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Performance-based funding models and researcher behavior: An analysis of the influence of the Norwegian Publication Indicator at the individual level

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Abstract

The growing use of performance-based research funding systems has motivated increased interest in how they influence researcher behavior. This article draws both on survey and publication data to examine developments in researcher behavior and publication activity for individual researchers since the implementation of the Norwegian Publication Indicator in 2004. The Publication Indicator is a system for documenting Norwegian academic publishing, with the aim of measuring publication activity and allocating research funding according to the publishing performance. A main feature of the model is that publications are classified at two levels, where higher-level papers are valued more in terms of the model's publication points. Points are then awarded based on the fractional counts. When following the group of researchers that has been active over the entire period, 2004–12, we find that average points per researcher have fallen over the period. However, at the same time, average publication counts and number coauthors per paper have increased substantially. Essentially, productivity in publication counts has increased but productivity in fractional counts has fallen, as has average publication points. While both increased publications and collaboration would appear to be viewed as positive developments from a policy standpoint, the model's point system risks discouraging collaboration.

Key words: performance-based research funding systems; bibliometric analysis; fractional counts; collaboration.

1. Introduction

The use of performance-based research funding systems (PRFS) has become prevalent in recent years. Starting with the introduction of the Research Assessment Exercise in the UK in 1986, 14 countries had implemented a PRFS as of 2010 (Hicks 2012). Among the objectives behind this trend are the allocation of research funds to the most productive institutions, the pursuit of excellence in research, enhancing accountability of public research, and promoting greater alignment of research to societal and economic needs. This increase in use also generates interest in how these models influence researcher behavior.

We have at best only a partial understanding of how these systems influence research and publication activity. In a series of papers, Butler has examined how Australian researchers appear to have changed their collective publication behavior in the early 1990s in response to a new funding model partly based on a simple measure of publication counts (Butler 2002, 2003a,b, 2004). Based on analyses of data from ISI's citation indices (later Thomson Reuter's *Web of Science*), Butler showed that Australian publication output increased considerably with the highest relative increases in lower-impact journals (Butler, 2003a,b). For a consecutive number of years, this behavior seemingly led to a general drop in overall citation impact. This development was the opposite of the intent with the funding formula which was to reward 'quality'.

The Norwegian Publication Indicator is a system for documenting Norwegian academic publishing, with the aim of measuring publication activity and allocating research funding according to publishing performance. With, in particular, the Australian case in mind, the main purpose of the Norwegian Publication Indicator was to increase research publication without a decline in impact. In order to avoid perverse incentives for researchers to produce more articles in lower-impact journals, publication channels are classified in two levels. Level 1 includes all the channels that can be described as 'scientific' or 'academic'. Level 2 channels are the most important channels within each subject area. The total number of publications (on a global basis) in Level 2 channels must not exceed 20% of a subject area's total scientific publications.

Analysis of the aggregate publication data collected within the Indicator indicates a strong increase in publication activity over the period 2004–12 (also when accounting for increases in personnel and resources), while measures of citation impact or the share of Level 2 publications has remained quite stable (Aagaard et al. 2014). Hence, trends in citation activity have more or less followed that for publications. Indeed, a situation as the one in Australia, where rapid increases in journal publication activity led to marked drops in national impact has not happened in Norway (Schneider, Aagaard and Bloch 2015). However, these aggregate developments may mask a variety of developments in publication activity at the individual level. Preliminary examination of the individual data provides a clear indication that the number (or share) of researchers with a publication has increased greatly over the period. However, it is less apparent what the effect has been on average publication activity for the individual researcher, for example, those researchers that have actively published throughout the period.

The purpose of this article is to examine developments in researcher activity over the period at the level of the individual researcher, controlling for increases in the share of researchers in the university sector that produces scientific publications. The analysis is based on the individual publication data collected as part of the Norwegian model for the period 2004–12 for the four main universities in Norway (University of Oslo, University of Bergen, University of Tromsø, and the Norwegian University of Science and Technology). These four universities accounted for 80% of total publications in Norway in 2005. In order to control for these changes in the number of active researchers, we focus on a fixed group that have published actively throughout the period. The data include information on each publication for university researchers, including channel (journal or publisher), type of publication, and the level of the channel. The data used in this study include only limited information on demographics of researchers, but still make it possible to examine to what extent publication activity has developed over the period at the individual level.

The article does not seek to make causal claims on the impact of the Indicator or other potential factors on researcher behavior, though we do present survey-based evidence on researchers' own assessments of the effects of the Indicator on their research. Our focus is instead on better characterizing trends in publication behavior, which in turn can inform discussion of potential causes and the design of PRFSs.

The article will investigate the following questions:

- Has the level of publication activity per researcher changed over the period, and if so, for what groups of researchers (in terms of academic position and field)?
- Has there been a change in the level of publication channel used, for example, in the share of publications that are Level 2?

Analysis of aggregate developments shows first that publication activity has increased greatly over the period, and far in excess of increases in researchers or resources during the period. Second, the number of researchers with a scientific publication has also increased substantially over the period, by 116%. It is thus evident that the share of researchers actively publishing has increased. However, how has publication activity developed for researchers that were also active prior to the implementation of the Indicator, or who consistently publish over time? We do not have data prior to 2004, but are however able to follow a fixed group of researchers to better identify developments over time.

Based on five waves of survey data, Kyvik and Aksnes (2015) examine publication productivity (measured in number publications) over the period 1980–2013. Controlling for age, they find that the average number of publications per researcher in Norway has increased over time. They argue that a number of factors have influenced this trend, such as improved qualifications of academic staff, improved research conditions, increased research collaboration, and the introduction of incentive and rewards systems.

Our analysis finds that the number of publications per researcher and collaboration (number coauthors per publication) has increased over the period, both overall and for individual academic research positions. Furthermore, the share of publications that are Level 2 has also increased overall and for some positions (professors, associate professors, and PhD students). In contrast to the number of publications, publication points per researcher have actually fallen over the period, with significant declines both overall and for professors, PhD students, and 'other' positions. Essentially, productivity in publication counts has increased but productivity in fractional counts has fallen, as has average publication points. While both increased publications and collaboration would appear to be viewed as positive developments from a policy standpoint, the model's point system risks discouraging collaboration.

The next section of the article describes the Norwegian Publication Indicator, while Section 3 presents some basic results on publication activity during the period 2004–12, including aggregate developments and survey results on the effects of the Publication Indicator. In Section 4, we examine the publication data at the individual level, analyzing differences in publication activity over the period. Section 5 concludes.

