

Influence of a performance indicator on Danish research production and citation impact 2000–12

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Abstract This paper analyses the patterns of Danish research productivity, citation impact and (inter)national collaboration across document types 2000–2012, prior to and after the introduction of the Norwegian publication point-based performance indicator in 2008. Document types analysed are: research articles; conference proceedings papers excluding meeting abstracts; and review articles. The Danish Research & Innovation Agency's basic statistics combined with Web of Science (WoS) are used for data collection and analyses. Findings demonstrate that the research article productivity increases steeply (37 %) after the start of the performance indicator and the citation impact progresses linearly over the entire period, regardless the introduction of the performance indicator. Academic staff progression is only 24 % during the same time period. The collaboration ratio between purely Danish and internationally cooperated research articles remains stable during the period, the number of collaborative countries increases while the ratio declines significantly for proceedings papers. The citation impact of internationally cooperated research articles increases since 2009 but drops for proceedings papers; also their productivity declines slightly from 2009 according to Research Agency statistics. Since 2006 the WoS indexing of proceedings papers is fast declining; as a consequence the ratio between Danish proceedings papers and research articles declines in WoS. According to Research Agency statistics a decline likewise takes place, starting from 2009. The positive growth in research articles mainly derives from the Science and Technology fields published in prestigious Level 2 journals; the development of articles published in less prestigious Level 1 journals derives from all fields. Three of the eight Danish universities have

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significantly altered their research publication profiles since 2009. The publication performance model is regarded as the significant accelerator of these processes in recent years.

Keywords Publication performance indicator · Citation analyses · Publication patterns · Denmark · Research articles · Review articles · Proceedings papers

Introduction

The rationale behind national research assessments is to observe and understand the patterns of research production monitored through research publications in a country. In addition research impact measures are applied in order to assess the influence the research produced may have on later research and development activities. As part of the research monitoring measures, and to allocate public research funding, the so-called ‘Norwegian publication performance’ indicator or model based on assigned publication points was introduced in 2008 into the Danish academic landscape (Schneider 2009). The motivation behind the present investigation is to observe the kind of influence the indicator model has had on the Danish research production and impact nationally as well as on the productivity at university and major academic area levels. Consequently, the investigation analyses the research development during the periods before and after the introduction 2008, that is, from 2000 to 2007 and 2008 to 2012.

Commonly monitoring of institutional and national productivity and citation impact are limited to peer reviewed journal articles (van Raan 1999, 2005; Moed 2005). The performance indicator model also takes into account peer reviewed proceedings and anthology papers, albeit hitherto assigning less scoring points to this publication channel. Thus, we have included the proceedings paper type as well in the present investigation.

When the performance indicator model was started up in 2009 68 groups of academics from the Danish universities were established to list knowledge resources and assign points to peer reviewed journals, publishers and conferences that publish scientific material authored by Danish academics for the year 2008. Each of the 68 groups represents an academic field or specialty. These groups have until now continued to assess the publication channels. The performance indicator takes into account published peer reviewed research and review articles, monographs as well as anthology and proceedings papers. In the publication period 2008–2012 proceedings (and anthology) papers were assigned .75 points. Journal articles received 1.0 point in Level 1 journals and 3.0 points in Level 2 journals, i.e. the leading journals of a field as judged by the relevant researcher group and covering maximum 20 % of the field journal output. From 2013 proceedings papers are supposed to receive similar points as articles, depending on the level of the conference, as assessed by the relevant academic group. For each document the points are fractionalized (min. .1) according to number of collaborating universities and institutions; then cumulated per institution. The model encourages collaboration by multiplying the institutional fraction obtained by 1.25 in collaborative publications.

Since 2009 the past year’s research output has been assigned points annually that are used to distribute a substantial portion of public research funding among the universities the following year. Only the cumulated results are publicly available per university and major academic area, such as the Humanities or Medicine/Health sciences (Forskningstyrelsen

2013); the intermediate or more detailed publication point distributions and document lists per unit and department are not publicly accessible. This is in difference to Norway where no multiplication of fractions takes place and all the documents and their point assignments are transparent as well as publicly accessible through an open access database (Sivertsen 2010). In Belgium the Flemish BOF-key applies whole counting at the institutional level (Debackere and Glänzel 2004; Engels, Ossenblok and Spruyt 2012).

With respect to the publication performance indicator a major underlying idea was to encourage publishing in so-called 'Level 2' journals when implemented in Norway (Aagaard and Schneider 2012). This has been studied in Norway and results demonstrate a substantial increase 2004–2009 of 55 % for articles in Level 2 journals (Sivertsen 2010; Sivertsen and Schneider 2012). From 2004 to 2012 the increase for all research articles in Norway was 70 %. This progression mirrors the growth of academic staff resources allocated universities during the same period (Aagaard et al. (2014, p. 42). The Belgian experience for the social sciences and humanities is analysed by Ossenblok, Engels and Sivertsen (2012).

The influence of peer reviewed proceedings papers on citation performance has not been studied extensively. Butler and Visser (2006) investigated the degree to which WoS contributes adequate data with respect to a variety of document source types, including conference proceeding and meeting publications. Martins et al. (2010) tested comprehensive conference paper indicators in the Electrical Engineering and Computer Science fields, comparing to journal-based indicators. How proceeding paper citations are distributed across a range of document types in computer science was investigated by He and Guan (2008) and Wainer, de Oliveira and Anido (2011). The latter group studied the references from all (predominantly proceedings) papers published in the ACM digital library 2006, and then mostly in relation to particular fields like computer science. Lately Ingwersen et al. (2014) studied the citation flow to and from proceedings papers in the renewable energy fields 2005–2009 demonstrating that proceedings papers in these engineering fields predominantly cite research articles. Proceedings papers have not been studied at all in relation to performance indicator models like the Danish/Norwegian one based on publication points.

The present analysis extends a study by Ingwersen and Larsen (2013), which looked at the impact of the Danish university mergers 2006 and the performance indicator at national level covering the period 2000–2010. In addition the present analysis investigates the patterns of research productivity and citation impact across document types prior to and after the introduction of the Norwegian performance system 2008, covering the period 2000–2012 and comparing to the development of full-time academic staff. Further, the productivity patterns in the major research areas (Science & Technology, Medicine and the Social Sciences) as well as for the eight Danish universities are included in the analyses in order to observe if the research production profiles have changed after 2008. The latter analyses are based on the Danish Research Agency's public available statistics 2008–2002 (Forskningsstyrelsen 2013). Extractions from Web of Science (WoS) provide context to the Agency data set in terms of time dimension, citation impact and collaboration ratios.

