils, with the result that they are not significant for FNU, FSS and FTP. In contrast, ATT results for grant publications are slightly stronger when FKK and FSE are removed, though with the same levels of significance (5% level). Results from the Mann-Whitney tests are generally the same with and without FKK and FSE.

Comparison of grantees and rejected applicants for full and subsamples

In the following we compare citation impact results for the full sample of PIs and rejected applicants and for subsamples where the first the lowest quartile (*ex ante*) is removed and then both the lowest and highest quartiles. We consider first the entire set of *ex post* publications for PIs and thereafter the publications that are linked to the DFF grant.

Table 5.9 shows the results where PI indicators are based on all publications after grant reception. Results are shown for the same four indicators as above: MNCS, PPtop10% and before-after differences for these two indicators. Both mean and median values are shown for each indicator, and for each of these we have conducted both *t*-tests and Mann-Whitney tests. The results of *t*-tests are indicated by asterisks for mean values for grantees and Mann-Whitney for median values (no asterisk implies that differences are not significant at the 10% level). If we examine the first rows of results for the full sample, we can see that both the *ex post* MNCS and PPtop10% for PIs are significantly greater (at the 1% level) than those for the rejected. In contrast to the matching procedure above, PIs and rejected applicants have not been matched here and thus

did not have similar bibliometric scores *ex ante*. Since, both the MNCS and PPtop10% are higher for PIS both *ex ante* and *ex post*, we cannot interpret this as an indication of an effect of DFF grants. The result does however indicate that DFF is funding on average those with the highest level of performance measured in terms of citation scores. The difference measures provide a more valid measure of a potential effect. While these difference measures are slightly higher for PIs, the differences are not statistically significant. Furthermore, the results indicate that average values for both the MNCS and PPtop10% have declined over time. The results for subsamples can help in determining whether this decline is general across researchers in terms of performance or if it is mainly due to a subgroup, for example the lowest or the highest performers.

The next rows in Table 5.9 show results for the subsample where the lowest quartile in terms of *ex ante* MNCS have been excluded. The lowest quartile includes 173 PIs and 340 rejected applicants. As for the full sample, *ex post* averages for both the MNCS and the PPtop10% are significantly higher for PIs, though now the before-after differences for these two indicators is significantly greater for PIs as well. However, while the difference between PIs and rejected applicants for these differences (the so-called difference-in-difference measure, DiD) are much larger than for the full sample, values for both groups are still negative and actually much lower than for the full sample.

This result changes when we examine values for the middle half of the sample, where both the lowest and highest quartiles have been removed. For all four indicators, values for grantees are again significantly higher, though now differences are positive for PIs. The mean value of the MNCS increases by 0.18 from the *ex ante* to the *ex post* period, which is a fairly sizeable increase. In contrast the increase in the PPtop10% for grantees is negligible, at 0.001. Hence, it would appear that declines both in mean normalized citation scores and proportions of highly cited articles are mainly driven by the highest *ex ante* performers, where the lowest 75% of researchers have generally experienced an increase in the citation rates of their work (both PIs and rejected applicants, though to a much larger degree for PIs). A possible explanation for this result is that the highest performing researchers (*ex ante*) are typically at a later stage of their careers, where it is more a question of maintaining their high level of research and much more difficult to improve further on it. While access to grant funding may be an important factor in maintaining these high levels, it does not appear that it is able to improve performance for this group.

Table 5.10 below shows results where *ex post* citation measures for PIs are calculated solely on the basis of publications that were reported to be linked to the DFF grant. If we compare first

values for MNCS for PIs' grant publications with those in table 5.9 for all publications, it can be seen that mean values are much higher for grant publications while median values are only slightly larger.

Table 5.9. Ex post MNCS and Ptop10% for PIs (all publications) and rejected applicants.

Full sample	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.28	1.062	-0.045	0	0.178	0.151	-0.012	0
Grantee	1.545***	1.254***	-0.023	0.003	0.214***	0.188***	-0.005	0

Q2-Q4	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.449	1.214	-0.322	-0.248	0.202	0.184	-0.065	-0.05
Grantee	1.651***	1.37***	-0.123***	-0.1***	0.229***	0.2***	-0.024***	-0.019***

Q2-Q3	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.247	1.088	0.052	-0.09	0.171	0.153	-0.013	-0.006
Grantee	1.407***	1.193***	0.18**	0.052***	0.192**	0.171***	0.012***	0.001**

Results of statistical tests shown after values for PIs; p-values (one-sided) for t-test shown for mean values and p-values for Mann-Whitney shown for median values. ***/**/* indicates that values are significantly higher for grantees compared to rejected applicants at the 1%/5%/10% level. No asterisk implies that the difference between grantees and rejected applicants is not significant at the 10% level.

This appears to indicate that the citation impact for grant publications has been much higher than non-grant publications for a minority of PIs, while citation impact has been similar for grant and non-grant publications for the group of PIs as a whole. This is also reflected in the results for difference measures. For example for the full sample, before-after differences for both MNCS and PPtop10% are both positive for grant publications compared to *ex ante* and are significantly greater than those for rejected applicants. In contrast, Mann-Whitney tests of whether overall distributions are different for PIs and rejected applicants are not significant for these difference measures. Results for the two subsamples are along the same lines, showing very large increases in mean values of the MNCS, but much smaller increases or a decline in the median.

As for the above results for all publications, for the two subsamples the results for grant publications show large and highly significant differences when examining changes in the MNCS and PPtop10%.

Table 5.10. Ex post MNCS and Ptop10% for PIs (grant publications) and rejected applicants.

Full sample	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.28	1.062	-0.045	0	0.178	0.151	-0.012	0
Grantee	1.81***	1.268***	0.246***	-0.059	0.233***	0.19***	0.013***	-0.01

Q2-Q4	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.449	1.214	-0.322	-0.248	0.202	0.184	-0.065	-0.05
Grantee	1.926***	1.413***	0.182***	-0.105***	0.251***	0.2**	0.002***	-0.022***

Q2-Q3	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.247	1.088	0.052	-0.09	0.171	0.153	-0.013	-0.006
Grantee	1.663***	1.204***	0.428***	0.014***	0.208***	0.167	0.027***	-0.012*

Results of statistical tests shown after values for grantees; p-values (one-sided) for t-test shown for mean values and p-values for Mann-Whitney shown for median values. ***/**/* indicates that values are significantly higher for grantees compared to rejected applicants at the 1%/5%/10% level. No asterisk implies that the difference between grantees and rejected applicants is not significant at the 10% level.

Summary

The validity of a non-experimental effect analysis is dependent on the comparability of treatment and control groups prior to 'treatment' (in this case, receipt of a DFF grant). In this sense, the analysis based on propensity score matching (PSM) should be considered to provide the most valid assessment of effects of DFF grants on the citation impact of grant recipients. The PSM procedure first removes around 300 grantees where it was not possible to make a valid comparison and then selects the most comparable (around 450 of the 999) rejected applicants to analyze the existence of an effect.

The results of the PSM are generally supportive of a positive difference in performance for PIs compared to matched rejected applicants. Both MNCS and PPtop10% are significantly higher

for PIs. This is particularly the case when using the Mann-Whitney test that compares overall distributions of the two groups. T-tests comparing mean values also show a positive effect, though these results are weaker.

At the same time, it is important to keep in mind the limitations to the analysis that has been described above. While this matching procedure goes a long way in ensuring the comparability of PIs and the control group of rejected applicants, it is still unable to control for unobserved factors that may vary over time. In addition, the low number of publications for some individuals can affect the precision of estimates.

Compared to all *ex post* publications for PIs, averages for MNCS and PPtop10% are much higher for grant publications while the median values are almost equal. This implies that values for grant publications are more highly skewed, with DFF grants yielding higher citation impact for some while for most the impact for grant and other *ex post* publications are more similar. The PSM results for grant publications appear to reflect this, with strong, positive results concerning mean values but much weaker results concerning the overall distribution of grant publications compared to that for matched rejected applicants.

The remaining approaches compare PIs and rejected applicants for the full and subsamples. As they do not utilize a matching procedure to ensure that citation performance is comparable prior to grant reception, it is only reasonable to consider the difference in difference (DiD) estimates that compare before-after differences in MNCS and PPtop10%. Comparison of the full and subsamples is particularly helpful in seeing where DFF grants may have had the greatest impact.

We do not find evidence of a significant difference in citation impact when considering the full sample. This appears to be in particular influenced by the lowest performing PIs ex ante. While their citation impact increases, it does not increase more so than for comparable rejected applicants.

Before-after differences in citation impact among the highest performers are greater for PIs; however, average citation impact declines over time for both groups. One possible explanation for this result is that this group consists of well-established researchers that are still produce work with high impact but are not able to maintain previous levels.

The strongest results were found for the middle group of grantees, who experienced large increases in citation impact that was also significantly higher than for rejected applicants.

Comparative analyses of journal publication behaviour among FKK and FSE applicants based on publications from the national BFI database from 2009 to 2012

In Chapter 4 we examined the publication behaviour for FKK and FSE grant publications in relation to the national and international journals these articles were published in. We used the "status" levels of journals as determined in the national Danish bibliometric indicator (BFI). Hence, we examined the proportion of level one and level two journal articles published between 2009 and 2012 for the councils and compared them to overall national trends. Indeed, publication behaviour for all five councils showed a larger "preference" for publishing in level two journals compared to national trends for the main research areas. The background for doing this analysis was the perceived poor coverage of especially FKK journal articles in the CI-WoS. As the main focus of this report is performance analyses based on impact, poor coverage of FKK and to a lesser extent FSE makes such analyses questionable. Hence, to support the overall publication analyses and in order to be able to better characterize these poorly covered fields, a journal publication behaviour analysis was included. Obviously, we still focus upon journal publication behaviour, which indeed plays a less important role in the social sciences and especially the humanities compared to the traditional STEM fields. But the two-tiered Danish classification of journals needed for an examination of publication activity according to journal "status" is a selective chosen subset of outlets but it only categories journal articles in from 2009-2012, in turn, however all language journal are covered. So, journal publication behaviour is the only viable means for examining FKK and FSE according to "preferences for publication".

Similar to the supportive BFI-journal publication behaviour analysis for FKK and FSE in Chapter 4, we also perform a corresponding analysis to support the above-outlined comparative analyses between PIs and rejected applicants. The analysis presented below is more restrictive than the analysis in Chapter 4 as we only consider PIs and rejected applicants from FFK and FSE. Also, the matching procedures are not as sophisticated as the impact analyses above due to lack of proper bibliometric matching data and because we needed other data collection techniques which we expected to would cause considerable attrition among cases, hence a pragmatic strategy was applied and then subsequent assessments of the results will determine the validity of the findings.

Below in Table 5.11 we present a comparison between PIs and rejected applicants in relation to their "preference" for publishing in level one and level two journals in 2009 to 2012. Notice, the publication sets examined include both grant and not grant publications. Also, it is not possible to do a meaningful analysis of pre and post application publication behaviour as we only

have journal "status" data from 2009 to 2012. We have, however, looked into more general publication profiles from 2001 to 2012 based on searches for individual PIs and rejected applicants in the Danish National Research Database (NRD), but the profiles from these results (i.e., publication types published) were quite similar; though generally we consider this data problematic. Hence, we only focus upon the actual journal publication activity from 2009 to 2012 as these data can be validated by combining the matches from the NRD database with publication information from the BFI-database. The data collection and matching techniques are outlined in Chapter 3; here we just sketch the process. All eligible PIs and rejected applicants (defined in the analysis in the previous section) were manually searched for in the NRD database and for those identified publication portfolios were established. Subsequently, supposed journal articles of all kinds published between 2009 and 2012 were extracted and constituted the reduced portfolio for each researcher (remember that the NRD database, while indexing publication type and year, has a lot of noise in its data). Finally, the portfolios of journal articles were automatically matched to journal publications in the BFI data base for the same period. Matching was done on title-strings as the bibliographic information reported to the BFI and NRD databases have the same source, namely local bibliographic information systems at the Danish universities.

From Table 5.11 we can see that PIs, both for FSE and FKK show larger preferences for publishing in level two journals compared to the rejected applicants. However, while the difference is marked for FSE, the difference is small for FKK.

Table 5.11. Journal publication behaviour for FKK and FSE PIs and rejected applicants based on data from the BFI database from 2009-2012.

	FSE: PIs	FSE: Rejected applicants	FKK: PIs	FKK: Rejected applicants
Number of researchers	138	270	115	256
Matched journal publications included in the analysis	508	831	635	421
Mean number of journal publications per portfolio	3.7	3.1	5.5	1.6
Publications in level 1 journals	52.6%	67.1%	65.7%	68.4%
Publications in level 2 journals	47.4%	32.9%	34.3%	31.6%

Given the complicated identification and matching procedures, combined with attrition and the fact the journal status may turn out to be somewhat elusive in many FKK fields, we really cannot draw any firm conclusions for small differences between PIs and rejected applicants in the FKK set. The differences, however, are marked for FSE, here we are able to say that PIs seem to have a greater

preference for publishing in level two journals over level one journals compared to the rejected applicant set. As we have stated before this resonates somewhat with the larger attention to journals publication in many FSE fields, but it is also worth a thought that peer review processes for hiring, promotion and funding to a large extent these days are based on scrutinizing researcher's cv for publication activity. Where publications are published, instead of actual impact, seems to matter. Thus the publication behaviour shown above may also indicate something about what is prioritized in the selection process, be it funding or determining what constitutes a level two journal? No matter what, there is marked difference between those funded and those rejected in the journal publication behaviour between 2009 and 2012 for the FSE applicants.

6. Results of surveys and interviews

Chapter 6 follows up on and supports the two previous chapters on bibliometric performance by presenting results from two surveys among PI's and rejected applicants. The chapter further extends this by presenting the overall results from a series of qualitative interviews tapping into the relative importance and consequences of being funded or getting a rejection among PI's and rejected applicants. Together, the survey results and the interviews thus provide a richer context for the interpretation of the bibliometric analyses.