2. Performance-based research funding and the Norwegian Model

A key rationale behind performance-based funding models is that competition provides greater incentives for efficiency and productivity at both the individual and institutional level, and concentration of resources can provide the strongest units better opportunities to compete internationally (Geuna and Martin 2003). There are, however, a number of potential problems with the use of these types of systems for research funding. It is, for example, argued that the models can promote risk-averse behavior, and that representation of complex tasks by simple quantifiable targets can create perverse incentives with adverse consequences. Another argument is that indicator-based models often will promote mono-disciplinary research at the expense of the interdisciplinary. In addition, there may be both large direct and indirect costs of these systems, and that these are often underestimated or ignored. Finally, there is the concern that these types of models could discourage certain types of research. Overall, there is thus a perception that formalized, indicator-based assessment systems can have an adverse effect on researchers, organizations, and the research system as a whole if they are not designed and used with great caution (Van Raan 2005).

An additional concern is that these models can promote a very narrow perception of usefulness for public research that neglects the role of research as knowledge resources, the importance of teaching, and research's wider democratic influence, where only quantifiable goals of research are considered legitimate (Budtz Pedersen 2008; Mejlgaard and Aagaard 2009).

Gläser (2007) points to some general implications that appear to be connected to all forms of national performance-based funding systems (Gläser 2007: 257): there is a tendency for institutions to pass down the overall financing models to lower levels; there is a trend toward greater institutional support for research—particularly for external application procedures; there are trends toward new employment practices with greater emphasis on research, and in particular on the most productive researcher; there is a tendency towards internal restructuring, focusing on critical mass, and interdisciplinary collaboration; and finally, there is increasing pressure on individual researchers using quantitative indicators.

It is also highlighted that effects of increased awareness and benchmarking often far exceed the actual redistributive effects, indicating that even relatively small models in economic terms can, at least in the short term, have a major impact on behavior in the university sector. However, there are also studies that suggest that the effect is often reduced considerably when evaluations are repeated (Hicks 2010).

We can distinguish between three main groups of models: the panel based, the publication based and citation based. These are very different approaches and hence have different advantages and disadvantages.

Panel-based models were the first type to be introduced within the UK Research Assessment Exercises (RAE), which was launched in 1986 and replaced by the Research Excellence Framework (REF) in 2014. The exercise has been repeated in 1989, 1992, 1996, 2001, 2008, and in 2014 as the REF. The RAE (now REF) system is based on peer review, where a panel assessed the quality of research in all institutions within a discipline or a particular area of research. Each panel's ranking is based on selected publications from each of the researchers' institutions, along with data on external funding, research activity, and reputation indicators. More than 90% of basic funding for UK universities was allocated on the basis of this system.

A second type is the so-called citation-based models, variants of which can be found in Belgium (Flanders), Poland, Slovakia, and Sweden. The argument behind these models is that citations measure publication impact, thus better accounting for the quality aspect than publication-based models. A direct relation between citations and quality has though not been sufficiently clarified in the literature, although positive correlations are often identified between positive peer reviews and a high impact (Lindsey 1989; Warner 2000).

The third type is the publication-based model, of which the Norwegian model and the Australian model described above are examples. The Norwegian Publication Indicator was developed by the Norwegian Association of Higher Education Institutions (Universitets- og høgskolerådet, UHR) in 2003–4 and is described in detail in the publication 'A Bibliometric Model for Performance-based Budgeting of Research Institutions' (Norwegian Association of Higher Education Institutions 2004). The indicator was first used to distribute funds to universities and colleges in 2006, and in 2008, the system was expanded with a unified database and classification system for the university and university college sector, healthcare organizations, and the institute sector (Sivertsen 2008). The Indicator is used to distribute approximately 2% of the total funds for the University and University College sector and thus constitutes a very small part of the total funding for this sector.

In an attempt to reduce incentives to increase publishing in low-impact channels, the Norwegian Publication Indicator is differentiated, with publication channels classified in two levels. Level 1 comprises in principle all scholarly eligible publication channels, where eligibility criteria are basic norms such as a standard external peer-review process. Level 2 is an exclusive number of publication channels which are deemed to be leading in a field and preferably with an international audience. Level 2 channels constitute at most 20% of a subject area's total (global) scientific publications. The Indicator's point system is weighted in terms of both level and publication form (journal articles, articles in anthologies and monographs). For example, a Level 1 journal article yields one point, and a Level 2 article yields three points, while Level 1 and 2 books yield 5 and 8 points, respectively. Hence, there is an asymmetry in the relation between Level 1 and Level 2 for books compared to journal articles.

Publication points for individual authors are based on fractional counts (e.g. for a Level 1 journal article with four authors, each author contribution counts 0.25 points). The Indicator itself is, however, only intended for use at an aggregated level (Norwegian Association of Higher Education Institutions 2004: 35). However, the transparency, simplicity, and usability of the point system, which are viewed as a clear strength of the Norwegian model, are also the factors which make it possible for local managers and administrators to use it directly at disaggregated levels. Aagaard (2015) describes how the incentive mechanisms embodied in the Publication filter down to use both at the departmental level and in measuring performance of individual researchers. This can both include the way in which the Indicator is used in relation to wages, bonuses, and promotions, and its broader use in monitoring and as a means of setting strategic goals.

3. Aggregate trends

Figure 1 shows the development in publication points for researchers in the Norwegian university and university college sector (UH), from the Indicator's implementation from 2004[1] to 2012. Total publication points for the UH sector have risen from 8,327 in 2004 to 15,189 in 2012, which amounts to a 82% increase over the period. As can also be seen in Fig. 1, the distribution of Level 1 and Level 2 points has remained very stable, with around 20% of total points from publications in Level 2 channels throughout the period. Hence, these aggregate developments do not indicate a shift in publication patterns toward channels with lower impact (e.g. from Level 2 to Level 1 channels), as was found to be the case for Australia (Butler 2004; Sivertsen and Schneider 2012; Schneider, Aagaard and Bloch, 2015). Though, it should be noted here that the level of classification of publication channels has not been constant over the period, and we thus cannot rule out that developments in the nomination process could have influenced these aggregated developments. Furthermore, aggregate developments within the fairly broad university and university college sector can include both changes in the

[1] 2004 is included as this is the first year of publication counting, though budget allocations did not in fact begin until 2005.