Due to the fractionalization principle of the performance system one might expect a decrease in institutional collaboration after 2008 at international as well national levels in all document types. By some (science and technical) universities fractionalisation was seen to penalize international collaboration by the research communities. From the perspective of Humanities and some social science fields the entire measurement system was regarded as an attack on the freedom of research and many critical opinions have been posted on academic blogs (e.g. <http://professorvaelde.blogspot.com>; <http://www.forskeren.dk>). From

the government perspective the hopes were, with the performance system as incentive, to reinforce an increase of the overall Danish research production and citation impact owing to better research quality by increased publishing in Level 2 journals.

Motivated by the aforementioned assumptions the present investigation has the following three research questions:

1. Did the introduction 2008 of the publication performance indicator for peer reviewed research and review articles and proceedings papers alter the overall Danish productivity patterns, citation impact or (inter)national collaboration in the following years—and compared to the preceding period?
2. Did the performance indicator alter the research productivity patterns in Science and Technology, Medicine and Social Sciences after 2008?
3. Did the performance indicator alter the research productivity patterns in the individual Danish universities after 2008?

It is important to stress three influential variables: (1) research funding, (2) university structure and (3) academic staff development. With respect to funding, the Danish public funding of universities and research has not declined as a result of the economic crisis from 2008. It is fairly constant at a .9–1.1 % of the national BNP and its potential influence on productivity and research quality may be regarded as neutral. As regards the university landscape in Denmark the most crucial event was the university mergers that took place 2006, reducing many smaller universities and research centres to eight larger universities, with University of Copenhagen as the largest and most prestigious university. According to the study by Ingwersen and Larsen (2013) the mergers did not seem to have a negative influence on productivity or citation impact. During the period 2000–2010 both productivity and impact of research articles grew linearly. Consequently, it would be interesting to discern if collaboration patterns, particular universities and major academic areas contribute to the observed trends. According to Aagaard et al. (2014) the growth of full-time academic staff in the Danish university sector 2004–2011 was 63 % and from 2008 to 2012 24 % (Forskningsstyrelsen, 2013)—see Fig. 2.

From a methodological standpoint the investigation makes use of the point-based performance indicator statistics from the Research Agency (Forskningsstyrelsen 2013). They demonstrate the real number of research documents published in Denmark 2008–2012 across universities and major research areas. The Agency data set is comparable to data extracted from the WoS citation indexes SCI, SSCI, CPCI-S and CPCI-SSH (Thomson-Reuters). They form the basis for the annual analyses and cover a period of 13 publication years: 2000–2012 cited 2000–2013, each year with a 3 year citation window. Thus the most recent year of impact analysis is 2011. Monographic material and the Humanities fields are not explicitly dealt with in the investigation owing to the language bias in WoS. However, some humanistic documents are involved by the application of CPCI-SSH. The issue of proceedings paper coverage in WoS is dealt with in the methodological section.

The paper is organized as follows. Data collection procedures, coverage and analysis methods including three collaboration indicators and the proceedings paper issue are described. This is followed by three sections on findings according to the research questions. The first deals with the overall development of productivity 2000–2012, citations to and impact of Danish research over the period 2000–2011 across research articles, proceedings papers¹ and review articles, with a citation window of 3 years per publication

¹ Proceedings papers include this WoS document category and exclude the category 'Meeting Abstracts'.

year. This is followed by a section on (inter)national cooperation across document types and citation impact developments. Analyses of the average number of collaborating countries and number of Danish research institutions across document types provide indications of publication behaviour that might have been influenced by the introduction of the publication performance model. The third section compares statistics from the development of the system to the WoS-based observations. This includes the distribution 2008–12 of research publications over the three major academic areas and the eight Danish universities. Discussion and conclusion sections close the paper.

Methodology

The data collection was carried out in WoS on February 26, 2014 on Science Citation Index (SCI), Social Science Citation Index (SSCI), Conference Proceedings Citation Indexes for Science (CPCI-S) and Social Science and Humanities (CPCI-SSH). For each year the Danish share of WoS indexed materials was observed to detect any anomalies in database developments. Nothing particular was detected regarding the Danish world share that remains rather constant at .80 % 2000–08; then it increases and surpasses 1.0 % in 2012. This implies that the Danish development largely follows the WoS dynamics over the period.

Research quality is measured in terms of citation impact. Full counting is applied. The citation window is kept at 3 years. This implies that 2011 is the last year with a workable 3-year citation window (2011–2013). Since the analysis period was February 26, 2014, and a share of citing publications for 2013 may not have been indexed by WoS at that point in time; hence the actual citation rates and impact scores for that period are of a conservative nature. Citation and publication analyses are studied for each document type separately: research articles; review articles; proceedings papers. ‘Other’ types of documents that include meeting abstracts, editorials, book reviews, letters to editors, errata, etc. are taken into account but omitted from further analysis, which solely concerns the former three types.

Methodological issues associated with WoS coverage

The WoS document category ‘proceedings papers’ is used to retrieve peer reviewed proceedings papers. They derive from the two CPCIs as well as from the original citation indexes (SCI and SSCI). In the latter case they are all also tagged by the category ‘article’; but in the CPCIs there exists a partial and changing overlap between the two document categories. According to (Thomson Reuters, ISI) the “most important and influential” conferences and conference proceeding volumes are indexed, e.g. published in thematic journal issues (thus also indexed as articles) or book series by institutional sponsors such as ACM or IEEE. From 2006 it is a fact that the two CPCIs are decreasing dramatically their proceedings paper indexing, Fig. 1 (left). Thus, all countries will suffer from this phenomenon, including Denmark, Fig. 1 (left), for which we observe a proportional decline already starting 2003. This indexing behaviour will automatically decrease the ratio of proceedings papers over research articles in WoS if the latter source simultaneously grows. The issue here is whether Denmark *in reality* declines its proceedings paper production and ratio. By knowing the real number of Danish publications 2008–2012 (Forskningsstyrelsen 2013), see below Fig. 6, we can indeed (1) observe a very small productivity decline for proceedings (and anthology) papers, Fig. 1, left, (2) calculate the paper over research