Methods

Surveys: A brief survey was conducted both among recipients of a DFF grant during 2005-2008 and among the control group of rejected applicants. The purpose of the survey among grantees is twofold. First, the survey seeks to validate and update lists of grant publications that were submitted shortly after project completion. The second objective of the survey is to obtain information on the PI's role in the project, on the research in the project itself, on the importance of the grant and on other funding activity around this period. The following topics are covered in the survey among grantees:

- The PI's role in the funded research project
- Other scientific outputs that were related to the granted project
- Types of contributions of the project (data, method, theory, equipment, etc.)
- Proof of concept for the main idea to be examined
- Other research grants before, during and after the grant period
- The importance of the rejection for the applicant's research, career, later funding opportunities, and the other project participants' subsequent career.

The survey was sent out to all grantees for which a valid e-mail address could be found. While the same questionnaire was used for postdoc fellowships, results are presented separately for postdocs. The resulting sample for grantees included 1399 individuals, including 116 postdoc fellowships. The response rate for the main group of PI's (excluding postdocs) was 64.9%, and 57.8% for postdocs. The relative low number of postdocs means that these results should be treated with caution. This is in particular the case when we look at the results of the individual councils.

The survey among rejected applicants seeks to examine what happened to the projects that were rejected, e.g., whether other sources of funding was found or if the project was abandoned and other funding activity around this period. The survey also asks about the effects of the rejection. The following topics are covered in the survey among rejected applicants.

- What happened to the project that DFF declined to finance?
- (if continued) How was / is the project funded?
- Other research grants over the period 2001-2008, both as PI and as participant.
- The importance of the rejection for the applicant's research, career, management competences, collaborations, later funding opportunities, status and recognition, and the other project participants' subsequent career.

The survey was sent out to all rejected applicants in the control group for which a valid e-mail address could be found, in all 1652 individuals. Out of these 1652, 730 participated in the survey, yielding a response rate of 44.2%.

Interviews: In addition to the surveys a number of qualitative interviews were conducted. The purpose of these interviews was to deepen and nuance the findings of the bibliometric analyses and surveys to grant recipients and rejected applicants to DFF. To this end, 30 individual interviews were conducted with 20 funded PIs (4 from each of the five councils) and 10 rejected applicants (2 from each council). It is important to note that this sample size cannot be representative of the entire population of granted and rejected applicants to DFF, and the variation across councils should merely be seen as an attempt to cover a wide variety of qualitatively different experiences.

The interviewees were thereby selected with the aim of ensuring variation on as many factors as possible, e.g., bibliometric performance data, number of applications and the (self-reported) significance of receiving/not-receiving a grant. The selection also aimed to ensure variation on gender as well as institutional affiliation.

Interviewees were contacted via email, and subsequently by phone, and the interviews were also conducted over the phone by two individual interviewers on the basis of the jointly developed interview guide that refers directly back to the actual survey responses by PIs and rejected applicants.

The overall themes of the interviews are listed below:

- Career context at time of application
- Fate of the (rejected) project

- Experienced (positive and negative) effects of grant rejection/ approval in relation to status, career
- Role of DFF and other sources of financing in later research funding strategy

In the following sections the results of both the surveys and the interviews are presented.

Characteristics of the projects: Types of outputs, contributions and status of the research idea

The first section with results in this chapter explores selected characteristics of the funded projects based on both the surveys and the interviews. Emphasis is here placed on questions of the status of the research idea at the time of the submission of the proposal, the contributions which the projects have led to, as well as the types of commercially oriented outputs that have come out of the funding.

Table 6.1. Q7. How advanced was the project's main research idea at the stage when the proposal was submitted? (in %). PIs of DFF grants (excl. Postdocs).

	All	FKK	FNU	FSE	FSS	FTP
No proof-of-concept	13.6%	7.9%	11.1%	12.5%	15.8%	17.4%
Some proof-of-concept	73.8%	66.7%	71.7%	78.8%	76.3%	73.0%
Already proven	9.5%	19.0%	11.9%	7.5%	6.3%	7.8%
Don't know/ not applicable	3.1%	6.3%	5.3%	1.3%	1.6%	1.7%
Number of observations	737	63	226	80	253	115

Table 6.1 shows the results from the PIs of DFF grants (excl. postdocs) on the question of how advanced the project's main research idea was at the stage when the proposal was submitted. To the extent that this question can be seen as an indicator of the degree of risk taking in the selection of projects the results indicate that there is a quite large majority of relatively safe, well consolidated research among the funded projects (84% some proof or already proven). In general we do not observe a large variation across the councils, although we see a tendency to more risk taking projects within FSS and FTP.

These results are partially supported by the interviews, where many informants perceive DFF as a relatively risk-averse funding source, which tends to support well consolidated ideas and researchers. As mentioned in the analysis of breakthrough research these findings may contribute to the explanation of why DFF grants lead to a somewhat lower share of breakthrough results than

DNRF. But again it should be emphasized that the two funding bodies play different roles in the Danish system and that a direct comparison could be misleading.

Some informants in the interview study, however, also highlight the innovative nature of their idea and describe their application as a high-risk project. They often express gratitude towards DFF for supporting their ideas, despite their reputation for being risk-averse. What we observe is in other words a somewhat mixed picture.

Table 6.2. Q7. How advanced was the project's main research idea at the stage when the proposal was submitted? (in %). DFF postdoc fellowships.

	All	FKK	FNU	FSE	FSS	FTP
No proof-of-concept	13.0%	0.0%	9.1%	60.0%	11.1%	7.7%
Some proof-of-concept	75.9%	57.1%	81.8%	40.0%	77.8%	92.3%
Already proven	5.6%	14.3%	9.1%	0.0%	5.6%	0.0%
Don't know/ not applicable	5.6%	28.6%	0.0%	0.0%	5.6%	0.0%
Number of observations	54	7	11	5	18	13

When we turn to results of the same question posed to the DFF postdoc Fellowships we see a very similar pattern. Only the results from FSE grant recipients are surprising, but this most likely reflects the very low number of respondents (5) and perhaps the formulation of the survey-question which may be seen as more suited to the hard sciences.

Following these results we then turn to the question of the contributions of the funded projects. Again we make a distinction between PIs and postdoc fellowship recipients. Table 6.3 shows the results from the PIs, while Table 6.4 deals with the responses from the postdocs.

Table 6.3. Q6. Please indicate the contributions of the research project (in %, possible to choose more than one category). PIs of DFF grants (excl. postdocs).

	Developing/ using new data	Developing/ using a new theory	Developing/ using a new method	Developing/ using new equipment	Developing/ using new materials	Other
FKK	76.5%	72.1%	60.3%	10.3%	11.8%	14.7%
FNU	66.7%	69.1%	66.7%	24.8%	15.0%	9.8%
FSE	64.9%	62.8%	41.5%	0.0%	3.2%	7.4%
FSS	75.1%	60.3%	52.5%	13.1%	9.8%	6.7%
FTP	63.4%	60.3%	71.0%	19.1%	24.4%	6.1%
Total	69.7%	64.1%	59.0%	15.8%	13.0%	8.3%
Number of observations: 737						

As we see in the table, large shares of respondents from all councils report that new data, theory and methods have come out of the grants. Not surprisingly a larger variation between different fields can be observed when it comes to new equipment and new materials. In general these figures are substantially lower for all fields, but in line with general expectations FNU and FTP scores the highest here.

Table 6.4. Q6. Please indicate the contributions of the research project (in %, possible to choose more than one category). DFF postdoc fellowships.

	Developing/ using new data	Developing/ using a new theory	Developing/ using a new method	Developing/ using new equipment	Developing/ using new materials	Other
FKK	54.5%	63.6%	27.3%	0.0%	18.2%	0.0%
FNU	66.7%	50.0%	58.3%	16.7%	8.3%	16.7%
FSE	50.0%	66.7%	16.7%	0.0%	0.0%	0.0%
FSS	85.7%	61.9%	57.1%	4.8%	4.8%	0.0%
FTP	70.6%	35.3%	47.1%	29.4%	23.5%	0.0%
Total	70.1%	53.7%	46.3%	11.9%	11.9%	3.0%
Number observations: 54						

Table 6.4 shows the results of the same question among the postdoc respondents. The pattern is very similar to the one observed above from the PIs, although the general shares are a little lower. Also this result is in line with expectations, as we hypothesize that the postdoc projects in general are a little less advanced than the larger research projects. Again it should be emphasized that the total number of observations is low, and hence that interpretations of the data should be done with caution.

As the last element in this section we then turn to the reported commercially oriented outputs of the grants. Table 6.5 shows the responses from the PIs, while Table 6.6 shows the results of the postdocs.

Table 6.5. Q4. Please give the number of other scientific outputs that were related to the granted project. Results for PIs of DFF grants (excl. postdocs).

	Sum patent applications	Sum approved patents	Pct. with patent appl. or grant	Sum spinoffs	Pct. with spinoff
FKK	0	0	0.0%	7	5.9%
FNU	10	6	3.7%	7	2.5%
FSE	0	0	0.0%	1	1.1%
FSS	20	9	5.1%	20	3.0%
FTP	37	17	21.4%	7	4.6%
Total	67	32	6.2%	42	3.1%

As Table 6.5 shows the number of these types of other scientific outputs that were related to the granted project is in general quite low across most councils. This is expected as the primary aim of DFF is to support curiosity-driven research rather than research oriented towards commercialization. Unsurprisingly, these types of other outputs are hardly found within FSE and FKK. The highest shares are found within FTP with 37 patent applications and 17 granted patents (21 percent of all).

Table 6.6. Q4. Please give the number of other scientific outputs that were related to the granted project. DFF postdoc fellowships.

	Sum patent applications	Sum approved patents	Pct. with patent appl. or grant	Sum spinoffs	Pct. with spinoff
FKK	0	0	0	0	0
FNU	0	0	0	0	0
FSE	0	0	0	0	0
FSS	0	1	4.8%	0	0.0%
FTP	4	0	5.9%	1	5.9%
Total	4	1	3.0%	1	1.5%

As table 6.6 shows these types of outputs are also low for the postdocs and only found within FSS and FTP. Again attention should be paid to the very low number of observations. Also, in the original reports where the grant outputs were documented, patent applications and patents are also mentioned. In Table 11.8 in the Appendix we have tabulated these initial reported outputs.

Role of the grant recipient in the funded research project:

In addition to the question of the characteristics of the funded projects the surveys and the interviews also looked at the role of the grant recipient in the funded research project. The main question is to what extent the PI is actively involved in the actual research. The same question was also answered by the postdocs.

As Table 6.7 below shows there is in generally a very large share of the PIs (80 percent) indicating that they not only are responsible for the grant and project management, but actively take part in the primary research activities. There are however some variation across the councils with FSE and FKK as the highest (92 and 87 percent respectively) and FSS and FTP as the lowest (72 and 76 percent respectively). This pattern is not surprising given our general knowledge of group sizes and traditions of collaboration within different scientific fields.

Table 6.7. Q1. What was your role in the funded research project? (in %). PIs of DFF grants (excl. postdocs).

	All	FKK	FNU	FSE	FSS	FTP
Project management, and actively part. in research activities	80.1%	86.8%	86.1%	91.5%	71.6%	76.3%
Project management, but only limited part. in research activities	8.2%	2.9%	4.5%	2.1%	12.2%	13.0%
Project management and research activities delegated to colleagues	11.4%	7.4%	9.4%	6.4%	16.2%	9.9%
Other	0.4%	2.9%	0.0%	0.0%	0.0%	0.8%
Number of observations	833	68	244	94	296	131

11 percent on average indicate that they were only responsible for the grant, while the daily project management and primary research activities were delegated to colleagues. The interviews indicate that the establishment of groups is seen as the primary aim of the grants, which supports the survey results above. Many younger PIs mention the possibility to create a research environment around oneself as a major advantage of receiving a grant and as something which has a very positive effect on their future career. Others mention the opportunity to focus on research as a major advantage by means of the exemption from other institutional obligations.

Table 6.8. Q1. What was your role in the funded research project? DFF postdoc fellowships.

	All	FKK	FNU	FSE	FSS	FTP
Project management, and actively part. in research activities	94.0%	90.9%	91.7%	100.0%	95.2%	94.1%
Project management, but only limited part. in research activities	*	*	*	*	*	*
Project management and research activities delegated to colleagues	4.5%	0.0%	8.3%	0.0%	4.8%	5.9%
Other	1.5%	9.1%	0.0%	0.0%	0.0%	0.0%
Number observations	67	11	12	6	21	17

* no answers in this category

When we turn to the same question for the DFF postdoc fellowships, Table 6.8 shows that almost all grant recipients within this category play an active role in the actual research activities. Anything else would also be highly surprising given the size of the projects and the position of the researchers at this level.

Importance of receiving a DFF grant or a rejection

Section 4 deals with the importance of getting a DFF grant as well as the importance of getting a rejection. Table 6.9 shows the results of the PIs, Table 6.10 the results of the postdocs, and finally Table 6.11 shows the results for the rejected applicants.

Table 6.9. Q8. How would you rate the importance of this specific DFF grant? (in %). PIs of DFF grants (excl. postdocs).