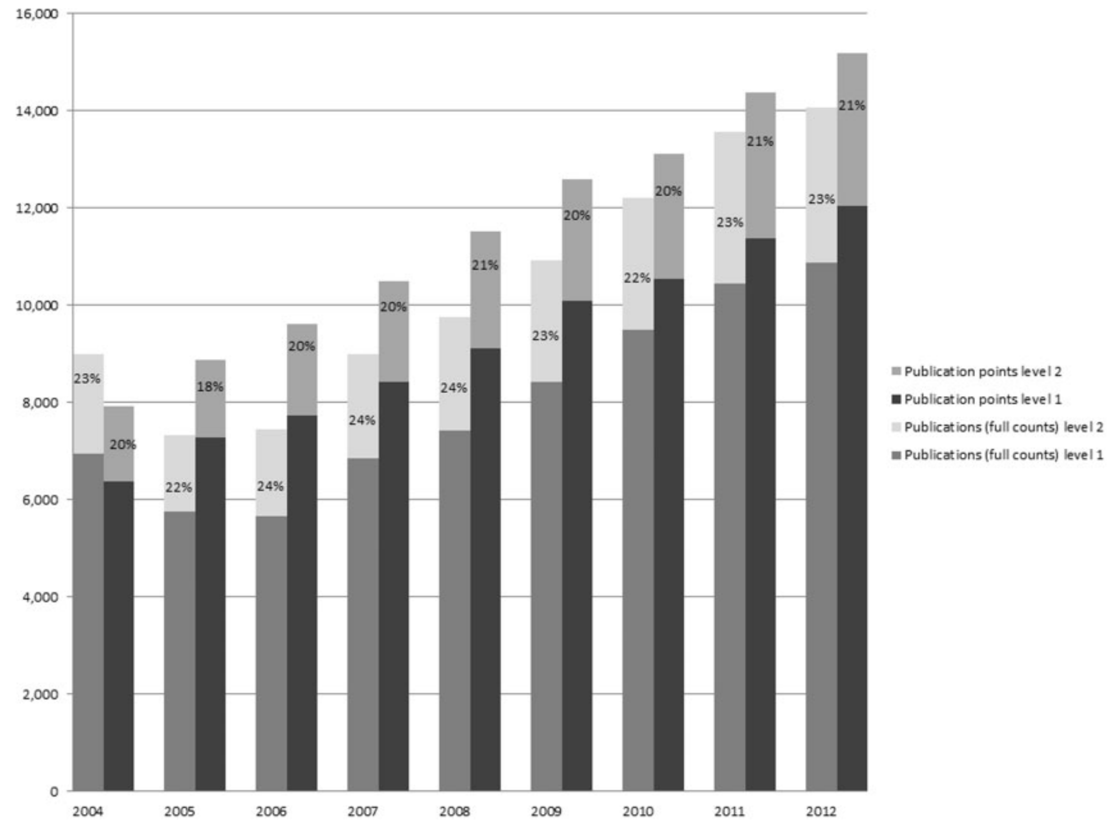

Figure 1. Development in publication output and publication points at the national level and distributed according to the two publication levels. *Source*: NSD/DBH data.

number of researchers that actively publish and changes in average individual publication activity over the period. We return to both of these points below.

This trend in publication activity is difficult to compare internationally, as we do not have data across all fields for other countries. However, Aagaard et al. (2014) compares increases in WoS publication in this period for four Nordic countries. WoS publications in Norway have grown by 69% from 2004 to 2012, which is higher than for Denmark (46%), Sweden (19%), and Finland (14%), as well as world (i.e. database) output (45%).

While publication counts have increased substantially over the period, citation impact has remained fairly constant over the period from 2004 to 2012. For example, the Mean Normalized Citation Score[2] for Norwegian publications covered in the Web of Science database was 1.1 in 2004 and 1.08 in 2010 (Aagaard, Bloch and Schneider 2015). Hence, there is no indication that Norwegian citation impact in general has fallen since the Indicator's implementation.

The list of publication channels (journals and publishing houses) included in the Indicator is reviewed each year, where new channels can be nominated either to be included as Level 1 or to be raised to Level 2. The overall number of registered channels has increased substantially for both levels since 2006, which raises the question to what extent increases in publication activity are in 'new' channels that were not registered in the beginning. To gain a better idea of the scope of these increases, we have classified all publications according to the channel's level at the time of publication and in relation to 2006, i.e.: Level 1 in 2006 and current year; Level 1 current year, but Level 2 in 2006; Level 2 in 2006 and current year; new Level 1; and Level 2 in current year, but Level 1 in 2006. As can be seen in the figure, the number of publications has increased by 79% from 2005 to 2012, from 7,188 to 12,879. Sixty-nine percent of publications in 2012 are from channels that were registered as of 2006. In addition, 11% of publications in 2012 are from channels that initially were Level 1, but have since been upgraded to Level 2. Though, at the same time, 4% of 2012 publications were from Level 1 channels that initially were Level 2. Finally, 11% of publications in 2012 are from Level 1 channels that were not registered as of 2006.

There are two possible interpretations to these trends. One is that early numbers of publications actually understate overall publication activity when the Indicator was established, as many researchers were publishing in channels that were not originally registered. A second interpretation is that there in fact have been large increases in publication activity and that increases in the number of publishing researchers naturally leads to a broader range of publication channels. We are unable to distinguish between these two, though the very gradual increases in publications in these new channels do not appear to suggest that there was heavy activity in these channels prior to their registration. And, it is also important to note again that growth in publication counts for 2006 channels has also been very strong, at around 70% for the period (Fig. 2).

[2] MNCS is 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.

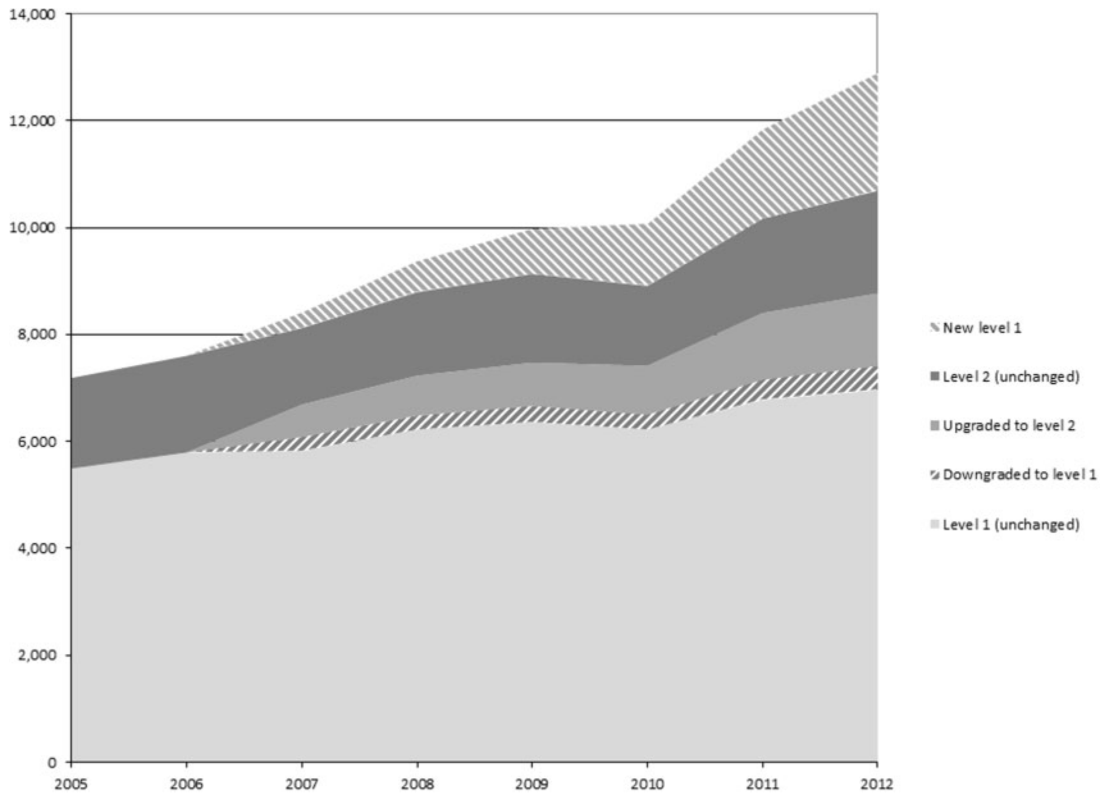

Figure 2. Distribution of publications across Level 1 and Level 2 channels.
Source: NSD/DBH data.