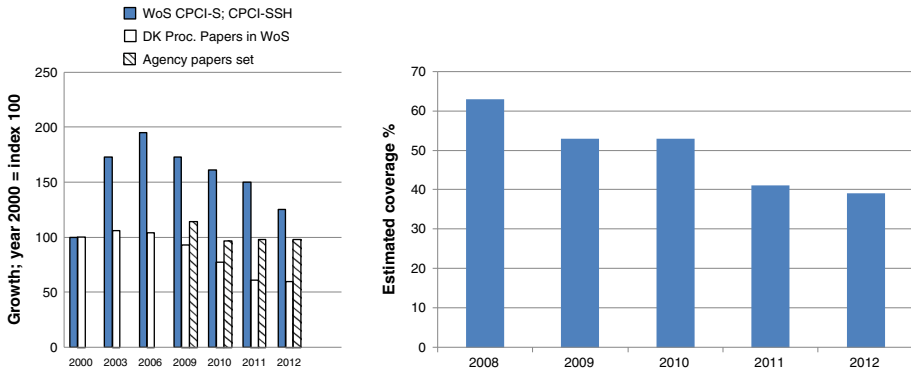


Fig. 1 Growth of CPCI-S, CPCI-SSH 2000–2012, Danish proceedings papers and the Agency data set 2009–2012 (*left*); WoS coverage of Danish proceedings papers 2008–2012 (*right*) (WoS, February 26, 2014; Forskningsstyrelsen 2013)

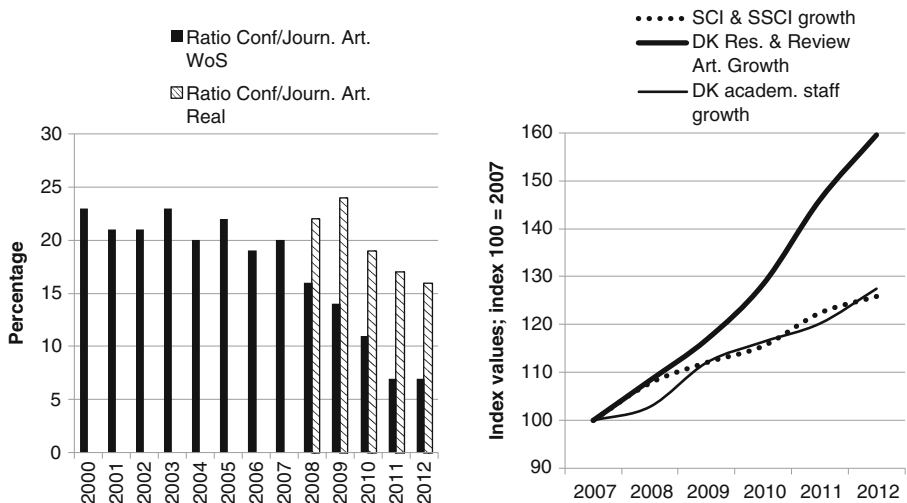


Fig. 2 Annual ratios in percentage of Danish proceedings papers vs. research and review articles, from WoS and Danish Research Agency 2008–2011 (*left*); 3-year citation impact development for research articles and review articles combined vs. SCI + SSCI progression and Danish academic staff evolution (*right*) (WoS, February 2014)

article ratio, Fig. 2, and (3) estimate the two CPCIs’ coverage for that period, Fig. 1, right. Given that the Research Agency’s proceedings paper production includes a 30 % share of anthology papers (in 2012; Forskningsstyrelsen 2013) the real proceedings paper coverage is larger than the minimum rate of 38 % (2012). For the remaining years the share of anthology papers is not available, but the proceedings paper coverage must be regarded as being higher than shown on Fig. 1, right. The decrease in CPCI coverage corresponds logically to the decline in CPCI indexing, Fig. 1.

For journal articles (research and review articles) the Research Agency stipulates the publication of 15,403 items out of which WoS covers 14,476 items (2012; Table 1) with a

coverage of 94 %. Owing to the comparability of the agency-defined Danish set, the coverage rates and the normalisation procedure in the calculation of citation impact scores by means of the number of research and review articles and proceedings papers indexed in WoS we find the scores and the international collaboration ratios as well as their trends valid. Where required statistical tests point to significant trends.

In order to avoid the said overlap in the WoS analysis between the document categories, foremost between research articles and proceedings papers, all documents indexed by both tags were kept as proceedings papers and thus excluded from the article category. Samples drawn from the overlap showed that such documents are indeed conference papers or contributions from proceedings but published in serial or thematic journal issues; thus the exclusion from the research article category is relevant.

Further, the ratio of proceedings papers vs. research articles is calculated per annum for the Research Agency set and compared to the WoS-based calculations. These two publication types are regarded the channels that directly communicate scientific knowledge; review articles are seen as submissions that summarize already published knowledge. In relation to (inter)national cooperation the investigation operates with the following indicators, based on WoS data:

1. *International cooperation ratio*, i.e., the ratio (between 0 and 1.0) of documents that are published in collaboration between Denmark and at least one other country. This ratio is calculated annually for research articles and proceedings papers separately.
2. *Average number of Danish institutions collaborating per document* within the set of purely national Danish publications for each document type.
3. *Average Number of countries per internationally collaborated document*.

In the Research Agency data set no indicators are available to separate purely Danish cooperation from international collaboration. In order to divide each annual set of research articles and proceedings papers into a purely national set of publications and a set of internationally authored documents for each type the analytic tools provided by WoS were applied to list, select and retrieve the documents from the collaborating countries to form a separate set of records, named the international cooperative set. The number of individual countries was isolated from this set. The total number of documents containing at least one country was calculated by aggregating the number of documents assigned each country in the set. This aggregated number of documents was then divided by the number of documents in the international cooperative set to produce indicator (3). Because the country field in WoS is name form controlled the number of different countries collaborating with Denmark provides an additional sub-indicator.

The set of purely national Danish publications in a document type was isolated by means of Boolean NOT logic of the international cooperative set on the initial set of that document type. The resulting purely Danish set was then analyzed by the Analyze Result tool of WoS for each document type with respect to the metadata category of 'Organizations Enhanced'. The total number of documents containing at least one institutional name was calculated by aggregating the number of documents assigned each 'Organization Enhanced' in the set. This aggregated number of documents was then divided by the number of documents in the national Danish set to produce indicator (2). It is important to stress that in this calculation name form control of institutions is not necessary. Since only one name form of each affiliated institution is commonly assigned each document, logic dictates that this calculation involving institutional names signifies the average number of *different* institutions collaborating per document. Thus, the analysis does not inform about the number of different unique institutions that collaborate. Indicators (2) and (3) were

Table 1 Annual Danish research publications and citations 2000–2012 with 3-year citation windows (in parenthesis); 2011 (2011–2013) is of conservative nature (WoS, February 26, 2014)