For your research at the time						
	All	**FKK**	**FNU**	**FSE**	**FSS**	**FTP**
Crucial importance	55.9%	50.8%	62.3%	57.0%	52.0%	53.9%
Considerable importance	35.4%	38.1%	31.8%	32.9%	39.3%	33.9%
Some importance	7.1%	11.1%	4.0%	8.9%	7.1%	9.6%
Little importance	1.0%	0.0%	0.4%	0.0%	1.2%	2.6%
No importance	0.7%	0.0%	1.3%	1.3%	0.4%	0.0%
Number of observations	732	63	223	79	252	115

For your career						
	All	**FKK**	**FNU**	**FSE**	**FSS**	**FTP**
Crucial importance	33.7%	25.4%	42.6%	34.2%	27.9%	33.0%
Considerable importance	36.7%	38.1%	36.3%	35.4%	35.9%	39.1%
Some importance	20.7%	25.4%	13.5%	13.9%	27.9%	20.9%
Little importance	6.7%	6.3%	4.9%	11.4%	6.8%	7.0%
No importance	2.3%	4.8%	2.7%	5.1%	1.6%	0.0%
Number of observations	731	63	223	79	251	115

The opportunities for later successful funding						
	All	**FKK**	**FNU**	**FSE**	**FSS**	**FTP**
Crucial importance	25.3%	17.5%	31.7%	26.9%	22.4%	22.6%
Considerable importance	39.9%	39.7%	39.8%	28.2%	41.6%	44.3%
Some importance	23.8%	28.6%	18.1%	24.4%	28.4%	21.7%
Little importance	6.9%	9.5%	5.4%	11.5%	5.2%	8.7%
No importance	4.1%	4.8%	5.0%	9.0%	2.4%	2.6%
Number of observations	727	63	221	78	250	115

On the other project participants' subsequent career						
	All	**FKK**	**FNU**	**FSE**	**FSS**	**FTP**
Crucial importance	34.5%	26.8%	33.2%	28.6%	36.0%	41.2%
Considerable importance	38.1%	39.3%	31.8%	38.6%	41.3%	42.1%
Some importance	18.0%	21.4%	20.3%	17.1%	17.4%	14.0%
Little importance	4.8%	0.0%	6.9%	8.6%	4.0%	2.6%
No importance	4.5%	12.5%	7.8%	7.1%	1.2%	0.0%
Number of observations	704	56	217	70	247	114

As Table 6.9 shows, almost all respondents indicate that getting the grant at the time of the proposal was crucial or very important for their research (on average more than 90 percent). We only see minor variations across fields with regard to this question. Also with regard to the importance of the grant for the careers of the recipients, a very large share sees it as crucial or of considerable importance. Here we see some variations across the different councils with most FNU grantees seeing it as crucial (42.6 percent), while the lowest number is found within FKK with 25.4 percent.

Also with regard to the opportunities for later successful funding, large shares see the DFF grant as highly important. Again we see the same pattern as above with FNU grantees rating the importance highest and FKK grantees rating it the lowest. This pattern might reflect the fact that the share of basic funding is much higher within the humanities than within the natural sciences. Finally Table 6.9 also shows that grantees across all areas see the grants as highly important for the careers of the other participants in the projects.

Similarly to these results from the survey above, and not surprisingly, the informants in the interviews generally rate the importance of the grants highly, both for their research at the time, for their career and for the career prospects of others. However, timing seems to affect the perception of career influence of the grants. A grant is perceived to be particularly significant for younger researchers in the beginning of their career, and less significant for more established researchers. The more experienced researchers among the informants are able to look back on their academic career and a range of grant applications along with rejections. The grant that helped them establish a field of research and gain ground in academia is considered the most influential one due to timing. Many informants reflect on and express concern for their younger colleagues, and mention that there ought to be more opportunities for them to establish themselves, similarly.

In terms of the perceived importance of the grant for future grants, there is as mentioned a general idea, that being funded makes it easier to obtain additional funding. Several informants who have both received grants and rejections, however, mention that the criteria for acceptance are not transparent and that the reasons given for receiving the grant vs. not receiving the grant are not particularly helpful in the development of new project applications.

The DFF postdoc fellowship grantees were asked the same questions. Their answers are presented in Table 6.10 below.

Table 6.10. Q8. How would you rate the importance of this specific DFF grant? DFF postdoc fellowships.

For your research at the time	All	FKK	FNU	FSE	FSS	FTP
Crucial importance	79.6%	75.0%	81.8%	75.0%	83.3%	76.9%
Considerable importance	16.7%	25.0%	9.1%	25.0%	16.7%	15.4%
Some importance	1.9%	0.0%	0.0%	0.0%	0.0%	7.7%
Little importance	1.9%	0.0%	9.1%	0.0%	0.0%	0.0%
No importance	*	*	*	*	*	*
Number of observations	54	8	11	4	18	13

For your career	All	FKK	FNU	FSE	FSS	FTP
Crucial importance	72.2%	62.5%	72.7%	75.0%	66.7%	84.6%
Considerable importance	18.5%	25.0%	9.1%	25.0%	27.8%	7.7%
Some importance	7.4%	12.5%	18.2%	0.0%	0.0%	7.7%
Little importance	1.9%	0.0%	0.0%	0.0%	5.6%	0.0%
No importance	*	*	*	*	*	*
Number of observations	54	8	11	4	18	13

The opportunities for later successful funding	All	FKK	FNU	FSE	FSS	FTP
Crucial importance	40.4%	37.5%	45.5%	0.0%	47.1%	38.5%
Considerable importance	28.8%	25.0%	36.4%	66.7%	29.4%	15.4%
Some importance	19.2%	12.5%	9.1%	33.3%	23.5%	23.1%
Little importance	7.7%	25.0%	0.0%	0.0%	0.0%	15.4%
No importance	3.8%	0.0%	9.1%	0.0%	0.0%	7.7%
Number of observations	54	8	11	4	18	13

On the other project participants' subsequent career	All	FKK	FNU	FSE	FSS	FTP
Crucial importance	2.2%	0.0%	0.0%	0.0%	0.0%	9.1%
Considerable importance	17.8%	25.0%	10.0%	0.0%	23.5%	18.2%
Some importance	31.1%	25.0%	40.0%	0.0%	41.2%	18.2%
Little importance	22.2%	0.0%	0.0%	33.3%	23.5%	45.5%
No importance	26.7%	50.0%	50.0%	66.7%	11.8%	9.1%
Number of observations	54	8	11	4	18	13

*no answers in this category

As Table 6.10 shows we see a very similar pattern among the postdoc grant receivers. Very large shares across the board rate the importance of the grant as crucial or of considerable importance for their research at the time, for their subsequent career and for the opportunities for later successful funding. The last question regarding the importance of the grant on the other

participants' subsequent career is not suited for the postdoc category of grants and should be disregarded.

Finally, Table 6.11 shows the results from the rejected applicants with regard to their view on the importance of the rejection.

Table 6.11. Q5. How would you rate the importance of the rejection of your application to the Danish Council for Independent Research? Rejected applicants.

For your research at the time	All	FKK	FNU	FSE	FSS	FTP
Very negative	43.8%	40.9%	43.8%	35.5%	39.4%	54.7%
Somewhat negative	46.0%	50.0%	43.8%	46.2%	52.7%	38.4%
No importance	8.1%	6.8%	9.9%	15.1%	6.7%	5.0%
Somewhat positive	0.3%	0.0%	0.8%	1.1%	0.0%	0.0%
Very positive	1.0%	2.3%	0.8%	0.0%	0.6%	1.3%
Don't know	0.8%	0.0%	0.8%	2.2%	0.6%	0.6%
Number observations	626	88	121	93	165	159

For your career	All	FKK	FNU	FSE	FSS	FTP
Very negative	20.1%	15.9%	24.6%	11.0%	19.4%	25.0%
Somewhat negative	43.6%	36.4%	43.4%	38.5%	44.2%	50.0%
No importance	32.2%	43.2%	25.4%	46.2%	33.9%	21.2%
Somewhat positive	0.8%	1.1%	2.5%	1.1%	0.0%	0.0%
Very positive	1.4%	2.3%	1.6%	0.0%	0.6%	2.6%
Don't know	1.9%	1.1%	2.5%	3.3%	1.8%	1.3%
Number observations	622	88	122	91	165	156

For your management competences	All	FKK	FNU	FSE	FSS	FTP
Very negative	7.1%	8.2%	6.6%	3.2%	7.3%	8.9%
Somewhat negative	22.2%	17.6%	21.3%	14.0%	28.5%	23.4%
No importance	62.9%	63.5%	62.3%	72.0%	59.4%	61.4%
Somewhat positive	1.3%	1.2%	3.3%	2.2%	0.6%	0.0%
Very positive	1.4%	1.2%	1.6%	0.0%	0.6%	3.2%
Don't know	5.1%	8.2%	4.9%	8.6%	3.6%	3.2%
Number observations	623	85	122	93	165	158

For your research collaborations	All	FKK	FNU	FSE	FSS	FTP
Very negative	19.1%	20.7%	18.0%	17.2%	15.9%	23.6%
Somewhat negative	43.7%	41.4%	43.4%	40.9%	45.1%	45.2%
No importance	31.8%	32.2%	33.6%	34.4%	34.1%	26.1%
Somewhat positive	0.5%	0.0%	0.8%	0.0%	0.0%	1.3%
Very positive	1.8%	1.1%	0.8%	2.2%	1.8%	2.5%
Don't know	3.2%	4.6%	3.3%	5.4%	3.0%	1.3%
Number observations	623	87	122	93	164	157

For opportunities for later funding	All	FKK	FNU	FSE	FSS	FTP
Very negative	26.4%	16.1%	31.1%	16.1%	23.0%	38.0%
Somewhat negative	29.1%	32.2%	27.9%	18.3%	41.2%	22.2%
No importance	30.7%	33.3%	32.0%	40.9%	28.5%	24.7%
Somewhat positive	1.3%	0.0%	0.8%	2.2%	0.6%	2.5%
Very positive	0.8%	1.1%	0.0%	1.1%	1.2%	0.6%
Don't know	11.7%	17.2%	8.2%	21.5%	5.5%	12.0%
Number observations	625	87	122	93	165	158

For your status and recognition as a researcher	All	FKK	FNU	FSE	FSS	FTP
Very negative	16.7%	13.8%	16.4%	11.8%	19.5%	18.4%
Somewhat negative	42.3%	33.3%	52.5%	35.5%	45.1%	40.5%
No importance	36.2%	46.0%	25.4%	45.2%	32.3%	38.0%
Somewhat positive	0.2%	0.0%	0.8%	0.0%	0.0%	0.0%
Very positive	0.5%	0.0%	0.0%	1.1%	0.6%	0.6%
Don't know	4.2%	6.9%	4.9%	6.5%	2.4%	2.5%
Number observations	624	87	122	93	164	158

On the other project participants' subsequent career	All	FKK	FNU	FSE	FSS	FTP
Very negative	12.5%	11.6%	8.3%	15.4%	12.3%	14.7%
Somewhat negative	33.4%	37.2%	20.7%	23.1%	41.7%	38.5%
No importance	38.1%	29.1%	47.9%	42.9%	37.4%	33.3%
Somewhat positive	0.5%	0.0%	0.8%	1.1%	0.6%	0.0%
Very positive	0.8%	1.2%	0.8%	1.1%	0.6%	0.6%
Don't know	14.7%	20.9%	21.5%	16.5%	7.4%	12.8%
Number observations	617	86	121	91	163	156

As the table above shows, the negative consequences of a rejection appear to be of highest importance with regard to the research of the applicants at the time of the submission of the application. Close to 90 percent rate the rejection as very negative or somewhat negative. We do not observe large variations across the different councils with regard to this question.

Also with regard to the importance of the rejection for the career of the applicants we see large shares indicating that the consequences have been very negative or somewhat negative. It is however worth noticing that almost a third of all respondents see the rejection as having no importance for their subsequent career. The shares are highest within FSE and FKK and lowest within FNU and FTP. As mentioned earlier this is most likely the result of a larger share of internal funding within the two former fields.

When we then turn to the importance of the rejection with regard to management competences we see a more mixed picture. Few see the rejection as very negative, some see it as somewhat negative, but a clear majority sees it as of no importance. In general there is limited variation across the different councils in relation to this question.

The importance of the rejection for research collaborations is in general rated higher across all areas. A little more than 60 percent see the rejection as very negative or somewhat negative in this respect. Again variations are small across the different fields.

Also the negative importance of a rejection is seen as substantial with regard to opportunities for later funding and for the status and recognition of the applicant. Again the shares are lowest for FKK and FSE and highest for FNU and FTP.

With regard to these issues the results from the interviews overall supports the findings from the survey, as the rejected applicants tend to describe the rejection as a negative experience, but at the same time as part of the game. As mentioned before the pressures for external funding is a very present concern for the researchers, and there seems to be a general acknowledgement that not everyone can receive grants. This is also a reason why informants do not perceive a rejection as a blow to their academic status or recognition, but more often describe it as something everyone experiences.

A very negative consequence of a rejection is the implications that it is seen to have on network relations. Some informants describe it as “embarrassing” to involve your academic network relations in an application which is then rejected, and others emphasize that it “wears on the relationships”. Similarly it is seen as negative that the application procedure is so long that it is hard to retain promising PhD students; a perception also found among the PIs. As mentioned above, the PIs commented on the reasons for reception/rejection being non-transparent, and therefore not very helpful in the development of new applications. The rejected applicants describe the same experience, and lament the missed opportunity for constructive feedback. The process of writing up the application is seen, in both groups, as constructive and as a good opportunity to think about and operationalize your research idea, but the feedback procedure of the council is perceived to be wanting.

Funding

In this section the attention is shifted to the funding issue. Also this section contains results from grant recipients as well as rejected applicants with regard to their success in obtaining funding from

other sources. Table 6.12 shows the results for the PIs, Table 6.13 shows the same results for the DFF postdoc fellowships, and finally Table 6.14 shows the results of the rejected applicants. The latter results are not directly comparable to the two former as the formulation of the questions had to differ somewhat due to the different situations for grant recipients and rejected applicants. The survey results are supplemented with interview results.

Table 6.12. Q5. Have you in the three years before the project, during the project period and the three years after project completion received other research grants from any of the sources below (besides the grant you received from the Council)? (% with at least one grant from given source). Results for PIs of DFF grants (excl. postdocs).