3.1 Survey results on the effect of the Publication Indicator

A survey conducted among researchers at Norwegian universities and university colleges explores a number of aspects related to potential influences on individuals' research behavior (Aagaard, Bloch and Schneider 2015). The first concerns researchers' familiarity with the indicator and its point system. If the researcher is not familiar with the Publication Indicator, then a direct influence seems unlikely, though indirect influence through their institution's management is still very possible. Fifty-eight percent of university researchers have knowledge of the level classification of channels in their research area, but only 31% know specific details of the Indicator, such as the point system or how the system is used to distribute funds to institutions.

Researchers were fairly evenly divided as to whether they viewed publication points as a reasonable performance measure for the individual researcher: 34% agreed with this, 36% disagreed, while 21% neither agreed nor disagreed. Survey results also indicate a very widespread use of the indicator at individual university departments. Twenty-two percent stated that the Indicator was highly used as a general monitoring tool in their department, 36% as somewhat used, and 14% that it was used to a lesser extent. Salary increases, bonuses, or promotions are stated as directly linked to publication points for a small share of university researchers, between 10 and 20%.

These results would thus appear to indicate that there is fertile ground for the Publication Indicator to influence researcher behavior, at least for a sizable minority of researchers. Figure 3 shows results concerning researchers own judgment on the actual impact of the Indicator. Around 31% state that the Indicator has led them to focus more on publication activity included in the indicator (at the expense of non-scientific publications, etc.), and 38% state that they are more apt to submit to Level 2 publication channels. Only 14% state that they publish with a smaller number of coauthors, and only 17% state that the Indicator has led them to increase their publication activity.

4. Publication activity–a micro-level analysis

As mentioned above, a key question here is whether the observed increases in volume are due to: (1) a greater number of researchers that actively publish, (2) an increase in publication activity among those that have been active throughout the period, or (3) a combination of the two? The analysis is based on the CRISTIN database of publications registered as part of the Publication Indicator. We do not have data on employment at the universities, so for years with no publications for a given researcher, we do not know if the individual has not published or has been employed outside of Norwegian higher education. For this reason, the analysis and calculations focus on those researchers with positive publication activity in a given year. As noted above, due to data availability, we focus only on the four main Norwegian universities.

Table 1 shows average publication points per (publishing) researcher over the period 2004–12 across academic positions. The number of researchers with a publication in the four main universities has increased by 73% from 2005 to 2012. In comparison, the number of R&D personnel in these four universities increased by

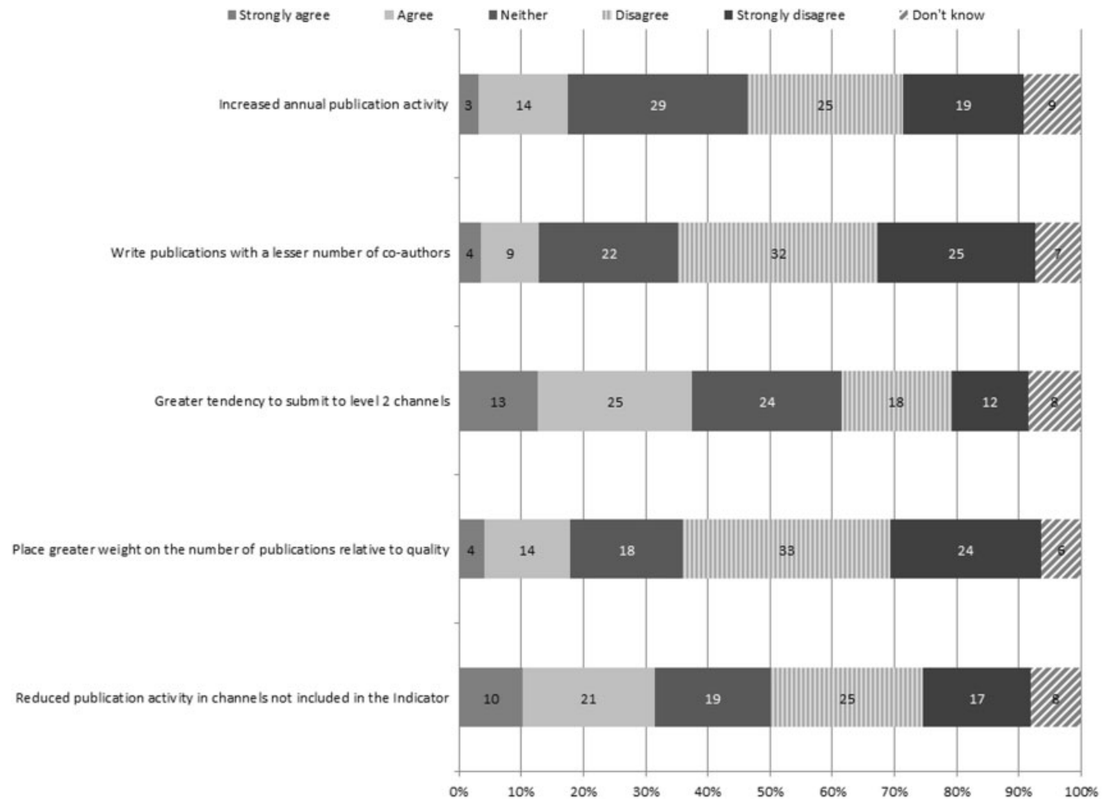

Figure 3. Has the Publication Indicator had the following effects on your current publication activity in 2014? Responses from university researchers. *Source*: Survey of researchers, Evaluation of the Norwegian Publication Indicator (Aagaard et al. 2014)

Table 1. Developments in average publication points (per publishing researcher), from 2004 to 2012 for the four main universities

	Year								
Position	2004	2005	2006	2007	2008	2009	2010	2011	2012
Professor	1.77	1.66	1.68	1.65	1.76	1.73	1.60	1.74	1.70
Associate Professors	1.18	1.34	1.27	1.18	1.26	1.21	1.10	1.08	1.14
Lecturer	0.77	0.85	0.69	0.73	0.83	0.84	0.82	0.80	0.79
Post doc	1.29	1.14	1.23	1.11	1.13	1.13	1.12	1.10	1.04
PhD student	0.78	0.75	0.68	0.71	0.69	0.66	0.67	0.60	0.64
Other	0.74	1.03	0.90	0.90	0.66	0.59	0.58	0.59	0.58
Total	1.33	1.28	1.18	1.12	1.15	1.10	1.01	1.03	1.02
Number of publishing researchers	4,830	6,038	6,572	7,317	7,788	8,541	9,234	9,855	10,425

Source: NSD/DBH data.

only 18% from 2005 to 2012.[3] The share of researchers with at least one publication has thus increased greatly over the period. This also means that the averages in Table 1 are based on a steadily growing group that includes both researchers that have published regularly over the entire period and others that may have begun publishing in registered channels during the period. The table shows that, overall, average points have fallen significantly over the period, from 1.33 to 1.02. In terms of initial research positions (at date of first publication in the period), averages decline for professors and for 'other' positions[4] and have increased over time for the remaining positions.