Document types	2000		(2000–2002)		2001		(2001–2003)		2002		(2002–2004)		2003		(2003–2005)		2004		(2004–2006)		2005		(2005–2007)		2006		(2006–2008)	
	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations
Research articles	6712	40687	6891	42950	6772	44136	7079	51972	7383	53582	7588	58928	7988	60655														
Proc. papers	1596	3208	1479	3255	1489	3116	1696	3539	1595	3887	1777	5146	1660	4634														
Review articles	341	4458	304	4696	357	3838	351	5805	446	6817	472	7291	558	8656														
Other types	1523	1272	1262	927	1645	953	1620	1022	2042	1093	2412	1507	2432	1568														
Total types	10172	49625	9936	51828	10263	52043	10746	62338	11466	65379	12249	72872	12638	75513														
Online	10172		9936		10263		10746		11466		12249		12638															
Document types	2007	(2007–2009)	2008	(2008–2010)	2009	(2009–2011)	2010	(2010–2012)	2011	(2011–2013)	2012	Total	Total															
	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	Citations	Publ	publ	publ															
Research articles	8532	69693	9178	78130	9840	83799	10931	98017	12432	109501	13600	114926	792050															
Proc. papers	1852	4745	1538	4553	1488	4422	1269	3177	975	1560	951	19365	45242															
Review articles	545	9605	651	12846	760	13892	721	12366	815	12992	876	7197	103262															
Other types	2755	2023	2760	1910	3111	2100	2869	2958	2888	3497	3577	30896	20830															
Total types	13684	86066	14127	97439	15199	104213	15790	116518	17110	127550	19004	172384	961384															
Online	13684		14127		15199		15790		17110		19004		961384															

calculated for the eight selected years 2001; 2003; 2006; 2008–2012. Citation impact for each document type divided into purely national and international collaborative sets was calculated for the seven selected years 2001; 2003; 2006; 2008–2011. Owing to lack of name form control citation impact at university level was not calculated in the present investigation.

In case of sets too large for WoS to handle when generating online citation reports, i.e. sets above 10,000 items, the set was logically divided into subsets according to the indicator (3) method above; subsequently the analysis results were aggregated. The Danish research article sets from 2010 to present constitute such large sets (Table 1). In total the analyses deal with almost 172,000 source documents and 961,000 citations.

The annual statistics from the performance indicator 2008–12 (Forskningsstyrelsen 2013) was used to form new descriptive publication statistics of the research and review articles (Levels 1 and 2) and proceedings (and anthology) papers, the eight universities as well as to the overall academic areas of Science & Technology, Social Sciences and the Medicine/Health Sciences covering the period 2008–2012. For 2008 the number of publications was estimated from the assigned points. As stated above on coverage, the Agency statistics cover more publications than indexed by WoS and the university set includes overlaps between the Danish universities. Nevertheless, the *trends* can be compared between our findings through WoS and those observed from the agency set.

Findings

Table 1 displays the annual number of Danish research publications indexed by WoS 2000–2012 including the three dominant document types, and the corresponding citation volumes. Figure 2 provides the corresponding citation impact development over the entire period.

The general trend for research articles, Table 1, is a steady increase of productivity over the entire period, in particular during the recent 3 year period 2010–2012, Fig. 2, right. For proceedings papers the years 2001, 2004 and 2006 display negative growth. The highest productivity is reached in 2007. From 2008 and onwards their productivity, according to WoS indexing, is declining fast. For review articles 3 years 2001, 2007 and 2010 demonstrate negative growth. The major type of documents in the document category ‘Other types’ consists of ‘Meeting abstracts’ throughout the period.

For citations given to research articles the growth is constantly very positive; for review articles smaller variations are observed during the period although the general trend is positive. This includes the 2011 research and review articles cited 2011–2013, with a citation volume of conservative nature due to extractions done in February 2014. The same decline observed for productivity of proceedings papers is observed for their citations.

Figure 2 shows the annual ratio of proceedings papers vs. research and review articles to the left, for WoS covering the entire period, compared to similar ratios according to the Danish Research Agency for 2008–2012 (Forskningsstyrelsen 2013). The right-hand side demonstrates comparative growth analyses of the SCI and SSCI databases of WoS (Aagaard et al. 2014), the corresponding WoS indexed Danish journal articles (research and review articles), from Table 1, and the Danish full-time academic staff (Forskningsstyrelsen 2013).

The WoS proceedings paper *ratio* illustrates the same trend as shown for the productivity, Table 1, with a definitive decline from 2008 in WoS. Also the Research Agency

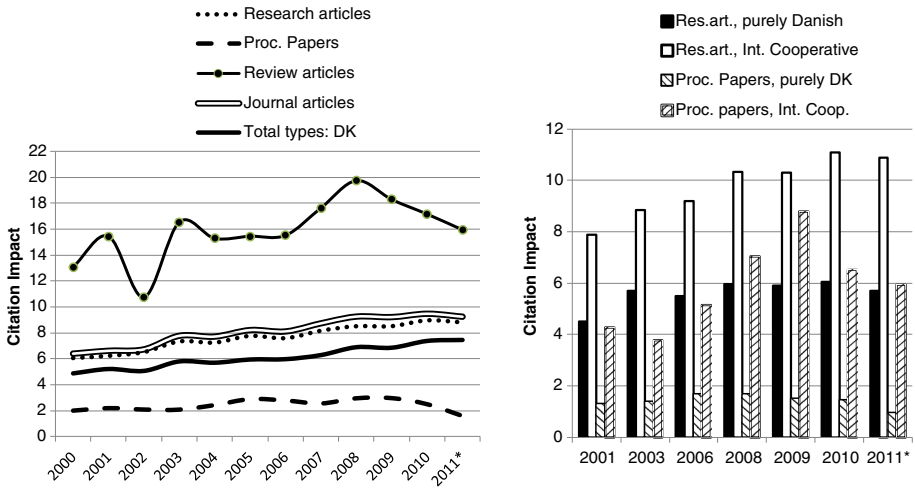


Fig. 3 Annual development of Danish citation impact to publication types 2000–2011 with 3-year citation window (*left*). Citation impact in seven selected years for research articles and proceedings papers, purely Danish vs. international cooperation (*right*). 2011*: citations 2011–2013 extracted from WoS, February 26, 2014