Before grant period	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.)	Other foreign sources	Average number of grants	Pct. with grant (any source)
FKK	28.3%	15.1%	11.3%	1.9%	7.5%	1.00	50.9%
FNU	51.7%	6.7%	25.7%	14.3%	9.5%	1.59	69.0%
FSE	39.2%	10.8%	17.6%	2.7%	8.1%	1.11	55.4%
FSS	49.1%	30.6%	59.9%	16.4%	10.3%	3.38	77.2%
FTP	51.9%	32.1%	27.4%	26.4%	10.4%	2.44	73.6%
Total	47.6%	20.0%	35.7%	14.7%	9.6%	2.24	69.6%

During or after grant period	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.)	Other foreign sources	Average number of grants	Pct. with grant (any source)
FKK	26.4%	32.1%	41.5%	7.5%	13.2%	1.70	81.1%
FNU	62.1%	35.2%	61.4%	27.6%	21.4%	4.03	93.3%
FSE	44.6%	39.2%	37.8%	18.9%	21.6%	2.74	85.1%
FSS	59.1%	48.7%	81.5%	31.0%	28.9%	8.25	96.6%
FTP	62.3%	60.4%	52.8%	39.6%	23.6%	4.82	98.1%
Total	56.4%	44.0%	62.8%	28.1%	23.7%	5.28	93.3%

Number of observations: 737

As Table 6.12 above shows, the DFF grantees here have in general been quite successful in obtaining other grants prior to the ones in focus here. But we also observe a large variation across the individual councils showing the different funding structures and funding possibilities between fields. It is shown that FTP grantees have quite high shares within all categories. The same is the case for FSS grantees. For this group the share is in particular high from private Danish sources. This is not surprising given our knowledge of the general Danish funding landscape, where the FSS

area has the most diverse external funding system. FKK and FSE have as expected the lowest shares.

When we turn to the responses to the question of the grantees have received funding from other sources during or three years after project completion we see the same general pattern. The grantees have in general been very successful in obtaining other grants. Again, this is in particular the case within FSS, but also FTP and FNU grantees are doing well. As we see the figure is more than 5 grants per grantee on average. Again, the differences between the different fields are most likely the result of different funding possibilities.

These findings are supported by the interviews which similarly have shown that the funding landscape for Danish researchers is quite diverse and uneven. There are great dissimilarities in the number of funding sources that are perceived to be relevant and available; few in the Humanities and more in the natural sciences, and partly the technical and social sciences. The need for external funding and the pressures for obtaining grants are however felt across the board.

Regarding the funding strategy and the perception of the individual funding sources, DFF grants are by some mentioned as more prestigious than others, mainly because of the competitiveness and the peer review system. Many respondents however also mention that the need and institutional pressure for external funding "triumphs" the status concern.

A widespread criterion in the funding strategies seems to be the size of the overhead; a priority which significantly increases the attractiveness of DFF grants. Some mention institutional "pressures" towards applying for DFF grants because of the significant size of the overhead, and a few highlight the symbolic meaning of overhead, as "giving something back to the department".

The results above support the perception among the informants that "money breeds money". Several PIs mention the importance of getting the first grant and describe how the initial grant led to the development of new grant applications, new network connections and new grants.

In table 6.13 we look at the responses from the postdoc grantees to the same questions. Again it is important to emphasize that the total number of observations is relatively low and hence that the findings should be interpreted with caution, in particular when focusing at the individual councils. As the figures show when we look at the success in obtaining other research grants before the project, the postdocs have received far fewer grants than the PIs in Table 6.12. This is fully in line with our expectations as postdoc applicants in general seek these grants more or less directly after the completion of their PhDs. There are in general large variations across the different

councils. This is most likely both a reflection of the low number of respondents and the differences in funding possibilities.

Table 6.13. Q5. Have you in the three years before the project, during the project period and the three years after project completion received other research grants from any of the sources below (besides the grant you received from the Council)? (% with at least one grant from given source). DFF postdoc fellowships.

Before grant period	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.)	Other foreign sources	Average number of grants	Pct. with grant (any source)
FKK	25.0%	75.0%	25.0%	0.0%	0.0%	1.25	100.0%
FNU	20.0%	10.0%	10.0%	0.0%	10.0%	0.6	50.0%
FSE	0.0%	0.0%	0.0%	0.0%	0.0%	0	0.0%
FSS	18.8%	6.3%	56.3%	6.3%	6.3%	1.875	68.8%
FTP	7.7%	23.1%	15.4%	0.0%	0.0%	0.462	46.2%
Total	15.2%	17.4%	28.3%	2.2%	4.3%	1.022	56.5%

During or after grant period	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.)	Other foreign sources	Average number of grants	Pct. with grant (any source)
FKK	0.0%	50.0%	25.0%	0.0%	50.0%	1.5	75.0%
FNU	50.0%	0.0%	60.0%	10.0%	10.0%	1.7	100.0%
FSE	33.3%	0.0%	66.7%	0.0%	33.3%	2	100.0%
FSS	37.5%	18.8%	68.8%	18.8%	12.5%	4.813	93.8%
FTP	7.7%	38.5%	69.2%	0.0%	23.1%	2.923	84.6%
Total	28.3%	21.7%	63.0%	8.7%	19.6%	3.13	91.3%
Number of observations: 54							

When we look at the success in obtaining other grants for the postdocs during the funding period or within three years after the completion of their project we see a similar pattern with large differences both among the different councils but also with regard to the different funding sources. Again the main explanation is most likely the different funding landscapes and the low number of observations. Finally, we then in Table 6.14 turn to the funding history of the rejected applicants. As mentioned in the introduction to this section, these figures are not directly comparable to the ones above due to different formulations of the questions. For obvious reasons it would not make sense to ask the rejected applicants of their experiences during or post the project (that they did not receive DFF funding for).

Table 6.14. Q3. Have you in the period 2001-2008 received research grants as the main applicant (PI) from any of the sources below? (% with at least one grant from given source). Rejected applicants.

2001-2004	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.	Other foreign sources	Total number of grants before grant period	Share pre
FKK	26.7%	16.7%	21.7%	3.3%	8.3%	2.867	50.0%
FNU	14.1%	12.8%	19.2%	10.3%	12.8%	1.026	50.0%
FSE	11.7%	20.0%	8.3%	11.7%	3.3%	1.017	43.3%
FSS	15.9%	25.8%	47.0%	6.8%	13.6%	3.939	66.7%
FTP	10.0%	23.3%	25.0%	9.2%	9.2%	1.842	46.7%
Total	14.9%	20.9%	27.8%	8.2%	10.2%	2.342	53.1%

2005-2008	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.	Other foreign sources	Total number of grants during or after grant period	Share post
FKK	11.7%	21.7%	35.0%	8.3%	18.3%	3.23	71.7%
FNU	10.3%	28.2%	35.9%	12.8%	29.5%	2.24	74.4%
FSE	5.0%	33.3%	40.0%	16.7%	11.7%	2.03	73.3%
FSS	11.4%	43.9%	72.7%	7.6%	16.7%	4.32	89.4%
FTP	4.2%	47.5%	49.2%	16.7%	23.3%	3.53	80.0%
Total	8.4%	37.8%	50.7%	12.2%	20.2%	3.30	79.8%
Number of observations		626					

What we see in Table 6.14 is, however, that also the rejected applicants appear to be quite successful in securing other funding. On average they received 2.3 grants in the period from 2001 to 2004 and 3.3 in the period from 2005 to 2008. Again, we see the same variations across the different fields reflecting different funding possibilities. It is also noticeable that the figures of the rejected applicants are somewhat lower than the figures for the grantees, but as mentioned the periods are not directly comparable.

Finally in this section Table 6.15 shows the results of the rejected applicants with regard to their success in receiving research grants as participants (not the main applicant) from the same funding sources as above in the period from 2001 to 2008. As the table shows, the pattern here is very similar to the pattern above (as main applicants), although the shares in general are somewhat lower.

Table 6.15. Q4. Have you in the period 2001-2008 received research grants as a participant (and not the main applicant) from any of the sources below? (% with at least one grant from given source). Rejected applicants.

2001-2004	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.	Other foreign sources	Total number of grants before grant period	Share pre
FKK	11.9%	11.9%	2.4%	16.7%	7.1%	0.714	33.3%
FNU	24.0%	17.3%	14.7%	26.7%	17.3%	1.44	60.0%
FSE	15.8%	12.3%	15.8%	14.0%	5.3%	0.912	42.1%
FSS	12.1%	24.3%	29.9%	12.1%	10.3%	1.645	55.1%
FTP	15.0%	20.8%	10.0%	20.0%	5.8%	1.308	48.3%
Total	15.7%	19.0%	16.2%	18.0%	9.2%	1.304	49.9%

2005-2008	Council for Independent Research (DFF)	Other public Danish sources	Private foundations in Denmark and private companies in Denmark	EU funds (European Commission programs, the ERC, etc.	Other foreign sources	Total number of grants during or after grant period	Share post
FKK	19.0%	16.7%	21.4%	31.0%	16.7%	3.048	76.2%
FNU	21.3%	33.3%	25.3%	21.3%	20.0%	1.907	78.7%
FSE	15.8%	26.3%	19.3%	33.3%	21.1%	1.754	71.9%
FSS	17.8%	38.3%	55.1%	17.8%	17.8%	2.953	75.7%
FTP	29.2%	55.0%	21.7%	30.8%	15.8%	2.917	81.7%
Total	21.7%	38.4%	30.9%	25.9%	18.0%	2.586	77.6%
Number of observations		626					

All in all the two tables above (Table 6.14 and 6.15) show that also the rejected applicants experience considerable success in obtaining research funding from other sources. The tables also show that a quite high share of the rejected applicants at other times have had success with a DFF application, prior or post to the rejection in focus here, or either as main applicant or as participants in other applications.

Status of the rejected projects

Finally, and in continuation of the results above, this section covers the consequences for the rejected projects. Table 6.16 shows what happens to a project after a rejection, while Table 6.17 shows how the projects that are implemented after rejection get funded.

As Table 6.16 shows, almost half of all projects are still seeking funding or are completely dropped after rejection. Among FSS grant seekers this share is however only a fourth.

Table 6.16. Q1. What happened to the project that DFF declined to finance? (in %).

	All	FKK	FNU	FSE	FSS	FTP
The project has been implemented or initiated	21.4%	18.4%	16.7%	20.6%	35.5%	11.9%
The project will be implemented later and other means have been found	7.8%	7.8%	6.5%	5.6%	7.6%	10.3%
The project is still seeking funding	43.7%	45.6%	50.7%	50.5%	24.9%	53.5%
The project has been implemented in a reduced version	20.4%	20.4%	23.2%	17.8%	26.4%	13.5%
The project will not be initiated	6.7%	7.8%	2.9%	5.6%	5.6%	10.8%
Number of observations	730	103	138	107	197	185

On average only 21.4 percent of the projects were fully implemented or initiated at the time of the survey. In addition to this, 7.8 percent indicate that other means have been found and that the project accordingly will be implemented later. Finally, another 20 percent indicate that the project has been implemented in a reduced version. Also with regard to these questions the FSS area stands out reflecting the fact that more funding opportunities are present within this area than within the areas of the other four councils. The other four areas are surprisingly similar with regard to these questions. The explanation of this similarity might be found in Table 6.17 below showing that different areas have different possibilities of combining internal and external funding.

Table 6.17. Q2. How was / is the project funded? (in %).

	All	FKK	FNU	FSE	FSS	FTP
With the institution's internal funds	40.2%	26.1%	35.9%	46.7%	46.0%	37.5%
With other external funding	44.9%	47.8%	48.4%	35.6%	44.5%	46.9%
With a combination of internal and external resources	14.9%	26.1%	15.6%	17.8%	9.5%	15.6%
Number of observations	356	46	64	45	137	64

Table 6.17 accordingly shows that of the projects which were implemented in spite of initial rejection other types of external funding play a role in 85 percent of the cases. Only 15 percent are fully internally funded afterwards. Not surprisingly this share is highest within FKK (26%) and lowest within FSS (9%). On average a little less than half of the projects which are implemented are fully funded from other external funding sources.

7. Funding analyses

When can a publication be considered "belonging" to a funding institution such as DFF as we assume in this report (and previously also the DNRF)? Obviously, this is by some means a problematic issue. Publications initially "belong" to authors who are affiliated and employed by research institutions. These are normally the units of analysis in bibliometric analyses. However, researchers and research groups, on top of their base funding, often also receive external funding, such as DFF and often several funding sources are linked to a project.

This brief chapter examines the funding data provided in the survey and funding acknowledgments given in a subset of the CI-WoS publications from the overall set of DFF-publications. In the surveys presented in the previous Chapter 6 we asked questions relating to funding, prior to the application, during the granting period (for both PIs and rejected applicants) and after the funding period. In this chapter we utilize the information on potential funding acknowledgments indexed since 2008/9 in WoS. We are basically interested in exploring to what extent DFF funding is the only source of funding linked to publications and more generally to explore funding flows and impact.

When reporting the output from a grant, PIs are asked to estimate in percentages to what extent the publication is linked to DFF funding; 100 percent means that no other funding sources have contributed to the research project from which the publication arises. In the survey PIs were given an opportunity to validate or fill in funding information for each publication basically indicating whether the publication was fully or partially funded by the DFF grant. Obviously, such a question is difficult to answer especially since the origins of some of these publications go more than ten years back. Eventually, of the 19,958 publications that were the target for validation, the funding issues had not been considered in 81 percent of them; either because of no response at all or, for those who did validate the publications, not relating to this specific task (notice, in the cases where the PIs originally have estimated funding, this information was preprinted in the surveys). This response rate is not particularly good. However, we may still be able to extract some general funding patterns from the 19 percent of the publications where we actually do have some information. Table 7.1 below shows the distribution between publications that can be considered as "fully funded" or "partially funded" by DFF, proportions of the total are distributed for each council.

A clear and perhaps expected pattern is visible from Table 7.1. For FSS, i.e., the biomedical fields, clearly most publications are a result of more than one funding source. To a somewhat lesser

extent this is also the case for fields subsumed under FNU and FTP. On the other hand, the proportions between "fully" and "partially" funded publications are more evenly distributed for FKK and FSE.

Table 7.1. Distribution of PI survey question on whether a specific publication was "fully" or "partially" funded by the DFF (notice, we only have information on 3874 publications out of a total of19,958, 2771 of the 3874 are journal publications).