At the same time, the average annual number of publications per researcher has actually increased over the period from 2.48 in 2004 to 2.96 in 2012. However, as mentioned earlier, these statistics are difficult to interpret, given the large increase in the number of publishing researchers. As Rørstad and Aksnes (2015) and Piro, Aksnes, and Rørstad (2013) note, publication rates can vary greatly by age, position, gender, and field. Hence, changes in the composition of researchers can greatly affect productivity rates. Furthermore, it may be the case that many researchers that begin publishing during the period are less productive.

[3] *Source*: NIFU: http://www.foustatistikkbanken.no/nifu/?language=no (accessed 6 April 2014). Statistics are not available for 2004. The growth of 18% is based on employment of the universities including their university hospitals.

[4] 'Other positions' covers nonacademic positions, guest researchers, and cases where the researcher's position was unknown.

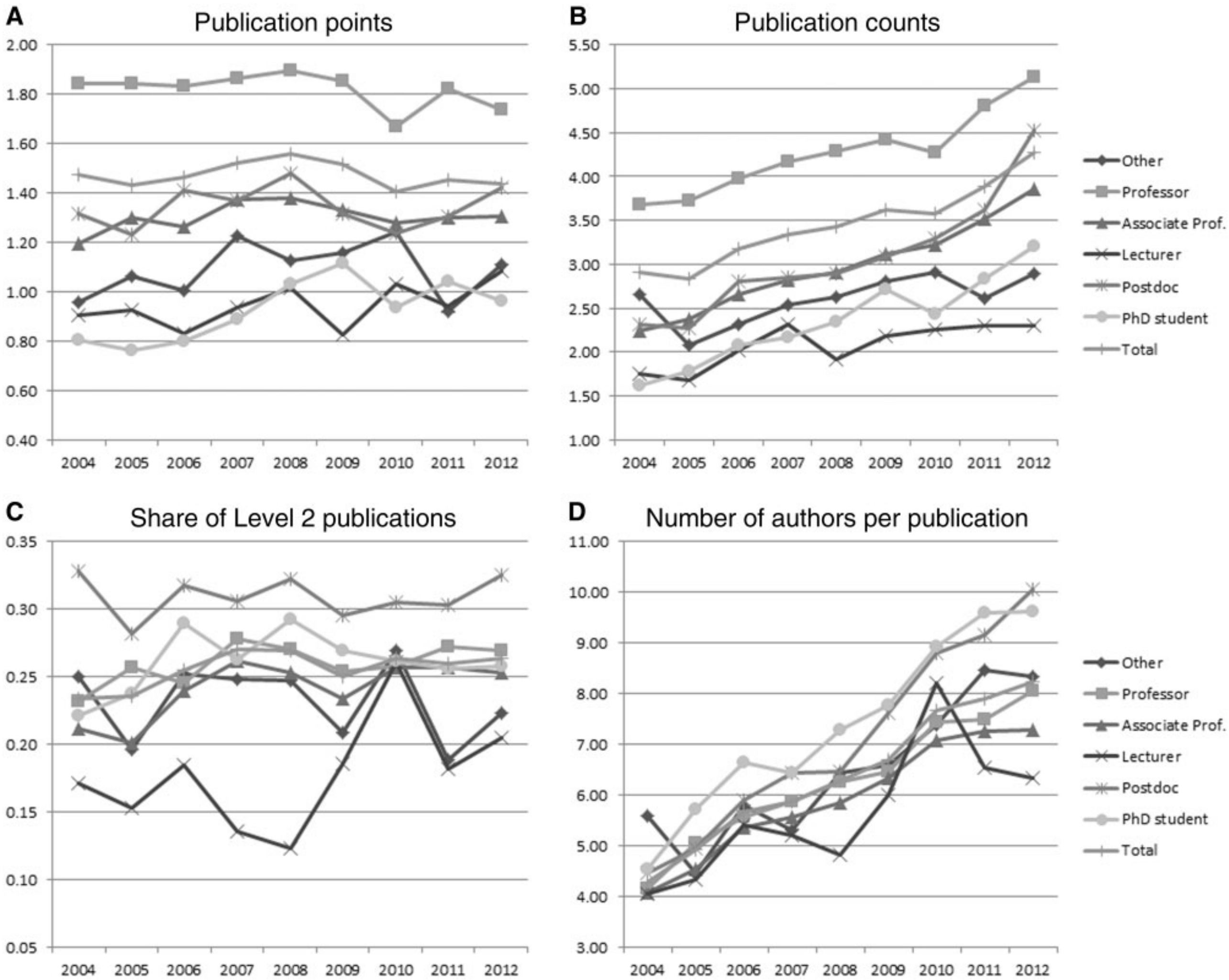

Figure 4. Publication activity per researcher for researchers active over entire period 2004–12. (**A**) Publication points, (**B**) Publication counts, (**C**) Share of Level 2 publications, (**D**) Number of authors per publication.
Source: NSD/DBH data.

In the remainder of this analysis, we will therefore focus on the same group of researchers over time. More specifically, we restrict the sample to researchers that have at least one publication in 2004 or 2005 and have at least one publication in 2011 or 2012. This leaves us with a sample of 4,323 researchers. In the following, we first examine trends over time in publication activity and thereafter test whether differences in publication activity for the first year of activity (either 2004 or 2005) compared to the last year of activity for the period (either 2011 or 2012) are statistically significant.

Figure 4 shows developments in publication activity across different positions for the sample. Positions are determined from the first year of publication and are held constant for the individual researcher over time. This allows us to, for example, follow developments in publication activity for early-career researchers as they gain experience. When looking at fixed groups in this way, we would thus expect increases for early-career researchers (postdocs and PhD students), but not for established researchers, such as associate and full professors.

Figure 4 shows four variables: publication points, number of publications (full counts, where no distinction is made between different types of publications), the share of publications (full counts) that is Level 2, and the average number of coauthors for individual publications.

Consider first publication points in Fig. 4A. Average points for researchers overall is essentially unchanged over the period, and ends at 1.44 points in 2012. Average points decline over the period for professors and increase for all other positions. With the possible exception of PhD students, these increases would appear though to be quite moderate. However, from Fig. 4B, we can see that the average number of publications has actually increased substantially, from 2.91 to 4.27 (47% increase), including for professors, with an increase of 40% over the period. Figure 4C shows developments in the share of publications that are from Level 2 channels. The overall share has increased over the period from 23% to 26%, and has also increased across all positions except for postdocs (where the share has been stable) and 'other' positions (where shares have fallen).