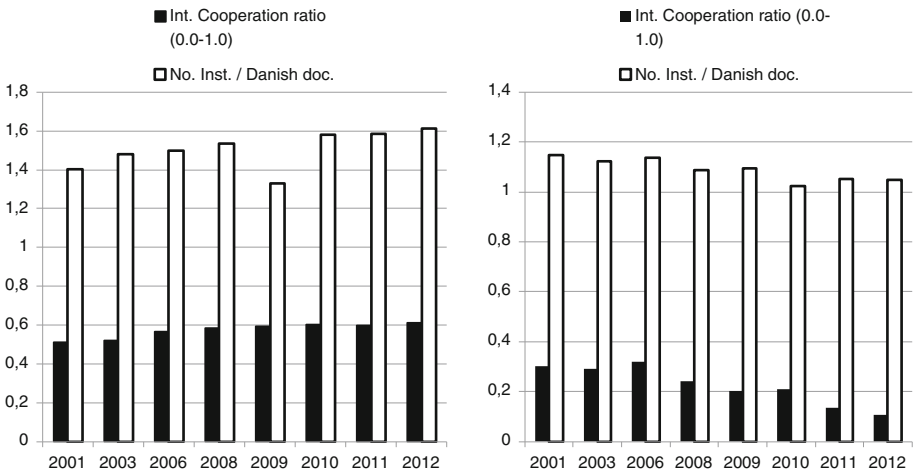


Fig. 4 International cooperation ratio (0–1.0) and mean number of Danish institutions collaborating per purely Danish publication. Research articles (*left*); Proceedings papers (*right*) (WoS, February 26, 2014)

statistics demonstrate a similar proportionally negative trend from 2009 for all the actual Danish publications. We may consequently trust the WoS-based *pattern* for Denmark. This coincides with the Danish journal article growth (research and review articles combined), Fig. 2, right, being very steep from 2008. The progression is 60 % 2007–2012 against 25 % for SCI and SSCI. We observe that this dramatic development far outperforms the growth of Danish academic staff producing the publications, with a progress of 27 % for that period. A Chi squared test shows that the Danish development pattern for journal (research and review) articles is significantly different from the WoS developments

($\chi^2 = 15.36$) as well as from the staff growth ($\chi^2 = 15.92$), $DF = 5$; $\alpha = .01$; $CV = 15.086$. The observed increase in Danish productivity is thus not only dependent on academic resources or simply following the WoS indexing development. Other not neutralized factors are at play, such as the performance indicator system.

The diagram, Fig. 3 (left), demonstrates the detailed annual impact trends for the different document categories. One observes a drastic drop in impact for review articles in 2010 almost to the 2003–2006 level. The *proceedings papers* are dropping in impact from 2009. However, the *research articles* constantly increase their citation impact, thus compensating the national Danish average citation impact (Total types DK) that is linearly rising during the entire analysis period. The small drop in 2011 is caused by the lack of indexing in WoS of all citing publications published in 2013, since the extraction was done in February 2014.

The steady impact progression of research articles alone and all journal articles (including review articles) is significant for the entire period ($\chi^2 = 143.23$; $DF = 11$; $\alpha = .01$; $CV = 24.725$), as is the negative impact trend for proceedings papers 2007–2011 ($\chi^2 = 49.38$; $DF = 4$; $\alpha = .01$; $CV = 13.277$).

Document types, (inter)national cooperation and citation impact

Figure 3 (right) demonstrates the citation impact obtained by the research articles and proceedings papers published by Danish institutions only or authored in international collaboration with other nations, as indexed by WoS. The impact of the *research articles* made in international collaboration is continuously substantially higher (almost the double) than that received by purely Danish publications, the latter staying level from 2008. In comparison, the international cooperative research articles demonstrate a steady and significant impact growth. Notably, the increase simply continues regardless the introduction of the Norwegian performance indicator system in 2008 ($\chi^2 = 22.14$; $\alpha = .01$; $DF = 6$; $CV = 16.812$). The positive impact development of the research articles, Fig. 3, left, is hence primarily caused by the international collaboration.

In contrast, the drop 2010–2011 in citation impact for the Danish proceedings papers, Fig. 3 (left), derives from a marked decline in the impact received by the international proceedings publications since 2009—but also to an extent from the purely Danish proceedings papers. The latter set of documents starts losing impact already in 2006 (right). However, this trend is not supported by statistical tests ($\chi^2 = 3.02$).

Figure 4 displays the international cooperation ratio (indicator 1) and the average number of Danish institutions collaborating per document within the set of purely Danish publications (indicator 2) for research articles (left) and proceedings papers (right).

According to WoS indexing the *international cooperation ratio* is stable around .60 for research articles during the period (left). The Aagaard et al. report displays an identical development although their analyses are using fractional counting (2014, p. 48). The ratio is declining significantly from .30 to .11 for the proceedings papers since 2006 ($\chi^2 = 19.09$; $\alpha = .01$; $CV = 18.475$; $DF = 7$). For both document types USA, Germany; England and Sweden constitute the dominating partners for Danish research institutions.

Indicator 2 (Danish collaborating institutions per document), Fig. 4, demonstrates variable average scores at 1.5 institutions per uniquely Danish research article (left). Except for 2009 the general indication is a slight increase in collaborating institutions since 2001. In contrast the analysis shows a slight but statistically non-significant decrease to

1.05 collaborating institutions for the purely Danish proceedings paper documents (right) ($\chi^2 = 1.33$).

For research articles the average number of countries per document cooperating with Denmark (indicator 3; Fig. 5) is variable around 2 foreign countries per document. Proceedings papers demonstrate in recent years an insignificantly higher number of collaborating countries. The performance indicator model (fractionalization) cannot be seen to have a negative (perceptive) effect from its introduction 2008. One may speculate that the indication of a more intense cooperation observed 2011–2012 (almost 2.5 foreign countries per publication for both types of documents), also observed in the purely Danish set among institutions, Fig. 4, is due to the multiplication factor for cooperation.

For research articles the total number of unique countries (sub-indicator 2) with which Denmark collaborates consequently increases steadily over the seven selected years, Table 2: from 103 countries in 2001 to 148 countries in 2012. At the same time the number of countries for proceedings papers reaches a peak in 2010, then dropping severely in 2011–2012. This drop coincides with the decline for proceedings paper productivity according to WoS indexing, shown in Table 1 above. Fewer publications result in fewer cooperating countries. Table 2 demonstrates that already from 2008 a decrease initiates primarily among the internationally collaborative papers according to WoS indexing. Although such trends are caused by the general decline in indexing of this document type in the CPCIs, in some part but not so pronounced this negative development is real, as demonstrated by the small negative productivity pattern detected from 2009 in the Research Agency's data on actual Danish proceedings (and anthology) paper production, Fig. 1, left and Fig. 6.

Statistics of actual publications 2008–2012

Figure 6 demonstrates extracts from the publication statistics published by the Danish Research & Innovation Agency (Forskningsstyrelsen 2013) for the publication years 2008–2012 associated with the performance indicator scores. The notion 'Papers' covers all proceedings papers and some book anthology papers or chapters, in particular in the Social Sciences. Humanities publications are omitted from the analyses.