	Fully funded by DFF	Partially funded by DFF
FKK	44% (91)	56% (121)
FNU	20% (265)	80% (1034)
FSE	42% (152)	58% (214)
FSS	7% (73)	93% (920)
FTP	33% (329)	67% (670)
Total	24% (915)	76% (2959)

To try and explore this further we approximate in what respect a publication can be credited as "belonging" to a funding institution and thus by implication be a product of that particular funding by performing an exploratory analysis of the funding acknowledgements present in WoS publications from 2008 onwards carried out for the DFF-publications. As explained in Costas and van Leeuwen (2012), WoS is collecting funding acknowledgment (FA) data from August 2008 onwards. In Table 7.2 we present some of the results regarding this analysis and focusing on the presence of FA within the overall set of DFF publications. The purpose is restricted to analysing DFF and other Danish funding agencies.

Table 7.2. Funding acknowledgement in DFF-publications from CI-WoS in the publication period 2008-2012.

	Number of publications	Percentage of total
DFF funding acknowledgement alone	741	18%
DFF funding acknowledgement and other Danish funding agencies	2347	57%
Publications linked to DFF, with funding acknowledgements to other Danish funding agencies, but *not* DFF	1034	25%
Total	4122	

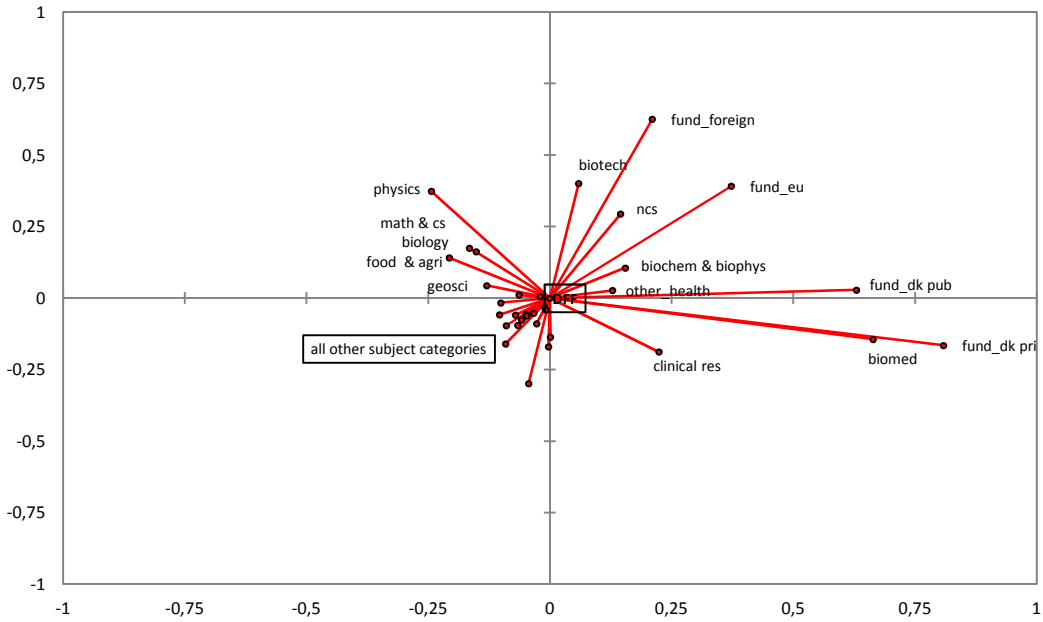
Results in Table 7.2 indicate that around 18 percent of all DFF journal publications with a FA have an acknowledgement to the DFF alone, while 57 percent have acknowledgments to the DFF and some other Danish funding agency(ies) (i.e., approximately in 50 percent of the cases with at least one private foundation or company and/or in approximately 37 percent of the cases, at least one other public research foundation or institution; notice there overlaps are frequent). Interestingly, 25 percent of the publications from 2008 to 2012 have acknowledgements to other Danish funding agencies, albeit not the DFF even though the publications are linked to DFF through the reports (notice, we are relying on the automatic natural language indexing of the acknowledgement fields in CI-WoS and errors are no doubt present, but so are missing acknowledgements from authors). We should emphasize that numbers of publications with acknowledgments are suspiciously low for FKK and FSE. Hence, these results are a picture of acknowledgement patterns in the STEM fields.

Finally, we have examined various combinations of acknowledgements and impact such as DFF and other Danish public and private funders, DFF and EU, DFF and other foreign funders and so forth. Such an analysis quickly becomes rather complicated but a pattern does seem to emerge: impact (normalized citation score per article) is generally good but seemingly on average highest when foreign funding institutions are acknowledged. This resonates with the findings about highest impact in publications with international collaboration. But here we should again stipulate that we are dealing with patterns which are only valid for the STEM fields covered by FSS, FNU and FTP. To explore this complex of overlapping variables we have performed a principal components analysis merely to explore co-variation in the variable set. As variables we have included the following funding variables, binary coded (these are the same code used above and we have manually standardized them and individually coded the 4122 publications): DFF (this is a dummy which means that DFF will intentionally go the center of the plot in Figure 7.1 because all publications are coded as one), EU, Other foreign funders, private Danish funders and other public Danish funders. Then we have coded each publication according to the subject category its parent grant is assigned. These are the same categories used in Chapter 4. Finally, we have the continuous bibliometric variable of normalized citation scores (ncs) for each publication.

The plot can be interpreted as follows: All vectors have their origin in the centre which is DFF. Thus all variables have a relation to DFF; the question is to what extent they are related to each other. Direction of the vectors indicates degree of co-variation, which essentially means that the same variables are present in the same publications. Length of the vectors indicates magnitude. We reiterate that the majority of publications with acknowledgements analysed come from FNU (45 percent) and FSS (34 percent). Some interesting patterns emerge. When publications funded by DFF also acknowledge other Danish private funding sources it is most often publications from grants coded as

"biomedicine". This pattern is very distinct. Indeed, private funding sources have the highest weight and a closer look at the acknowledgment reveals that the Lundbeck and Novo Nordisk foundations have funding acknowledgements in almost one in every four article in this restricted DFF set and a substantial part of these acknowledgments are related to research in the biomedical area. Acknowledgement to other Danish public funders, for example, DNRF, while also in a general direction towards "biomedicine" (and private funding), the direction still indicates a broader coverage albeit still in the biomedical-biochemical areas. The direction of the citation vector indicates that DFF publications where foreign funding sources are acknowledged (including EU) seem to attract most citations.

Figure 7.1. Principal components analysis of funding acknowledgements in 4122 CI-WoS publications; further variables on citations and subject categories are included: Plot of loadings on the first two principal components.



Further, it seems that these other funding sources and the concentration of citation density are centred on grants coded as "biotechnology" and "biochemistry". The latter resonates with impact analyses presented in Chapter 4. Surely, more and more sophisticated analyses can be done, but this small explorative study indicates some distinct and perhaps well-known patterns in the data set.

The results of this chapter are only suggestive but they stress the challenges of "ownerships" of publications and emphasizes that publications can be a result of many influences and several funding organizations. One successful funding often leads to another; this is the well-known phenomenon of preferential attachment, also popularly known as the "Matthew effect".

8. Limitations and caveats

In this brief chapter we summarize in bullets some of the caveats and limitations of the present analysis which should be considered in relation to the interpretation and extrapolation of the results. We refer to the previous chapters for a more detailed discussion of these challenges.

- Bibliometric data and analyses. The performance analyses are restricted to a set of publications limited to the universe of CI-WoS. The data set is therefore limited to mainly English language journals articles, or rather those indexed by CI-WoS. Therefore the results are most relevant in fields where the main publication activity is in (international) journals. With this limitation in mind, it is reasonable to claim that for three perhaps four of research councils, international journals are the main publication outlet and thus a good indicator for scientific and scholarly performance. Another 'usual suspect' is the validity of the indicators used. No doubt, we have applied the best indicators available, but in order to interpret them in a meaningful way, one needs to accept the assumption that they measure impact and that impact somehow reflects the importance of literature use in the scientific community, and that this eventually indicates something about the usefulness or importance of knowledge claims purported in the publications.

- Input data quality and identification and matching processes. The original input data for the bibliometric analyses are the reported grant outputs and names and email addresses for PIs and rejected applicants. The quality of the input data varies considerably which complicates the identification and matching processes in other databases needed to obtain data for the subsequent publication and performance analyses. To try to compensate for this, a survey was constructed to validate reported publication data. Nevertheless, the quality and exhaustiveness of the validation also varies considerably. Consequently, the reported and validated publications are of all sorts, both scholarly and non-scholarly, many are published, some are in the process and some never materialized. The publication lists should therefore be seen more as the reported estimated output of the grants and not a fully complete list. Under the given circumstances, it is impossible to verify every publication. The same is generally true for the identification of publication portfolios for PIs and rejected applicants. The complicated identification and matching procedures where data sets are created for performance analyses, eventually contains attrition where some researchers, publications

and/or grants will be excluded; hence the data sets cannot be considered either the full population of grants from the period, nor a probability sample from such a population. Hence, we cannot rule out systematic bias in these complex processes.

- Benchmark units. In scientometric studies we usually compare like with like such as a research institution with other research institutions and preferably of roughly similar size in output. The benchmark units in this report are not without problems. While the set of publications linked to DFF can be seen as a subset of Danish publications, there are considerable differences in size and coverage. In that respect, the DNRF set of publications seems to be a more suitable benchmark unit for DFF. But such a comparison is also not ideal because, while both units are funding institutions, and of approximately similar size when it comes to publications from 2005 to 2010, the two have quite different modes and funding instruments of widely different scales. Essentially, they play different roles in the Danish research funding ecology. This should be taken into consideration when interpreting the results. An ideal benchmark unit would obviously be very similar funding institutions as DFF but such do probably not exist and we have not been able to construct one.

- Units of analysis. Treating the set of DFF publications as a unit of analysis is unusual and not without problems. Usually publications are assigned to researchers, research groups, departments, institutions or countries, well-defined discrete units. Assigning publications to a funding institution is somewhat fuzzier as publications are a result of many influences and often several funding organizations, and most importantly, determining to what extent a publication is a result of a certain funding can be elusive. Consequently, one publication can "belong" to many different units and different levels of aggregation, depending on the point of view.

- For the time being, the question whether the effect sizes of the annual drops in the Danish PPtop10% and MNCS indicators when removing the DFF-publications can be considered an important or large drop remains unanswered; we simply do not have anything to compare the results with. Statistical significance tests are not an appropriate solution. Our conclusion that the drops are notable is based on our impression and experience with similar data analyses.

- Definition and identification of “breakthrough” articles. The “breakthrough” analysis is exploratory and the methodology is still under development. So far, the approach has been useful and valid, but it is very important to emphasize that given its assumptions, chosen definitions and operationalization it also has several limitations and is certainly not flawless. Refined citation analyses are only able to detect the strongest signals. As signals become weaker we are not able to detect them and given our definition and operationalization therefore not able to identify potential ‘breakthrough’ articles. However, within its limits, we argue that the approach is interesting; we have delineated our approach with reasoned arguments, it is simple and replicable. If signals turn out to be strong our approach will detect them and this we have done in this analysis. Hence, all articles in the WoS database have been treated equally. Yet something will obviously go undetected. Other thresholds and definitions could have been applied and so forth.

- Examining potential effects of being funded. The methodology used for examining potential performance effects of being funded has some limitations that complicate efforts to isolate potential effects. The first concerns the nature of bibliometric data itself. Bibliometric data is typically highly skewed, which means that individual values (that may be driven by individual specific factors) can greatly influence aggregated results. A second limitation is unobserved factors that may also affect developments in citation impact, and potentially in different ways for PIs and the control group. Possibly the most important among these is alternative funding sources. It is likely that the far majority of individuals from both groups (PIs and rejected applicants) have received external funding from a variety of sources; this is actually indicated in the survey answers in Chapter 6. Individuals’ research activities may often rely on a complex stream of different forms of funding, making it very difficult to isolate the effects of a single source. We are though able to identify whether individuals have received a DFF grant or not over the period, however even here we do not know whether rejected applicants have been involved in other DFF grants as a participant (and not the PI). Nonetheless, we still view the comparison of PIs with rejected applicants to be very valuable in shedding light on the effects of DFF grants, in particular given that we are able to identify those publications that are directly linked to DFF grants.

9. Conclusions

In this final Chapter we briefly summarize the main conclusions that can be derived from this bibliometric study; for more details see the summary at the beginning of the report.

The main conclusion of the report is that the DFF sets of publications perform at a high level both when it comes to the proportion of highly cited publications (PPtop10%) and the mean normalized citation scores (MNCS). Performance at the council level is also high albeit with some small variations among individual councils. As expected, coverage for FKK is "poor" so performance indicators for this council should be treated very carefully or simply dismissed. The sets of DFF publications contribute noticeably to the overall Danish impact given its relative size. Interestingly, while there are variations in performance between subject areas, all areas with publication numbers above 50 seem to perform consistently above the international level. The comparative analyses between PIs and rejected applicants are generally supportive of a positive effect of grant receipt for PIs. When comparing subsamples, the strongest results were found for the middle group of grantees, who experienced large increases in citation impact that was also higher than for rejected applicants.

The following bullets highlight more specific conclusions; the conclusions basically follow the chapter structure and are therefore not in any prioritized order.

- Some 19,958 publications were reported as output from 1322 grants. Some 82 percent of the grants examined come from three research councils FNU, FSS and FTP and together they contribute 78 percent of all reported publication types.
- By far the most prevalent reported publication type for all councils combined is journal articles contributing with 50 percent of the total output. But the emphasis upon journal publication varies considerably between the five research councils. For FSS, close to three out of four reported outputs are journal articles, for FNU it is slightly more than 2 out of three reported outputs. The numbers are lower for FTP, slightly under half of the reported output is journal articles, whereas for FSE it is one in three and for FKK one in five. The analyses thereby revealed some distinct but well-known differences in publication behaviour between the five research councils. It is very clear that the main publication activity reported for grants funded by FSS, FNU and to lesser extent FTP is journal articles, whereas

the publication behaviour for FSE and FKK is more heterogenic and less depended on journal publication.