Hence, while average publication points have fallen over the period 2004–12, both, the average number of publications and the share that was published in Level 2 channels has increased. The most likely explanation behind this is the fractionalization of publication points by the number of coauthors.[5] As Fig. 4D shows, the average number of coauthors per publication has increased dramatically over the period, particularly for PhD students and postdocs. Given the fractionalization system for publication points, individuals have received fewer points per publication as the average number of coauthors has increased. As Piro, Aksnes, and Rørstad (2013) show, publication activity varies greatly across fields. They find large differences in productivity across fields, depending on how productivity is defined. The 'hard sciences' (natural, technical, and medical sciences) produce a much large number of publications per person and have a higher number of coauthors. However, in terms of fractional counts, the 'soft sciences' (social sciences and humanities) are more productive.

We have also examined developments for different fields. Classifications of individual publications may not be able to identify the primary field of individual researcher, as they may span more than one field. As a rough measure of field, we instead classify researchers according to the field of their university department, using three broad categories: Social Sciences and Humanities, Natural and Technical Sciences, and Medical Sciences. The results for these can be found in the Appendix. The results show that publication points increase in both Social Sciences and Humanities and Natural and Technical Sciences, but fall markedly for Medical Sciences. This is however not due to slower growth in number of publications, in fact, growth of publications is largest in Medical Science, but due to large increases in coauthors, which means less fractionalized points per publication.

4.1 Testing differences in publication activity

Given the skewedness of publication data, changes in average values may not properly reflect changes in the overall distributions across researchers, and many of these changes over time may not be statistically significant. To examine this more formally, we compare values for the first year of publication (which is either 2004 or 2005 for the researchers in this sample) with values for the last year of publication (2011 or 2012). And, again, given that the data are highly skewed, we employ a nonparametric test to compare the first and last years. The Mann–Whitney test is essentially a test of whether the overall distribution of values for the two periods is statistically the same.

When comparing publication points for 2004/5 with 2011/12, it can be seen that mean values have either increased or are essentially unchanged with the exception of professors, but median values have actually fallen in a number of these cases. This suggests that a smaller group of researchers have substantially increased their points, while points have actually fallen for the majority of researchers. For example, average points have increased for lecturers and postdocs, while median values have fallen. For PhD students, average points have also increased, while median values are unchanged. The statistical tests indicate that distributions of publication points are significantly lower for professors, postdocs, 'other' positions, and for researchers overall. Differences are not significant in the other cases. Hence, while total publication points for this group has increased greatly over the period 2004–12, points per researcher have actually fallen over the period.

[5] Other possible factors are changes in the types of publications, for example from books to journal articles. However, changes in the distribution of publications across different types has been fairly minor (see Aagaard et al. 2014 or Aagaard, Bloch and Schneider 2015).

In contrast to publication points, and as would be expected from Fig. 4B above, there have been strong increases in the number of publications per researchers. Differences are significant both overall and for all individual positions, with the exception of 'other' positions. Collaboration has also grown over the period, with increases in the number of coauthors per publication exceeding increases in publications. These increases in the number of coauthors over time are significant in all cases.

In general, the share of publications that are Level 2 has also increased over time. Differences are positive and highly significant overall and for professors, associate professors, and PhD students, while test statistics are insignificant for lecturers and 'other' positions, though close to a 10% threshold for P-values.

Table A.2 shows the results for the tests for each field. The table shows that the fall in publication points per researcher is mainly driven by a decline within the Medical Sciences, where points per researcher are essentially unchanged within Natural and Technical Sciences and have increased within the Social Sciences and Humanities. In all fields, the average number of publication counts per researcher has increased (38% for Social Sciences and Humanities, 29% for Medical Sciences, and 73% for Natural and Technical Sciences); however, while increases in average number of coauthors are similar to that for publications in other fields, they are much higher within the Medical Sciences. Over the period, the average number of coauthors for Medical Sciences has more than doubled, from 5.9 to 12.5.

5. Discussion and conclusion

The purpose of this article has been to go beyond aggregate-level analysis of publication activity and examine the developments at the individual level for researchers during the period for which the Norwegian Publication Indicator has been in place. While our analysis is clearly motivated by an interest in the effects of the Indicator on research and publication activity, we do not directly attempt to establish causality, as we are unable to isolate potential effects of other national and international factors. The main question that we seek to answer is whether the large increase in publication activity since the establishment of the Indicator in 2004 is mainly due to increases in the number of researchers who have been actively publishing or due to increases in publication activity per researcher overall. In other words, have researchers that actively published at the beginning of the period also increased their publication activity?

In order to do this, we need to examine developments in a fixed group of researchers over time. One option would be to examine researchers that have been in the sample for the entire period from 2004 to 2012 (and thus have published both in 2004 and 2012). However, this risks introducing a bias toward the most productive researchers. To make the analysis more inclusive, the sample includes all university researchers who have both published in 2004 or 2005 and either in 2011 or 2012.

Our analysis finds that the number of publications per researcher and collaboration (number coauthors per publication) have increased over the period, both overall and for individual academic research positions. Furthermore, the share of publications that are Level 2 has also increased overall and for some positions (professors, associate professors, and PhD students). These would all appear to be very positive developments that align well with the ambitions behind the Publication Indicator that publication activity should increase without leading to a shift towards lower-impact journals or to lesser collaboration. However, it can perhaps be questioned whether publication activity has increased for the individual researcher when both the number of publications and the average number of coauthors has increased. Is researcher productivity 'collaboration neutral'? For example, does it require the same amount of effort to produce five articles with four coauthors compared to two articles with one coauthor, or does it require greater effort to produce the five articles? While it would appear important to take account of the number of coauthors (fractional counts), measuring individual researcher productivity is a still a complex task (see e.g. Abramo, Cicero and D'Angelo 2013; Abramo, D'Angelo and Rosati 2013).

The relation between collaboration and productivity is likely very complex; however, simple correlations indicate that fractional counts are positively correlated with the number of collaborators over a period, while they are negatively correlated with the average number of coauthors per paper (Lee and Bozeman, 2005; Hu, Chen and Liu 2014). This suggests that there may be some forms of 'coordination costs' involved with collaboration that are increasing in the number of coauthors (Cummings and Kiesler 2007).

In contrast to the number of publications, publication points per researcher have actually fallen over the period, with significant declines both overall and for professors, PhD students, and 'other' positions. These overall trends mask some differences in trends across sectors. In the Social Sciences and Humanities, increases in both the number of publications and the number of coauthors have been smaller than in the 'hard sciences'. Both, for the Social Sciences and Humanities and for the Natural and Technical Sciences, average publication points have increased slightly from 2004 to 2012. In contrast, average publication points have fallen markedly in the Medical Sciences, as increases in number publications have been offset by even larger increases in collaboration.