Developments in the three academic areas

In general, Denmark is highly productive with respect to *Level 1 articles*, the most leading publication vehicle (growth: 36.5 %); their development is primarily caused by a 37 % increase in the Social Sciences, 24 % in Medicine and 29 % in S&T, see also Fig. 7. For *Level 2 articles* (growth: 36.8 %) a 46 % increase occurs in the Sciences & Technology area over the 4 years 2009–2012, that is, a year after the start of the performance indicator system. As stated earlier, the growth of academic staff, Fig. 2, right, is far less pronounced (24 %) than that of Danish WoS journal articles as well as of Levels 1 and 2 articles from the Research Agency data set, 2008–2012. The performance indicator system and its influence on local budgets can be regarded an important vehicle or incentive for the production advancements—seemingly shifting some efforts from paper to article production.

For Medicine the Level 1 article growth is only 16.4 % but 22.7 % for the Social Science fields 2009–2012. The detailed Fig. 7 demonstrates that the growth in the S&T fields starts in 2010 in parallel for both level types of journal articles, like for Level 2

Fig. 5 Average number of countries per document cooperating with Denmark (included) (WoS, February, 2014)

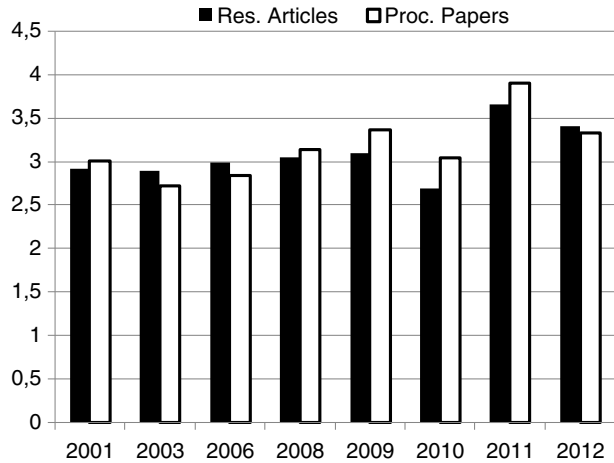


Table 2 Development of international cooperation, number of cooperating countries and purely Danish authorship across document types during eight selected years (WoS, February 26, 2014)

	2001	2003	2006	2008	2009	2010	2011	2012
Research articles								
Purely Danish authorship	3375	3396	3453	3821	4011	4349	4991	5288
Int. coop. authorship	3516	3683	4535	5357	5829	6582	7441	8312
Total no. of documents	6891	7079	7988	9178	9840	10931	12432	13600
Number of countries	103	120	127	125	137	137	132	148
Proceedings papers								
Purely Danish authorship	1031	1201	1131	1168	1189	1003	847	851
Int. coop. authorship	448	495	529	370	299	266	128	100
Total no. of documents	1479	1696	1660	1538	1488	1269	975	951
Number of countries	67	65	57	71	61	85	49	43

articles in the Social Sciences, whilst the increase starts immediately for both types of research articles in Medicine. This delay in S&T and Social Science can probably be regarded as a kind of ‘incubation time’ for researchers in those fields to adjust to the indicator system. In Medicine researchers act faster to change in the conditions and incentives for publication production for all the three document types. Aagaard et al. (2014) demonstrates the identical dramatic increase for Danish journal articles as such (p. 42) and compares to the other Nordic countries.

For actual proceedings (and anthology) papers the general trend, Fig. 6, is slightly negative from 2009 with Medicine, Fig. 7, as the dominant area in decline (−66 %), although for a small population, and the Social Sciences as well as S&T each with −6 %. One should notice the developments of the Social Science Level 1 articles vs. proceedings and anthology papers, with the former as the actual dominating vehicle of research output since 2010. However, the latter type seems to recover from 2011 demonstrating a positive trend.

Fig. 6 The development of journal articles, Levels 1 and 2, and papers published in proceedings and anthologies; scores from 2008 are estimated (from Forskningsstyrelsen 2013)

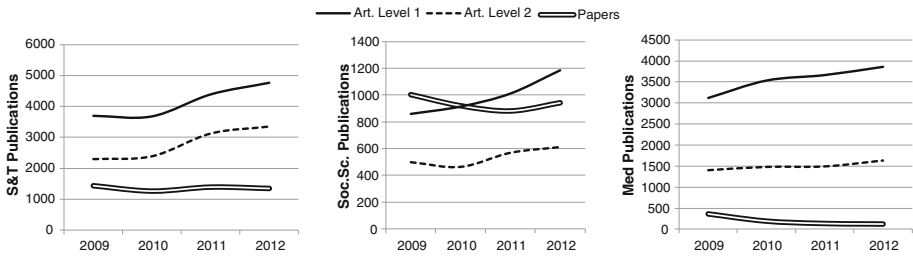
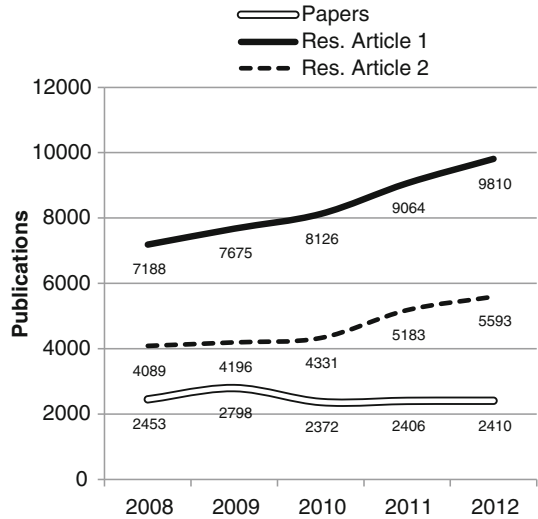


Fig. 7 The development of journal articles, Levels 1 and 2, and papers published in proceedings and anthologies in Science & Technology (left), Social Science (middle) and Medicine (right). (From Forskningsstyrelsen 2013)

Developments in the eight Danish universities

Figures 8 and 9 display the distributions of the three document types across the eight Danish universities 2009–2012; their temporal university profiles of document types, so to speak. In the distributions the Aalborg, Aarhus, Copenhagen and Southern universities constitute the largest universal universities, with research in all the three major academic areas as well as in the Humanities. The other four universities analysed are specialized. Roskilde University focuses on certain S&T disciplines, and some Humanities and Social Science disciplines. Note that even when an institutional share drops, its contribution in volume may indeed increase when the overall national productivity increases.

According to Fig. 8 the development for Level 1 articles (left-hand side) is rather smooth for the small specialized universities as well as Aarhus University. The Technical University is losing ground slightly since 2010 while University of Copenhagen constantly has lost more in Level 1 shares since 2009 (from 38.6 to 35.3 %). University of Southern Denmark and Aalborg University demonstrate growing segments of Level 1 articles through the period.