- The publication behaviour discernible for the five research councils provides a picture of what is prioritized and what is considered a scholarly or scientific output in the respective areas. Obviously, this is important when interpreting performance results mainly based on journal publication behaviour.
- The journal publication activity in the most selective journals in the BFI indicator (level two) for publications linked to grants from all five research councils is generally considerably higher than the national trends in publication behaviour from 2009 to 2012.
- The citation impact analyses are based on 6963 unique journal articles from 1042 grants. 49 percent of the publications are linked to FNU, 30 percent to FSS, 16 percent to FTP, 4 percent to FSE and 1 percent to FKK.
- For the impact analyses, coverage in the citation database for the whole DFF set of publications is "excellent". Likewise, at the council level of analysis coverage is "excellent" for FSS, FNU and FTP, but "moderate" for FSE and "poor" for FKK. Nevertheless, the "poor" coverage of FKK is higher than expected and is due to the inclusion of fields like psychology and philosophy under FKK where journal publication activity is considerably more prominent than many other fields in the humanities.
- In general, articles from the overall DFF sets are published in journals with high impact in their respective fields; MNJS scores varying around 1.50 can be considered a high impact profile.
- In the overall DFF set of publications, approximately 19 percent of the articles are among the 10 percent most cited in the database (given the publication and citation windows).
- Likewise, the mean normalized citation score for articles in the overall DFF set is considerably above the international level with 1.80. Related to this, the proportion of non-cited publications in the overall DFF sets is somewhat lower than expected for units of the same size, as well as publication and citation windows.
- The 280 publications linked to the restricted set of postdoc grants funded in 2006 perform remarkably well, well above the overall set of DFF-publications. The articles are published on average in journals with very high impact, and the actual impact of the articles is between 160 to 180 percent above the expected reference value for PPtop10% and 127 to 145 percent

above the expected average database citation rate for MNCS. But we note that the publication set is small compared to DFF and the benchmark units.

- The DFF set of publications constitute some 7.8 percent of all Danish CI-WoS journal articles in the period 2005-2010. These publications receive some 9.7 percent of the total number of Danish normalized citations.
- Publications linked to DFF constitute some 9.7 percent of all highly cited Danish publications in the period 2005-2010 (top 10 percent).
- Excluding the DFF set from the Danish set of publications from the same period results in a decrease of Danish indicator values, 0.3 percentage points for both the MNCS and PPtop10%.
- Performance of the DNRF benchmark unit for the period 2005-2010 is above the performance for the DFF set. This was expected because in principle conditions given to Centres of Excellence generally favours conditions known to have positive influence on high performance. But the differences in indicator values between the two sets are generally small and most importantly both sets perform at very high levels.
- The performance of the DNRF set of publications is somewhat higher than the DFF set with MNCS at 1.88 compared to 1.80, PPtop10% at 21.6 percent compared to 19.1 percent for DFF and MNJS is 1.58 compared to 1.50 for DFF
- The most characteristic difference between the DFF and DNRF sets of publications is their relative influence upon the Danish PPtop10% indictor when one of the sets is removed. The percentage point drop in the Danish PPtop10% indicator is 0.3 when removing the DFF set and 0.6 when removing the DNRF set.
- Interestingly, some 15 percent of the articles linked to the overall DFF set of publications also have a link to Centres of Excellence in the DNRF set.
- Contextualizing the performance level of the overall DFF set places it among the highest performing universities in Europe, albeit such comparisons are difficult.
- Performance calculated for grant types generally reveals high impact for all grant types, but there is some indication that impact is highest for the largest grant types.
- The sets of publications linked to the five individual research councils all perform above the international level. Nevertheless, the FKK set should be treated with much caution due to “poor” coverage. While FSS, FNU, FTP and to a slightly lesser degree FSE, all show high

performance, the performance of the set of articles linked to FSS have a somewhat higher performance level when postdoc publications are included.

- All councils perform considerably better than their benchmarks. The largest drop in indicator values happen in the case of FNU where both MNCS and PPtop10% drops by 0.2 percentage points. The FNU set forms 6.5 percent of the publications in the Danish benchmark set and it contributes with 7.8 percent of the total number of normalized citations to Danish articles and 7.9 percent of all highly cited Danish articles. The difference between the performance with and without the FSS publications is 0.1 percentage points. The FSS set forms 4.1 percent of the publications in the Danish benchmark set and it contributes with 5.1 percent of the total number normalized citations and 4.9 percent of all highly cited Danish articles. A drop in PPtop10% of 0.1 is the only visible difference for FTP. The FTP set forms 2 percent of the publications in the Danish benchmark set and it contributes with 2.4 percent of the total normalized citations and 2.5 percent of all Danish highly cited articles (Ptop10%). Finally, the difference between the performance with and without the FSE publications is 0.1 percentage points. The FSE set forms 4.3 percent of the publications in the Danish benchmark set and contributes with 5.4 percent of the total number of normalized citations to Danish articles and 5.3 percent of all highly cited Danish articles. Notice, the contributions are within the restricted subject sets.
- While several research fields, defined from the subject classification of the grants, show high performance, the most stable seems to be “community medicine & epidemiology” and “biochemistry & biophysics”, as well as “micro and nanotechnology”, “geosciences” and “ICT”.
- The presence of articles from the WoS subject category “multidisciplinary sciences” (e.g., journals such as Nature, Science or PNAS) seem to decisively influence the performance level in many research fields. Comparing the performance of research fields to somewhat similar subject categories in WoS, where the latter does not include articles from “multidisciplinary” journals, shows a marked drop in performance. However, examining the performance of the DFF set of publications for the WoS subject category “multidisciplinary sciences” shows an exceptionally high performance level with PPtop10% of 44 percent and an MNCS of 6.
- In terms of collaboration, some 57 percent of the publications from the DFF set come from international collaboration. As expected, impact is markedly higher among the publications

with international collaboration. But also interesting, when collaborating with international colleagues, publication behaviour tends to be directed toward the highest impact journals as measured by the MNJS.

- Collaboration patterns are somewhat more varied at the council level. As expected, international collaboration is generally more widespread in areas where journal publication is the main publication activity but impact levels are still clearly highest for articles with international collaboration.
- In terms of producing potential "breakthrough" articles from 2005 to 2010 according to our proposed methodology of selecting and filtering among extremely highly cited articles in context, the DFF set of publications basically come up with the same proportions of articles relative to their size as the Danish benchmark set for all three breakthrough categories. The DNRF benchmark set has markedly higher proportions in all three categories and a markedly larger share of all Danish "breakthrough" articles.
- In a restricted subsample of CI-WoS journal publications, it was found that in 82 percent of the publications linked to DFF, at least one other funding source was acknowledged and in 57 percent of the DFF publications, at least one other Danish funding source was acknowledged (i.e., approximately in 50 percent of the cases with at least one private foundation or company and/or in approximately 37 percent of the cases, at least one other public research foundation or institution).
- The results of the comparative analysis where we reduce the set of researchers to those highly comparable based on propensity score matching are generally supportive of a positive effect of grant receipt for PIs. Both MNCS and PPtop10% are higher for grantees.
- When comparing the full sample of researchers without matching procedures, we do not find evidence for differences in citation impact. It appears that this result is particularly influenced by the lowest performing PIs. While their citation impact increases, it does not increase more so than for comparable rejected applicants.
- Comparing subsamples, before and after differences in citation impact among the highest performers are greater for PIs; however, average citation impact declines for both groups.
- The strongest results were found for the middle group of grantees, who experienced large increases in citation impact that was also higher than for rejected applicants.
- Examining journal publication behaviour between funded and rejected FKK and FSE applicants show marked differences for FSE where funded applicants (PIs) have a

preference for publishing in level two journals over level one journals compared to the rejected applicants.

- Survey results among PIs suggest that a large majority of the research proposals submitted (and funded) were already well consolidated at the time of submission, an indication of less risk taking but also an effect of shorter funding periods.
- Survey results among rejected applicants suggest that for two-thirds of the respondents rejection has had consequences for their career. The shares are highest within FSE and FKK and lowest within FNU and FTP.
- Survey results among PIs shows that DFF grantees have in general been quite successful in obtaining other grants prior to the ones in focus here.
- Interestingly, survey results among the rejected applicants also suggest that they appear to be quite successful in securing other funding
- Finally, results from the survey among rejected applicants suggest that almost half of all projects are still seeking funding or are completely dropped after rejection. Among FSS grant seekers this share is however only a fourth. On average only 21.4 percent of the projects were fully implemented or initiated at the time of the survey.

10. References

Caron, E. & van Eck, N. J. Forthcoming. Large scale author name disambiguation using rule-based scoring and clustering. Paper accepted for the 2014 Enid STI conference, September 3-5, Leiden, Netherlands.

Costas, R., van Leeuwen, T.N. (2012). Approaching the "Reward Triangle": general analysis of the presence of Funding Acknowledgments and "Peer Interactive Communication" in scientific publications. *Journal of the American Society for Information Science and Technology*, 63(8): 1647-1661.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Gläser, J., & Laudel, G. (2007). The social construction of bibliometric evaluations. IN: Eds. R. Whitley & J. Gläser *The changing governance of the sciences* (pp. 101-123). Springer Netherlands.

Martin, B. & Irvine, J. (1983). Assessing basic research: Some partial indicators of scientific progress in radio astronomy. *Research Policy*, vol. 2(12), 61-90.

Moed, H.F. (2005). *Citation analysis in research evaluation*. Springer.

Piro, Fredrik Niclas; Aksnes, Dag W.; Rørstad, Kristoffer; (2013). A macro analysis of productivity differences across fields: Challenges in the measurement of scientific publishing. *Journal of The American Society For Information Science And Technology*. ISSN: 1532-2882.

Schneider, J. W. (2013). Caveats for using statistical significance test in research assessments. *Journal of Informetrics*, 7(1) 50-62.

Schneider, J.W. (2014) Null hypothesis significance tests. A mix-up of two different theories: the basis for widespread confusion and numerous misinterpretations. Forthcoming in *Scientometrics*. http://link.springer.com/article/10.1007%2Fs11192-014-1251-5.

Schneider, J.W. & Costas, R. Forthcoming. Identifying potential 'breakthrough' research articles using refined citation analyses: Three explorative approaches. Paper accepted for the 2014 Enid STI conference, September 3-5, Leiden, Netherlands.

Schneider, J.W. & van Leeuwen, T. Forthcoming. Analysing robustness and uncertainty levels of bibliometric performance statistics supporting science policy. A case study evaluating Danish post-doc funding. Accepted for publication in *Research Evaluation*.

Schubert, A.; Glänzel, W. and Braun, T. (1987). Subject field characteristics citation scores and scales for assessing research performance. *Scientometrics*, 12(5): 267-292.

Waltman, L., Calero-Medina, C., Noyons, E.C.M, Tijssen, R.J.W., van Eck, N.J., van Leeuwen, T.N., van Raan, A.F.J., Visser, M, and Wouters P. (2012) The Leiden ranking 2011/2012: Data collection, indicators, and interpretation. *Journal of the American Society for Information Science and Technology*, 63, 12, 2419-2432.

Waltman, L.; Van Eck, N.J. (2012). A new methodology for constructing a publication-level classification system of science. *Journal of the American Society for Information Science and Technology*, 63(12): 2378-2392.

11. Appendix

Tables and figures supporting Chapter 4.

Table 11.1. Descriptive statistics of grant sizes in Danish kroner for the 1042 grants with matched WoS journal publications (1000 Euros is roughly 7500 Danish kroner).

	Larger research projects	Ole Rømer-grants	Postdoc-grants	Research center	Research projects	Skou-grants	Steno-grants
No. of observations	175	3	83	8	700	26	47
Minimum	257,750	4,803,038	160,900	5,231,917	60,000	1,438,737	552,708
Maximum	16,575,344	6,567,943	2,719,837	7,875,000	6,408,321	3,557,582	4,320,000
Range	16,317,594	1,764,905	2,558,937	2,643,083	6,348,321	2,118,845	3,767,292
1st Quartile	1,237,200	5,496,762	813,233	6,127,453	674,325	2,056,967	2,133,859
Median	1,676,925	6,190,486	1,430,635	6,900,620	1,261,713	2,328,862	2,386,128
3rd Quartile	3,203,563	6,379,215	2,011,826	7,754,069	2,025,000	2,889,686	2,836,485
Mean	2,851,906.3	5,853,822.3	1,426,334.2	6,767,276.8	1,665,420.7	2,421,641.0	2,522,212.0
Standard deviation	3,165,280.0	758,827.7	700,822.1	994,306.1	1,361,742.1	552,055.5	705,065.9

Figure 11.1. Distribution of grant sizes among grant types.

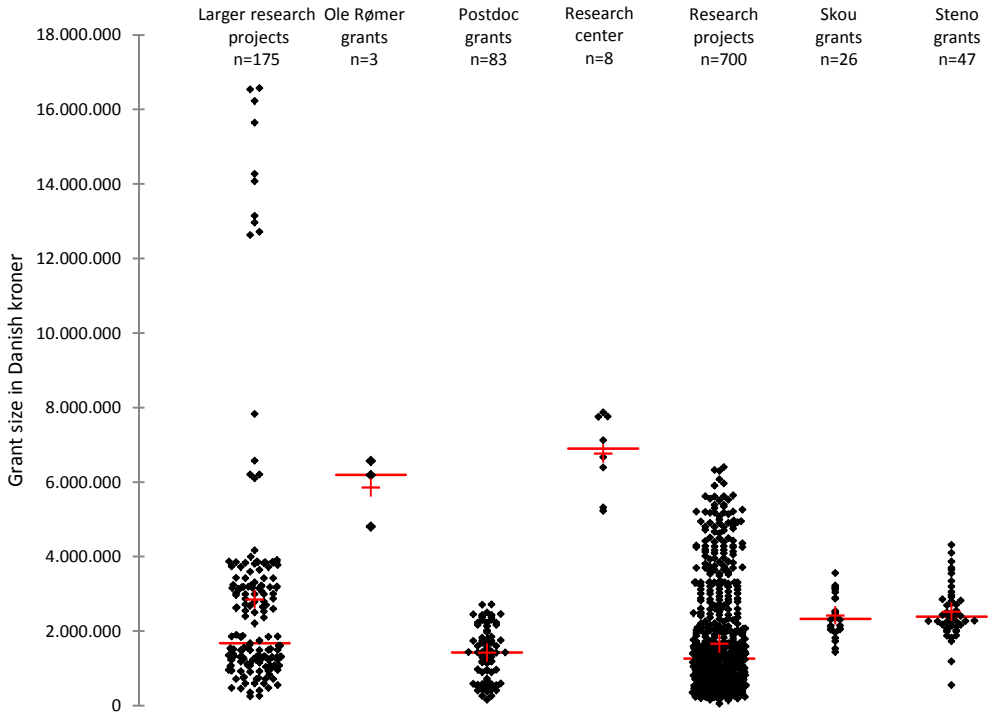


Figure 11.2. Distribution of authors per article.