There are some additional issues here concerning points for Level 1 and Level 2 publications and for different types of publications, but the main issue is the relation between collaboration and productivity when considering fractionalized publications. This issue is central to interpreting the results and for their potential implications.

A first interpretation is if productivity is in fact 'collaboration neutral', which implies that publication activity per researcher essentially has fallen, as is indicated by developments in publication points. In this case, publication points function as a fairly reasonable measure of publication activity. Increases in aggregate numbers thus primarily reflect broader participation in publishing of university staff, which is also evidenced by the large increases in the number of publishing researchers from 2004 to 2012. However, given that the share of participation cannot increase indefinitely, this could imply that any potential effects of the Publication Indicator will deteriorate over time.

An alternative interpretation is if collaboration (in relative terms) takes greater effort, it could imply that publication activity has in fact increased over time; i.e. even when accounting for the fact that the number of coauthors has increased greatly over time, increases in publications reflect greater publication activity. However, if this is the case, then it raises questions on the adequacy of the point-based system as a measure of publication activity. The method of fractionalization would thus 'penalize' researchers for increased collaboration, leading to a decline in number of points despite increased publication activity. While we have not found any evidence to the case, this would still present the possible risk that this has a negative influence on researcher behavior to reduce collaboration in order to increase publication points. The likelihood of this possibility is further enhanced by the tendency of many university departments to use the Publication Indicator as a management tool also at the individual level (see Aagaard 2015).

Establishing causality is very difficult here. We are unable to control for the potential effects of other factors. We are unable to generate an adequate counterfactual group or a control group that would allow for comparison. Both the number of publications and collaboration have increased greatly during the period examined here; however, it is not clear, for example, if these trends are greater than those in other countries (in particular, those without performance-based models) or to trends in Norway prior to the introduction of the Publication Indicator. While not fully comparable, Kyvik and Aksnes (2015) show that average number of publications (article equivalents) per person (for three year periods) was 4.5 in 1979–81,

Table 2. Statistical tests of differences in publication activity for 2004/5 compared to 2011/12

Position	04/05 Mean	11/12 Mean	04/05 Median	11/12 Median	Mann–Whitney P-value	04/05 Mean	11/12 Mean	04/05 Median	11/12 Median	Mann–Whitney P-value
	Points					Publications				
Professor	1.80	1.68	1.17	1.00	0.000*** (−)	3.42	4.69	2.00	3.00	0.000*** (+)
Associate professors	1.20	1.28	0.75	0.79	0.971	2.12	3.52	2.00	2.00	0.000*** (+)
Lecturer	0.87	0.99	0.70	0.51	0.215	1.59	2.06	1.00	1.00	0.004*** (+)
Postdoc	1.25	1.31	0.80	0.71	0.023** (−)	2.13	4.04	2.00	2.00	0.000*** (+)
PhD student	0.76	0.93	0.48	0.49	0.307	1.64	2.79	1.00	1.00	0.000*** (+)
Other	1.01	0.99	0.58	0.38	0.000*** (−)	2.22	2.52	1.00	2.00	0.254
Total	1.35	1.34	0.85	0.73	0.000*** (−)	2.56	3.77	2.00	2.00	0.000*** (+)
	Share level 2					Number co-authors				
Professor	0.23	0.27	0.00	0.17	0.000*** (+)	4.11	7.70	3.33	5.00	0.000*** (+)
Associate professors	0.21	0.26	0.00	0.00	0.000*** (+)	4.06	7.14	3.14	5.00	0.000*** (+)
Lecturer	0.16	0.19	0.00	0.00	0.104	3.85	6.38	3.00	4.00	0.001*** (+)
Postdoc	0.31	0.31	0.00	0.20	0.306	4.53	9.63	4.00	7.00	0.000*** (+)
PhD student	0.22	0.25	0.00	0.00	0.004*** (+)	5.16	9.47	4.00	6.75	0.000*** (+)
Other	0.19	0.22	0.00	0.00	0.124	4.64	8.64	4.00	5.50	0.000*** (+)
Total	0.22	0.26	0.00	0.00	0.000*** (+)	4.38	8.07	3.50	5.25	0.000*** (+)

***$P < 0.01$, **$P < 0.05$, *$P < 0.1$

Source: NSD/DBH data.

5.8 in 1989–91, and 6.6 in 1998–2000. As a rough comparison, if we multiply annual averages in Table 2 by 3, we have 7.7 publications in 2004/5 and 11.3 in 2011/12. While not fully comparable, these numbers are at least suggestive that the increase in publication has been greater over the period of the Publication Indicator than earlier, likely with a corresponding increase in collaboration. However, we would again emphasize that we do not see this evidence upon which we can conclude a clear cause–effect relationship. In contrast, we are more confident in concluding that the Publication Indicator has been successful in activating a larger share of researchers either to begin publishing on a regular basis or to shift publication activity toward the types of scientific channels covered by the Indicator. We are unable to think of any other factor that could have led to such a large increase in the number of publishing researchers.