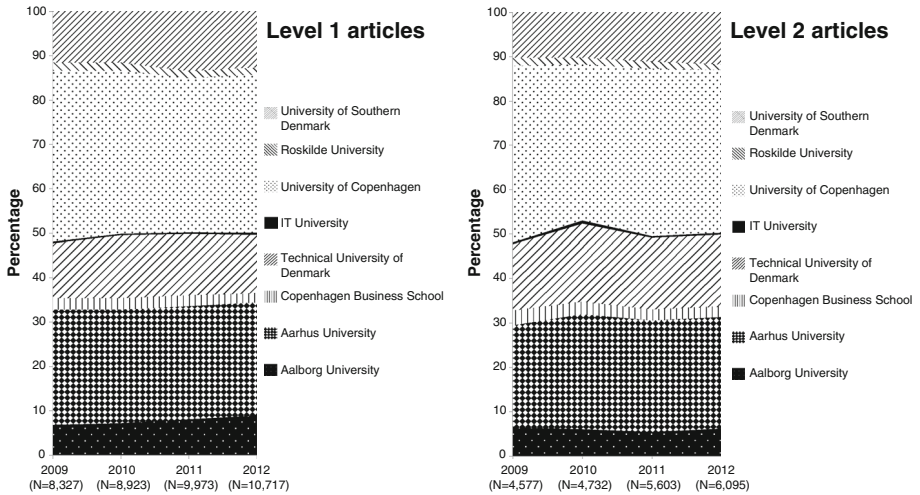


Fig. 8 Danish university segments of Level 1 (left) and 2 articles (right) 2009–2012. (Forskningsstyrelsen November 2013)

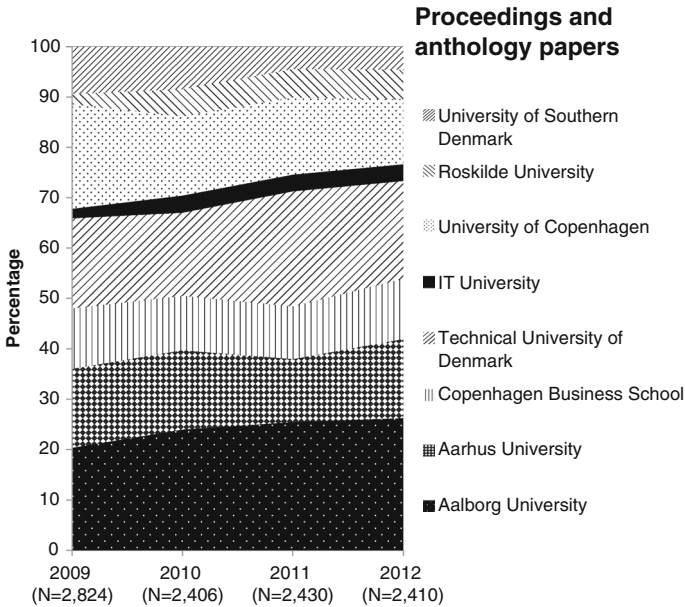


Fig. 9 Danish university shares of proceedings and anthology papers 2009–2012. (Forskningsstyrelsen November 2013)

Figure 8, right-hand side, on Level 2 article distributions shows more movements. In 2010 one observes an increase by Aarhus University and the Technical University. Like for Level 1 articles Copenhagen University has diminished its share towards 2012, from 39.8 % in 2009 to 36.8 % in 2012. Like for Level 1 articles University of Southern

Denmark increases its Level 2 article share in 2011–2012. The proportions of university segments across the two article types are quite similar.

Figure 9 displays a quite different pattern for proceedings and anthology papers. University of Copenhagen drops its share of these types quite substantially, from 20.8 to 12.8 % over the 4-year period. Also University of Southern Denmark decreases its share (from 9.3 to 4.3 %). The universities of Aalborg, Roskilde and the Technical University increase their segments, foremost Aalborg from 20.4 to 26.3 %. Since the overall number of papers drops (see the N values, Fig. 9), the more stable institutions like Aarhus University and Copenhagen Business School both contribute proportionally to the decrease in actual number of documents.

Discussion

Research question one on effects of the performance indicator on productivity and impact

In research question 1 we asked if the introduction of the performance indicator 2008 did alter the productivity and/or citation impact for Danish academic research (excluding the humanities and monographs) in the following years, compared to the period immediately prior to the introduction?

The answer is yes for productivity – to an extent for citation impact and international cooperation

The performance system does influence and reinforce the already active and positive developments in *research article production* and *impact*, Table 1 and Figs. 2, 3 and 6. The increase in productivity is significantly larger (52 %) than that of academic staff (24 %) and WoS progression (27 %) 2008–2012, compared to the period 2000–2007. The indicator has encouraged researchers to publish articles through Levels 1 and 2 journals, owing to the assignment of higher scores, Fig. 6, rather than via proceedings papers. This is evident not only in the WoS data set but also in the Agency set. In particular 2010–2012 Level 2 articles demonstrate a substantial growth (37 %). With respect to review articles the developments are rather variable across the period; from 2009 the quality of the review articles are simply not recognized by peers at the same high level as done in 2007–08.

The citation impact of journal articles (research and review articles in WoS) shows a significant linear growth during the entire period 2000–2011. It is thus not possible to ascertain if the performance indicator has furthered this trend. Neither can it be said to have had a negative influence. The observed trend is in accordance with findings by Narin et al. (1991), Glänzel (2002) and Luo et al. (2011) on higher impact observed in internationally authored articles in most areas, but in particular in biomedical, chemistry and mathematical as well as in stem cell research. The Aagaard et al. study (2014, p. 47) demonstrates an identical trend for Danish journal articles 2000–2010 although their analysis is based on fractional counting and mean normalized journal score (MNJS) constantly with a value >1.1 where 1.0 is world average.

We observe a weak negative productivity for the actual proceedings (and anthology) papers in the Agency set, which is far more pronounced in the WoS landscape. However, the same trends are visible in WoS as in the Agency data set with respect to proceedings

paper over journal article ratios since 2009, Fig. 2, left. According to the Agency data set the productivity decline in particular takes place in the Medical Sciences (−66 %).