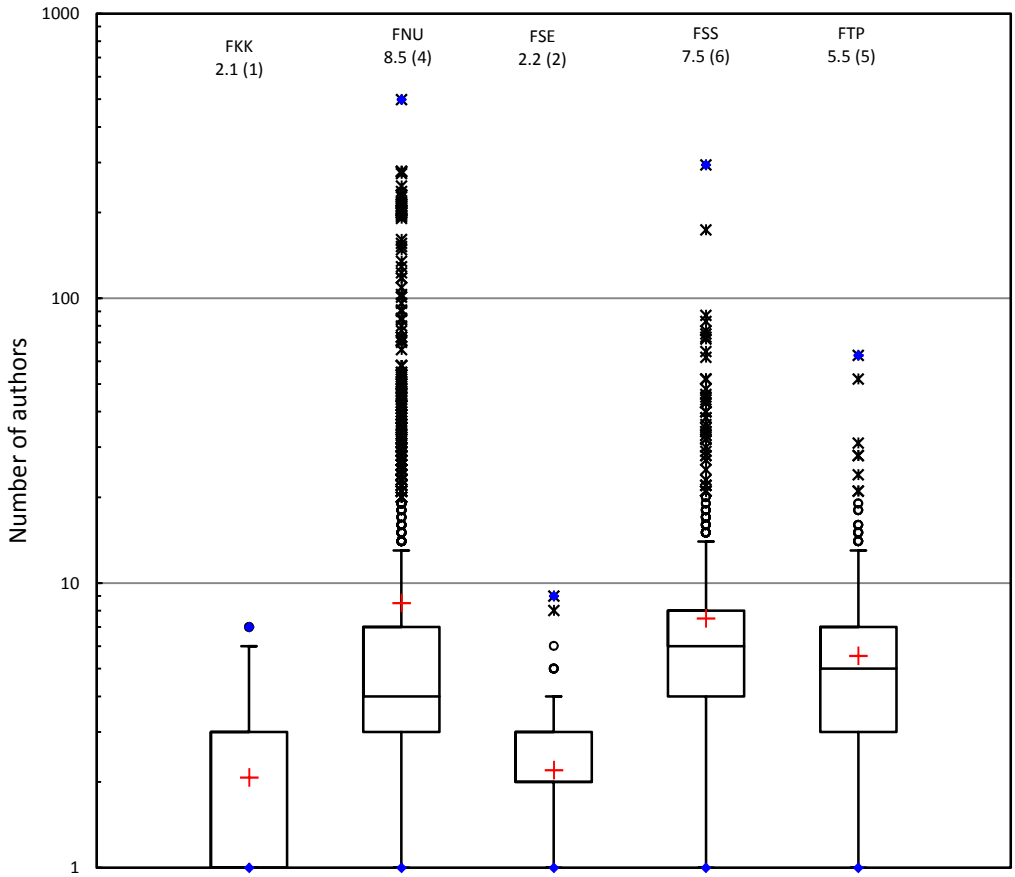


Table 11.2. DFF publications distributed among CI-WoS subject categories, including MNCS and PPtop10% indicators.

ci-wos sc	p	mncs	pp_top_perc	cum pct of p
BIOCHEMISTRY & MOLECULAR BIOLOGY	455.4	1.44	15.5%	6.6%
ASTRONOMY & ASTROPHYSICS	276.5	1.46	17.7%	10.7%
MULTIDISCIPLINARY SCIENCES	275.0	5.91	44.4%	14.7%
PHYSIOLOGY	176.7	1.49	15.9%	17.3%
MATHEMATICS	170.8	1.57	15.8%	19.8%
CELL BIOLOGY	168.7	2.04	26.4%	22.2%
NEUROSCIENCES	167.5	1.12	11.8%	24.7%
ENDOCRINOLOGY & METABOLISM	163.9	1.42	14.7%	27.1%
GENETICS & HEREDITY	162.8	1.91	20.3%	29.5%
CHEMISTRY, PHYSICAL	157.8	1.27	13.4%	31.8%
CHEMISTRY, MULTIDISCIPLINARY	150.5	1.55	15.9%	34.0%
ECOLOGY	127.8	1.57	17.6%	35.8%
PHYSICS, ATOMIC, MOLECULAR & CHEMICAL	123.6	1.46	21.1%	37.6%
PHYSICS, MULTIDISCIPLINARY	121.8	2.38	31.4%	39.4%
ONCOLOGY	121.0	1.56	21.7%	41.2%
OPTICS	117.5	2.21	23.5%	42.9%
MICROBIOLOGY	117.2	1.38	14.8%	44.6%
PHARMACOLOGY & PHARMACY	115.8	2.00	23.3%	46.3%
PLANT SCIENCES	103.0	2.22	26.2%	47.8%
PHYSICS, CONDENSED MATTER	100.4	1.71	24.2%	49.3%
MARINE & FRESHWATER BIOLOGY	97.4	1.41	16.3%	50.7%
IMMUNOLOGY	95.8	1.18	13.6%	52.1%
ECONOMICS	92.0	1.77	18.9%	53.4%
BIOCHEMICAL RESEARCH METHODS	91.4	2.13	30.2%	54.7%
ZOOLOGY	87.8	1.17	12.0%	56.0%
PHYSICS, PARTICLES & FIELDS	80.3	1.66	19.0%	57.2%
STATISTICS & PROBABILITY	76.8	1.29	17.4%	58.3%
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	76.7	2.36	27.6%	59.4%
GEOSCIENCES, MULTIDISCIPLINARY	75.1	1.98	21.3%	60.5%
BIOPHYSICS	73.9	0.93	6.6%	61.6%
PHYSICS, APPLIED	73.5	1.99	15.9%	62.7%
GEOCHEMISTRY & GEOPHYSICS	72.0	1.47	20.5%	63.7%
EVOLUTIONARY BIOLOGY	70.8	1.30	17.4%	64.8%
ENVIRONMENTAL SCIENCES	70.0	1.59	13.8%	65.8%
BIOLOGY	67.0	1.62	15.0%	66.8%
MATERIALS SCIENCE, MULTIDISCIPLINARY	67.0	1.76	17.1%	67.8%
CHEMISTRY, ORGANIC	64.0	1.14	7.2%	68.7%
HEMATOLOGY	59.5	1.03	8.3%	69.6%
OCEANOGRAPHY	51.9	1.79	21.3%	70.3%
UROLOGY & NEPHROLOGY	51.0	1.66	16.6%	71.1%
PUBLIC, ENVIRONMENTAL & OCCUPATIONAL HEALTH	46.1	1.82	25.1%	71.7%

CARDIAC & CARDIOVASCULAR SYSTEMS	46.0	1.48	20.9%	72.4%
PHYSICS, MATHEMATICAL	45.0	3.33	19.5%	73.1%
MATHEMATICS, APPLIED	41.7	0.79	5.8%	73.7%
SPORT SCIENCES	41.7	1.76	24.4%	74.3%
CLINICAL NEUROLOGY	39.0	1.40	17.3%	74.8%
MINERALOGY	36.5	0.61	4.1%	75.4%
ENTOMOLOGY	35.5	2.16	33.2%	75.9%
ENGINEERING, ELECTRICAL & ELECTRONIC	34.9	1.26	17.8%	76.4%
BUSINESS, FINANCE	34.8	1.95	18.2%	76.9%
PERIPHERAL VASCULAR DISEASE	34.2	1.18	16.6%	77.4%
VIROLOGY	33.7	1.28	17.3%	77.9%
SOIL SCIENCE	33.3	0.76	4.5%	78.4%
CHEMISTRY, ANALYTICAL	32.0	1.12	9.9%	78.9%
CHEMISTRY, MEDICINAL	31.7	1.33	15.8%	79.3%
NANOSCIENCE & NANOTECHNOLOGY	31.3	2.07	26.1%	79.8%
GEOGRAPHY, PHYSICAL	31.3	2.80	29.0%	80.2%
TOXICOLOGY	31.1	1.44	14.6%	80.7%
VETERINARY SCIENCES	30.3	2.50	27.7%	81.1%
NUTRITION & DIETETICS	29.7	1.53	28.7%	81.6%
COMPUTER SCIENCE, THEORY & METHODS	28.5	0.66	5.0%	82.0%
MECHANICS	28.4	1.23	10.9%	82.4%
MEDICINE, RESEARCH & EXPERIMENTAL	28.2	2.14	30.3%	82.8%
RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING	28.2	1.57	17.0%	83.2%
POLITICAL SCIENCE	26.2	1.65	17.8%	83.6%
DERMATOLOGY	25.8	1.60	11.6%	84.0%
INFECTIOUS DISEASES	24.8	1.61	11.0%	84.3%
CHEMISTRY, INORGANIC & NUCLEAR	24.6	1.21	6.7%	84.7%
METEOROLOGY & ATMOSPHERIC SCIENCES	23.5	2.72	30.2%	85.0%
FOOD SCIENCE & TECHNOLOGY	21.9	1.08	7.6%	85.4%
AGRICULTURE, DAIRY & ANIMAL SCIENCE	21.5	0.86	5.2%	85.7%
MEDICINE, GENERAL & INTERNAL	21.2	7.08	43.1%	86.0%
GASTROENTEROLOGY & HEPATOLOGY	21.0	1.83	27.4%	86.3%
PEDIATRICS	21.0	0.85	6.9%	86.6%
OPHTHALMOLOGY	20.5	1.32	17.1%	86.9%
CRYSTALLOGRAPHY	19.9	0.65	18.6%	87.2%
PSYCHIATRY	19.8	1.97	20.0%	87.5%
SPECTROSCOPY	19.0	1.65	14.2%	87.8%
PSYCHOLOGY, EXPERIMENTAL	18.2	1.17	11.3%	88.0%
MEDICAL LABORATORY TECHNOLOGY	18.0	1.56	18.1%	88.3%
MATHEMATICAL & COMPUTATIONAL BIOLOGY	17.3	2.09	15.2%	88.5%
PHYSICS, FLUIDS & PLASMAS	17.1	1.12	17.4%	88.8%
BIODIVERSITY CONSERVATION	17.0	1.63	24.0%	89.0%
PALEONTOLOGY	17.0	1.29	20.9%	89.3%
PHYSICS, NUCLEAR	16.8	0.87	9.3%	89.5%

MATHEMATICS, INTERDISCIPLINARY APPLICATIONS	16.1	1.57	18.5%	89.8%
COMPUTER SCIENCE, SOFTWARE ENGINEERING	15.7	0.87	3.9%	90.0%
ANATOMY & MORPHOLOGY	15.7	1.54	14.2%	90.2%
BEHAVIORAL SCIENCES	15.5	1.12	10.5%	90.4%
LIMNOLOGY	14.8	2.35	31.1%	90.7%
DEVELOPMENTAL BIOLOGY	14.4	3.56	39.3%	90.9%
CHEMISTRY, APPLIED	14.0	1.69	20.1%	91.1%
OBSTETRICS & GYNECOLOGY	13.8	2.72	28.2%	91.3%
PSYCHOLOGY, MULTIDISCIPLINARY	13.7	1.29	22.0%	91.5%
ACOUSTICS	13.3	1.77	24.4%	91.7%
ENGINEERING, CHEMICAL	13.1	2.55	22.9%	91.9%
GERIATRICS & GERONTOLOGY	13.0	2.07	21.2%	92.1%
SOCIAL SCIENCES, MATHEMATICAL METHODS	12.9	1.81	22.9%	92.2%
OPERATIONS RESEARCH & MANAGEMENT SCIENCE	12.7	1.00	6.5%	92.4%
MANAGEMENT	12.7	1.61	19.7%	92.6%
RESPIRATORY SYSTEM	12.7	1.66	17.5%	92.8%
AUDIOLOGY & SPEECH-LANGUAGE PATHOLOGY	12.5	1.55	24.9%	93.0%
COMPUTER SCIENCE, INTERDISCIPLINARY APPLICATIONS	12.1	1.67	22.0%	93.2%
COMPUTER SCIENCE, ARTIFICIAL INTELLIGENCE	12.0	1.51	21.6%	93.3%
COMPUTER SCIENCE, INFORMATION SYSTEMS	11.8	0.47	4.4%	93.5%
ENGINEERING, ENVIRONMENTAL	11.8	1.95	21.2%	93.7%
INSTRUMENTS & INSTRUMENTATION	11.6	1.36	14.5%	93.8%
FISHERIES	11.1	1.24	11.5%	94.0%
PATHOLOGY	10.7	0.88	8.1%	94.2%
ANESTHESIOLOGY	10.5	1.23	19.0%	94.3%
WATER RESOURCES	10.5	0.94	9.9%	94.5%
ENGINEERING, BIOMEDICAL	9.8	1.62	25.1%	94.6%
METALLURGY & METALLURGICAL ENGINEERING	9.2	2.11	16.6%	94.7%
GEOLOGY	9.0	0.70	0.0%	94.9%
LOGIC	9.0	0.88	8.8%	95.0%
PHILOSOPHY	9.0	1.70	20.4%	95.1%
AGRICULTURE, MULTIDISCIPLINARY	8.8	1.89	17.9%	95.3%
ALLERGY	8.8	1.73	22.3%	95.4%
BUSINESS	8.8	1.52	17.0%	95.5%
COMMUNICATION	8.8	2.63	17.9%	95.7%
TELECOMMUNICATIONS	8.8	1.80	14.3%	95.8%
REPRODUCTIVE BIOLOGY	8.4	2.25	42.0%	95.9%
ANTHROPOLOGY	8.2	0.92	11.9%	96.0%
SURGERY	8.0	1.55	18.8%	96.1%
PUBLIC ADMINISTRATION	7.6	1.86	19.8%	96.3%
RHEUMATOLOGY	7.5	0.73	0.6%	96.4%
MATERIALS SCIENCE, BIOMATERIALS	7.2	1.99	31.4%	96.5%
SOCIOLOGY	7.2	1.43	8.2%	96.6%
INTERNATIONAL RELATIONS	7.0	0.96	4.8%	96.7%