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Appendix

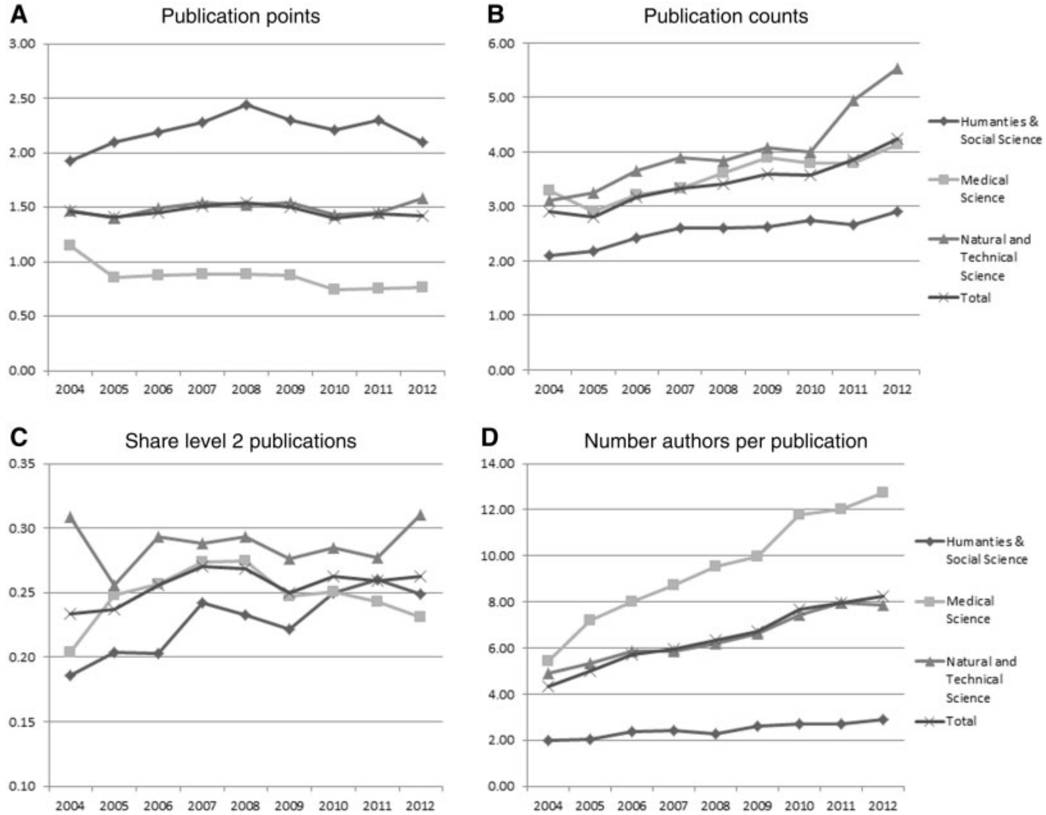

Figure A1. Publication activity per researcher for researchers active over entire period, 2004-2012. Fixed groups classified by field in beginning of period. (**A**) Publication points; (**B**) Publication counts; (**C**) Share level 2 publications; (**D**) Number authors per publication.
Source: NSD/DBH data.

Table A1. Developments in average publication points (per publishing researcher) for researchers active over the entire period, from 2004 to 2012 for the four main universities

		Year								
Field and position	Number of observations	2004	2005	2006	2007	2008	2009	2010	2011	2012
Humanities and Social Sciences										
Professor	567	2.25	2.54	2.54	2.66	2.66	2.57	2.46	2.68	2.35
Associate Professors	358	1.57	2.00	1.86	2.01	2.26	2.07	1.96	1.97	1.85
Lecturer	56	1.44	1.25	1.21	1.24	1.36	0.88	1.70	1.40	1.69
Post doc	88	1.82	2.26	2.49	2.36	3.20	2.26	2.39	2.64	2.45
PhD student	161	1.37	1.26	1.43	1.55	2.12	2.29	1.84	2.16	1.96
Other	104	1.61	1.58	1.80	2.13	1.90	1.99	2.00	1.62	1.53
Total	1,334	1.92	2.10	2.19	2.28	2.44	2.30	2.21	2.30	2.10
Medical Sciences										
Professor	623	1.56	1.15	1.11	1.09	1.12	1.13	0.91	0.95	0.92
Associate Professors	342	0.93	0.75	0.79	0.88	0.81	0.80	0.73	0.80	0.85
Lecturer	53	0.54	0.55	0.52	0.61	0.62	0.55	0.43	0.40	0.44
Post doc	140	0.99	0.74	0.85	0.78	0.81	0.76	0.73	0.70	0.86
PhD student	240	0.51	0.50	0.54	0.49	0.51	0.56	0.51	0.51	0.45
Other	231	0.72	0.54	0.59	0.65	0.55	0.58	0.46	0.38	0.40
Total	1,629	1.15	0.85	0.88	0.89	0.88	0.88	0.75	0.75	0.76
Natural and Technical Sciences										
Professor	565	1.82	1.96	1.99	2.01	2.09	1.98	1.80	2.00	2.08
Associate Professors	347	1.15	1.10	1.21	1.26	1.14	1.19	1.18	1.17	1.25
Lecturer	15	0.83	0.82	1.01	1.10	1.33	1.52	1.12	1.11	1.20
Post doc	171	1.37	1.13	1.45	1.38	1.24	1.36	1.15	1.18	1.38
PhD student	186	0.78	0.70	0.76	0.89	0.90	1.01	0.75	0.78	0.83
Other	165	1.16	1.08	0.99	1.19	1.06	1.17	1.37	1.01	1.54
Total	1,449	1.48	1.40	1.50	1.54	1.53	1.54	1.43	1.45	1.58

Main fields of science.
Source: NSD/DBH data.

Table A2. Statistical tests of differences in publication activity by main fields of science for 2004/05 compared to 2011/12

Field and position	Points					Publications				
	04/05 Mean	11/12 Mean	04/05 Median	11/12 Median	Mann-Whitney P-value	04/05 Mean	11/12 Mean	04/05 Median	11/12 Median	Mann-Whitney P-value
Social Sciences and Humanities										
Professor	2.23	2.33	1.50	1.56	0.415	2.37	2.91	2.00	2.00	0.000***(+)
Associate professors	1.66	1.84	1.00	1.33	0.156	1.74	2.68	1.00	2.00	0.000***(+)
Lecturer	1.19	1.54	1.00	0.83	0.749	1.25	1.75	1.00	1.00	0.007***(+)
Post doc	1.85	2.34	1.00	1.50	0.140	1.64	2.44	1.00	2.00	0.004***(+)
PhD student	1.25	1.93	1.00	1.00	0.001***(+)	1.37	2.48	1.00	2.00	0.000***(+)
Other	1.55	1.68	1.00	1.00	0.208	1.71	2.14	1.00	2.00	0.25**(+)
Total	1.84	2.07	1.00	1.40	0.001***(+)	1.93	2.66	1.00	2.00	0.000***(+)
Medical Sciences										
Professor	1.46	0.86	1.03	0.54	0.000***(−)	4.14	4.82	3.00	3.00	0.166
Associate professors	0.81	0.80	0.50	0.46	0.077*(−)	2.33	3.74	2.00	3.00	0.000***(+)
Lecturer	0.50	0.40	0.37	0.30	0.083*(−)	1.76	2.17	1.00	2.00	0.201
Post doc	0.84	0.77	0.55	0.44	0.026**(−)	2.27	4.19	2.00	3.00	0.000***(+)
PhD student	0.46	0.42	0.33	0.21	0.000***(−)	1.63	2.23	1.00	1.00	0.001***(+)
Other	0.59	0.35	0.34	0.20	0.000***(−)	2.04	2.14	1.00	1.00	0.705
Total	0.97	0.69	0.53	0.38	0.000***(−)	2.85	3.69	2.00	2.00	0.000***(+)
Natural and Technical Sciences										
Professor	1.75	1.92	1.05	1.16	0.760	3.69	6.30	2.00	3.00	0.000***(+)
Associate professors	1.09	1.18	0.70	0.75	0.752	2.30	4.18	2.00	2.00	0.000***(+)
Lecturer	0.89	0.95	0.89	0.29	0.407	1.80	2.73	1.00	2.00	0.273
Post doc	1.26	1.23	0.81	0.63	0.015**(−)	2.25	4.00	2.00	2.00	0.002***(+)
PhD student	0.72	0.73	0.50	0.41	0.477	1.90	3.78	1.00	1.50	0.000***(+)
Other	1.05	1.22	0.67	0.53	0.523	2.62	3.78	2.00	2.00	0.458
Total	1.32	1.42	0.78	0.75	0.281	2.82	4.87	2.00	2.00	0.000***(+)

***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.
Source: NSD/DBH data.