International collaboration

Findings suggest that the significant decline in citation impact 2007–2011 for proceedings papers is caused by purely Danish as well as the internationally collaborative papers (Fig. 3, right), yet predominantly by the international set. This negative trend is also observed 2008–2012 with respect to the significant international cooperation ratio decline for proceedings papers, but not for cooperating Danish institutions, Fig. 4, right. Since SCI and SSCI both increase their indexing of publications, Fig. 2, right, the number of available citations to all items increases. Consequently more citations are in fact available to a declining number of proceedings papers as indexed by the two CPCIs. Logically, their impact might have grown. However, according to WoS proceedings papers did not receive more citations or higher impact after 2008.

Initially we speculated that the fractionalization used in the performance indicator might have a penalizing effect on *all* collaboration patterns. However, the findings, Fig. 4, left, do *not support* this idea for the research articles. On the contrary, the international cooperation ratio as well as the mean number of Danish institutions in cooperation per article is entirely stable according to WoS indexing; and the average number of countries per article actually *increases* from 2009. It is very likely though that the lower indicator score assigned proceedings papers combined with fractionalization applied 2008–2012 by the system has discouraged some from publishing in proceedings papers, shifting their efforts to journal articles.

With respect to citation impact of the internationally collaborative research articles compared to purely Danish authored articles one observes a steady impact increase from 2001 throughout the period. Simultaneously a continuous impact increase takes place until 2009 for international proceedings papers, followed by a radical drop into 2012, Fig. 3, right-hand side. The dramatic decrease in citation impact for the internationally produced proceedings papers from 2009 coincides with the lower productivity observed from the same time for proceedings papers.

Research question two on major research areas

According to the Agency data set the average growth of Level 2 research articles over the 4 years 2009–2012 is 37 %, with the Science and Technology fields showing a growth of 46 %, the Social Sciences 22 % and Medicine 16 %. This progression of Level 2 articles is substantial but weaker than the 55 % found for the 6 years 2005–2009 in Norway after the introduction of their version of the performance indicator system (Sivertsen 2010; Sivertsen and Schneider, 2012). The Level 1 article average growth is 36 %, with the Social Sciences as the most significant (37 % growth), followed by S&T (29 %) and Medicine (24 %).

In the Social sciences it seems evident that the performance indicator from 2009 has encouraged researchers to publish in Level 1 journals rather than through proceedings papers, Fig. 7, middle. For the same publishing effort authors obtain a higher score for articles than for the latter document type in the system. This trend may possibly have reached a turning point in 2012 with proceedings paper production in progress according to the figure. A kind of 1–2 year ‘incubation time’ for researchers in S&T and the Social Sciences seems to occur prior to the acceleration of research article productivity at both

levels. In Medicine researchers seem continuously to increase their article productivity without hesitation and fast to abandon proceedings papers as a research channel. While the general Danish proportion of Level 2 articles of all articles is 36.3 % (2012) it is notable that in the Science & Technology fields the proportion is significantly higher, 41.3 %, implying that this major area more fully employs Level 2 journals than other major research areas.

Research question three on university productivity

All in all the universities of Aalborg and Southern Denmark have stepped up their productivity since 2009 with respect to journal article production. Aalborg also increases its proceedings paper segment as do the specialized IT and Technical universities. The use of proceedings papers as a major vehicle for knowledge dissemination in engineering and computer science fields is evident. In contrast, University of Copenhagen and University of Southern Denmark substantially drop their shares of this type of research publications, the former university also slightly decreasing its segments of Level 1 and 2 articles over the period. Of the large universal universities Aarhus maintains its proportional productivity in all the three document types.

Summary of significant findings supporting the influence of the performance indicator

The following statistical significant trends *coincide* with the introduction 2008 of the performance indicator and support its influence on publication behaviour, based on the WoS and Danish Research Agency data set findings:

- (a) Danish journal article productivity progression is linear 2000–2007 and from 2008 to 2012 rather steep (52 %), much more profound than the advancements of Danish academic staff (24 %) and WoS (27 %) during the same 5 year period, Fig. 2, right;
 - a. In WoS the steep growth 2010–2012 is 24 %, equivalent to that observed in the Agency data set: 23.6 %, Fig. 6;
- (b) The international collaboration ratio of Danish proceedings papers is linear 2000–2007 and declines constantly the following years to .11, Fig. 4, right;
- (c) From 2010 research publishing efforts are increasingly intensive for journal articles, shifting away from proceedings papers, except in the Social Sciences where the latter publication channel is shown to recover, Fig. 6 and 7.

Other significant trends that are neutral considering the performance indicator

- (d) Danish research articles in international cooperation demonstrate linear growth 2000–2012, Table 2;
- (e) Danish research articles in international cooperation demonstrate linear impact growth 2000–2011, Fig. 3, right;
- (f) Danish journal (research and review) article impact demonstrates a strong linear growth 2000–2011, Fig. 3, left;
- (g) Danish proceedings paper impact decreases significantly 2007–2011, i.e. de decline initiates prior to the introduction of the performance indicator, Fig. 3, left.

With respect to finding (d) the performance indicator's fractionalisation factor has not influenced the outcome since 2008, perhaps neutralised by the multiplication factor in action. The growth of research article production supports the corresponding citation impacts, points (e) and (f). Correspondingly finding (g) may be reinforced by decrease of international cooperation 2008–2012 (point b).

Conclusions

The publication behaviour regarding *research articles* seems positively affected by the introduction of the performance indicator from 2008. The indicator functions as the central accelerator and positive incentive for the developments of level 2 articles, in particular published by the Science & Technology fields. For proceedings papers one detects a negative perception leading to a weak decrease in production during the same period, observed through the Research Agency data set.

The overall positive trends of steady journal article and citation impact progression already evolving from 2001 have continued linearly, regardless the introduction of the indicator. From a research political perspective this is acknowledgeable. The slight drop in the productivity of proceedings papers initiated 2009 according to the Research Agency derive mainly from Medicine and to some extent from the Social Sciences where research articles at Level 1 replace proceedings papers as the most used publishing channel after 2010. However, signs show a certain recovery of proceeding paper production in that major research area where this document type commonly is regarded an important vehicle for knowledge distribution. Lower scores assigned to proceedings and anthology papers than to journal articles evidently have some effect on productivity.

The significant decrease in the international collaboration ratio for proceedings papers owes to fewer points assigned combined with the performance indicator's fractionalization factor and its (probably) overestimated perception in the research communities. The multiplication factor applied to collaborative publications seems only effective among Level 1 and 2 articles with their stable collaboration ratios. The analysis also demonstrates an influence of the performance indicator on the publication patterns of some universities.

Finally, it is evident that the introduction of the performance indicator thus far has not introduced a 'salami-tactics' in the production behaviour in the Danish science system and a consequential decline in citation impact, as witnessed in Australia in connection with other but more simplistic point-based assessment systems (Butler 2003, 2004).

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