POLYMER SCIENCE	7.0	1.29	7.7%	96.8%
HISTORY & PHILOSOPHY OF SCIENCE	6.8	2.68	35.7%	96.9%
RELIGION	6.5	3.26	21.6%	97.0%
PARASITOLOGY	6.3	1.24	21.1%	97.1%
ENERGY & FUELS	6.1	2.61	16.4%	97.2%
OTORHINOLARYNGOLOGY	6.0	1.07	12.2%	97.2%
HISTORY	5.5	2.08	21.8%	97.3%
INDUSTRIAL RELATIONS & LABOR	5.0	0.91	0.0%	97.4%
ORNITHOLOGY	5.0	0.84	0.0%	97.5%
SOCIAL SCIENCES, INTERDISCIPLINARY	4.9	1.47	3.0%	97.5%
ENGINEERING, MECHANICAL	4.7	1.53	21.3%	97.6%
FORESTRY	4.7	0.66	2.4%	97.7%
ORTHOPEDICS	4.7	1.77	34.2%	97.7%
AREA STUDIES	4.5	1.38	4.8%	97.8%
CRITICAL CARE MEDICINE	4.5	2.46	22.2%	97.9%
LANGUAGE & LINGUISTICS THEORY	4.5	0.42	2.1%	97.9%
ELECTROCHEMISTRY	4.4	1.20	10.2%	98.0%
AUTOMATION & CONTROL SYSTEMS	4.2	0.19	0.0%	98.1%
MICROSCOPY	4.2	1.64	18.0%	98.1%
PSYCHOLOGY, DEVELOPMENTAL	4.2	0.58	6.0%	98.2%
DEMOGRAPHY	4.0	0.59	1.3%	98.2%
HEALTH CARE SCIENCES & SERVICES	4.0	0.56	3.3%	98.3%
CONSTRUCTION & BUILDING TECHNOLOGY	3.8	1.76	19.8%	98.4%
ENGINEERING, CIVIL	3.5	2.79	35.5%	98.4%
LINGUISTICS	3.3	0.61	2.8%	98.5%
MYCOLOGY	3.3	1.07	15.0%	98.5%
ENVIRONMENTAL STUDIES	3.3	0.52	6.0%	98.6%
AGRONOMY	3.1	1.51	27.0%	98.6%
DENTISTRY/ORAL SURGERY & MEDICINE	3.0	0.51	8.3%	98.6%
ENGINEERING, MULTIDISCIPLINARY	3.0	1.04	4.8%	98.7%
HUMANITIES, MULTIDISCIPLINARY	3.0	5.21	57.3%	98.7%
NUCLEAR SCIENCE & TECHNOLOGY	2.8	0.83	2.3%	98.8%
HORTICULTURE	2.8	0.50	0.0%	98.8%
MATERIALS SCIENCE, COATINGS & FILMS	2.8	0.69	0.0%	98.9%
PLANNING & DEVELOPMENT	2.6	0.71	0.0%	98.9%
CELL & TISSUE ENGINEERING	2.5	0.58	0.0%	98.9%
ANDROLOGY	2.5	2.17	60.0%	99.0%
ETHNIC STUDIES	2.5	0.95	2.0%	99.0%
MATERIALS SCIENCE, CERAMICS	2.5	0.66	0.0%	99.0%
REMOTE SENSING	2.4	1.08	13.8%	99.1%
TRANSPORTATION	2.4	2.97	43.4%	99.1%
HEALTH POLICY & SERVICES	2.3	0.92	0.0%	99.1%
INFORMATION SCIENCE & LIBRARY SCIENCE	2.3	2.65	21.4%	99.2%
TRANSPORTATION SCIENCE & TECHNOLOGY	2.2	3.39	46.7%	99.2%

THERMODYNAMICS	2.2	0.31	0.0%	99.2%
ARCHAEOLOGY	2.1	2.10	35.6%	99.3%
EDUCATION & EDUCATIONAL RESEARCH	2.0	0.75	0.0%	99.3%
GERONTOLOGY	2.0	0.28	0.0%	99.3%
SUBSTANCE ABUSE	2.0	1.19	0.0%	99.4%
MEDICAL INFORMATICS	1.9	1.16	20.4%	99.4%
COMPUTER SCIENCE, CYBERNETICS	1.8	0.81	0.0%	99.4%
ERGONOMICS	1.8	0.81	0.0%	99.4%
TROPICAL MEDICINE	1.7	0.52	0.0%	99.5%
TRANSPLANTATION	1.6	0.47	0.0%	99.5%
ENGINEERING, GEOLOGICAL	1.5	0.30	0.0%	99.5%
ETHICS	1.5	0.72	3.3%	99.5%
LITERATURE, GERMAN, DUTCH, SCANDINAVIAN	1.5	0.00	0.7%	99.6%
MEDICINE, LEGAL	1.5	1.24	16.7%	99.6%
REHABILITATION	1.5	2.48	66.7%	99.6%
URBAN STUDIES	1.5	2.19	48.6%	99.6%
ENGINEERING, MANUFACTURING	1.4	0.97	4.4%	99.6%
IMAGING SCIENCE & PHOTOGRAPHIC TECHNOLOGY	1.4	1.59	23.5%	99.7%
NEUROIMAGING	1.3	2.16	50.0%	99.7%
PRIMARY HEALTH CARE	1.3	0.37	0.0%	99.7%
ROBOTICS	1.3	0.46	3.5%	99.7%
COMPUTER SCIENCE, HARDWARE & ARCHITECTURE	1.3	1.33	8.5%	99.7%
SOCIAL ISSUES	1.3	0.54	0.0%	99.8%
SOCIAL WORK	1.3	1.71	0.0%	99.8%
AGRICULTURAL ECONOMICS & POLICY	1.0	1.63	2.3%	99.8%
ARCHITECTURE	1.0	0.00	3.7%	99.8%
CRIMINOLOGY & PENOLOGY	1.0	1.79	0.0%	99.8%
HOSPITALITY, LEISURE, SPORT & TOURISM	1.0	0.00	0.0%	99.8%
LITERATURE	1.0	0.00	0.0%	99.8%
LITERATURE, ROMANCE	1.0	0.00	8.2%	99.9%
MINING & MINERAL PROCESSING	1.0	0.54	0.0%	99.9%
PSYCHOLOGY, CLINICAL	1.0	1.46	22.6%	99.9%
GEOGRAPHY	0.8	0.41	0.0%	99.9%
ENGINEERING, INDUSTRIAL	0.7	0.23	0.0%	99.9%
ASIAN STUDIES	0.5	0.00	0.0%	99.9%
CULTURAL STUDIES	0.5	10.30	100.0%	99.9%
EDUCATION, SCIENTIFIC DISCIPLINES	0.5	0.00	0.0%	99.9%
ENGINEERING, OCEAN	0.5	0.00	0.0%	99.9%
HISTORY OF SOCIAL SCIENCES	0.5	0.90	0.0%	99.9%
LAW	0.5	0.00	0.0%	100.0%
MEDIEVAL & RENAISSANCE STUDIES	0.5	3.69	36.4%	100.0%
NURSING	0.5	1.86	48.9%	100.0%
PSYCHOLOGY, MATHEMATICAL	0.5	0.95	0.0%	100.0%
SOCIAL SCIENCES, BIOMEDICAL	0.5	7.05	100.0%	100.0%

MATERIALS SCIENCE, CHARACTERIZATION & TESTING	0.3	0.57	0.0%	100.0%
PSYCHOLOGY, BIOLOGICAL	0.3	0.33	0.0%	100.0%
ART	0.3	3.16	25.0%	100.0%
INTEGRATIVE & COMPLEMENTARY MEDICINE	0.3	1.45	0.0%	100.0%

Tables and figures supporting Chapter 5.

Table 11.3. Results of probit regression and comparison of mean values for the matched sample (excl. FKK & FSE).

	Coeff.	Std.Err.	P-value
Dependent var.: Receipt of grant (dummy variable)			
Ex ante PPtop10%	0.356	(0.258)	0.167
Ex ante MNCS	0.079	(0.037)	0.034
Constant	-0.146	(0.048)	0.002
Number of obs	1889		
LR chi2(2)	24.82		0.000
Pseudo R2	0.010		

Comparison of means for matched sample

	Mean			t-test	
	Granted	Rejected	% bias	t-stat	p>|t|
Pscore	0.509	0.509	0.0	0.01	0.989
Year of birth	1960	1960.2	-2.9	0.26	0.563
Ex ante MNJS	1.286	1.182	17.7	4.74	0.000
Ex ante MNCS	1.311	1.274	3.2	1.05	0.292
Ex ante PPtop10%	0.185	0.193	-4.8	-1.17	0.241

Table 11.4. Average treatment effects on the treated for MNCS and Ptop10%, all publications. (excl. FKK & FSE)

		Grantee	Rejected	Difference	S.E.	P-value (t-stat)	P-value (Mann-Whitney)
Ex ante MNCS	Unmatched	1.548	1.289	0.259	0.052		
	ATT	1.427	1.353	0.074	0.063	0.121	0.007
Ex ante PPtop10%	Unmatched	0.214	0.178	0.036	0.007		
	ATT	0.196	0.189	0.007	0.011	0.255	0.022
Diff MNCS	Unmatched	-0.057	-0.057	-0.000	0.058		
	ATT	0.116	0.080	0.036	0.063	0.284	0.050
Diff PPtop10%	Unmatched	-0.011	-0.011	0.000	0.009		
	ATT	0.010	-0.005	0.015	0.012	0.109	0.007

Table 11.5. Average treatment effects on the treated for MNCS and PPtop10%, grant publications. (excl. FKK & FSE).

		Grantee	Rejected	Difference	S.E.	P-value (t-stat)	P-value (Mann-Whitney)
Ex ante MNCS	Unmatched	1.810	1.289	0.529	0.077		
	ATT	1.681	1.352	0.329	0.094	0.000	0.0936
Ex ante PPtop10%	Unmatched	0.231	0.178	0.053	0.009		
	ATT	0.212	0.187	0.025	0.013	0.025	0.621
Diff MNCS	Unmatched	0.234	-0.057	0.291	0.078		
	ATT	0.368	0.077	0.292	0.094	0.001	0.100
Diff PPtop10%	Unmatched	0.008	-0.011	0.019	0.010		
	ATT	0.027	-0.006	0.033	0.014	0.010	0.065

Table 11.6. Ex post MNCS and Ptop10% for grantees (all publications) and rejected applicants.(excl. FKK & FSE).

Full sample	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.289	1.082	-0.057	-0.005	0.178	0.16	-0.011	0
Grantee	1.548***	1.255***	-0.057	-0.023	0.214***	0.188***	-0.011	-0.007

Q2-Q4	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.45	1.218	-0.306	-0.237	0.202	0.187	-0.058	-0.048
Grantee	1.635***	1.361***	-0.134***	-0.115***	0.227***	0.2***	-0.024***	-0.022***

Q2-Q3	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.254	1.103	0.062	-0.063	0.173	0.16	-0.009	-0.006
Grantee	1.394***	1.183***	0.166**	0.042**	0.19**	0.168**	0.009**	0.001*

Results of statistical tests shown after values for grantees; p-values (one-sided) for t-test shown for mean values and p-values for Mann-Whitney shown for median values. ***/**/* indicates that values are significantly higher for grantees compared to rejected applicants at the 1%/5%/10% level. No asterisk implies that the difference between grantees and rejected applicants is not significant at the 10% level.

Table 11.7. Ex post MNCS and Ptop10% for grantees (grant publications) and rejected applicants. (excl. FKK & FSE).

Full sample	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.289	1.082	-0.057	-0.005	0.178	0.16	-0.011	0
Grantee	1.818***	1.267***	0.234***	-0.069	0.231***	0.19***	0.008**	-0.017

Q2-Q4	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.45	1.218	-0.306	-0.237	0.202	0.187	-0.058	-0.048
Grantee	1.922***	1.403***	0.178***	-0.111***	0.248***	0.2*	-0.001***	-0.025***

Q2-Q3	Mean Expost MNCS	Median Expost MNCS	Mean Diff MNCS	Median Diff MNCS	Mean PPtop10%	Median PPtop10%	Mean Diff PPtop10%	Median Diff PPtop10%
Rejected	1.254	1.103	0.062	-0.063	0.173	0.16	-0.009	-0.006
Grantee	1.656***	1.196***	0.42***	-0.003**	0.205***	0.167	0.024***	-0.018

Results of statistical tests shown after values for grantees; p-values (one-sided) for t-test shown for mean values and p-values for Mann-Whitney shown for median values. ***/**/* indicates that values are significantly higher for grantees compared to rejected applicants at the 1%/5%/10% level. No asterisk implies that the difference between grantees and rejected applicants is not significant at the 10% level.

Tables and figures supporting Chapter 6.

Table 11.8. Number of patent applications and patents initially reported.

	Patent applications	Patents
FNU	10	8
FSS	20	12
FTP	41	22
Total	71	42