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PEER REVIEW AND BIBLIOMETRIC INDICATORS OF SCIENTIFIC PERFORMANCE: A COMPARISON OF CUM LAUDE DOCTORATES WITH ORDINARY DOCTORATES IN PHYSICS

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Quality judgments of predominantly local senior scientists regarding the scientific performance of candidates for a doctorate degree in physics were compared to the non-local short-term and long-term impact of the work published by these candidates before and after graduation. It was hypothesized that publications of cum laude degree-holders ('cum-laudes'), both shortly before and shortly after the award of the degree, would be higher cited both on the short and long run than publications of 'ordinary' degree-holders. Before graduation, cumlaudes were significantly more productive, as well as authors of more highly cited publications than ordinary doctorates. Publications authored by cumlaudes some years before their graduation received on the average more than twice as many citations as publications authored by non-cumlaudes. However, in particular for cumlaudes, productivity and impact decreased sharply in years after graduation. After graduation, cumlaudes continued to be more productive than non-cumlaudes, but the impact of their publications equalled those produced by non-cumlaudes. The results offer little evidence for the Matthew effect and the Ortega hypothesis, but support the validity of both peer review outcomes and bibliometric impact assessments of scientific performance.

Introduction

The assessment of scientific performance has gained a strongly increasing interest in the last ten years. Among the numerous studies, devoted to this subject, we find work on the peer review system, and studies on quantitative methods and techniques, presented sometimes as alternative to, but most frequently as supporting tools for peers. Here we can mention the pioneering work of the *Cole's.*[1] Regarding the 'bibliometric' approaches to the assessment of scientific performance we refer to work by *Narin,*[2] *Irvine* and *Martin,*[3] especially on a macro-scale, and by our group[4,5] on a more micro-scale (within-university).

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Recently, limitations of peer-review now have become more apparent[3,6] and at the same time bibliometric approaches have turned to the more modest goal of 'monitoring' the impact—and not exactly the 'quality'—of scientific performance. Nevertheless, sceptics still doubt the validity and reliability of even the weaker versions of both peer review and bibliometric approaches to the assessment of scientific performance. In the present study, an attempt is made to examine the validity of peer review and bibliometric measures more closely. In addition, a number of hypotheses, were formulated based upon theories regarding the allocation and assessment of scientific merit.

In order to test these hypotheses, quality judgements of predominantly local senior scientists on the work of candidates for a doctorate degree in physics will be compared to the non-local short-term as well as long-term impact of this work, published by the candidates before, during, and after the year in which their dissertation was accepted. In about 13 percent of the cases, these candidates were recipients of the honours degree, a doctorate 'cum laude'.

The following hypotheses were tested. A first hypothesis was based upon *Merton*'s[8] Matthew-effect, named after the biblical quote from the evangelist: "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath". The Matthew-effect would predict little difference between cumlaude and non-cumlaude graduates before graduation, as there seems to be little basis for those outside the particular university to distribute merit according to observable distinctions. After graduation, however, papers by cumlaudes should be more highly cited than those of non-cumlaudes.

The Ortega-hypothesis offers another point of view. According to *Ortega y Gasset* "experimental science has progressed thanks in great part to the work of men astoundingly mediocre, and even less than mediocre".[9] According to this Ortega-hypothesis, a relatively large share of citations and highly cited publications obtained by graduates would be received by the relatively mediocre non-cumlaudes.

The third hypothesis assumes that both peer review and bibliometric measures are partially valid indicators of scientific performance. Thus, it is hypothesized that cumlaudes perform superiorly, and that their publications are cited more often, both on the short and on the long-term, than those of non-cumlaudes. When it is also assumed that cumlaudes outperform non-cumlaudes because they are better researchers, it would be expected that cumlaudes continue to outperforme non-cumlaudes after graduation, and also continue to produce more highly cited publications than non-cumlaudes.

A fourth, perhaps rather cynical, possibility is that the quality of the research project, and not the quality of the particular student or researcher is the most important determinant of both productivity and impact of research papers. In that case, cumlaudes

would outvie non-cumlaudes, and also be authors of a larger number of more highly cited papers, for as long as their publications concern their graduate work. As some papers regarding the graduate research will be published one or two years after graduation, cumlaudes are expected to score better on bibliometric measures until that time, starting some time after the start of their graduate work. However, as they embark upon new research projects after graduation, their initial advantages may disappear.

However, each of the four preceding hypotheses presumes that both peer review and bibliometric measures reflect, at least partially, some of the quality and influence of scientific performance. Another stance has been taken by sceptics like the *MacRoberts,*[11] who claim that citations offer only a very partial reflection on the influence of a paper, if at all. In that case, no significant differences could be expected between cumlaudes and non-cumlaudes. The same outcome would be predicted by sceptics of the peer review process.

Output and impact of both cumlaudes and non-cumlaudes were studied from five years before graduation until three years after graduation, in order to obtain insight into the concurrent validity of the cum laude award with regard to the impact of a scientific oeuvre.

Method

As a data source we used the files of the Leiden Science Indicators Project, especially the publication and citation data of a fourteen-year period (1970–1983) for the physics departments at the University of Leiden. These data, used in a bibliometric study of research performance, are amply discussed in earlier work of our group.[4,5]

In-house citations (references given by other publications with a Leiden address) were not included in the citation counts. In order to remove potential differences due to type of publication, only research articles were included in the publication file (i.e., the articles coded as a blank, " ", by ISI). Book publications were excluded (ISI codes beginning with "BK "). Regarding publications with multiple authors, only the status (cum laude or not) of those authors was taken into consideration, who could fulfill all conditions posed to inclusion. Thus, if for instance only papers published before graduation are considered in a particular analysis, the status of co-authors who have already graduated is disregarded. This was done in order to focus as much as possible on the performance of the graduates, independently from co-authorships. The doctorate files of the University of Leiden have been searched for the data regarding the cum laude award. In four physics departments 19 cumlaudes and 119 non-cumlaudes were found.

Results will be presented with regard to some intriguing patterns which emerged, giving rise to suggestions on the 'mechanisms' leading to the cumlaude award.

Results

In order to assess the productivity of graduates and the impact of their work in a period closely related to their doctorate thesis, the number of publications and the average short-term impact (i.e., 'citation window' of 0 to 2 years after publication, 0 is year of publication) of research publications produced in the five-year period starting two years before and ending two years after the year of graduation was examined (see Table 1).

When publications are compared which are authored by cumlaudes and non-cumlaudes, the cumlaude group produced 6.7 publications on average, substantially more than the 4.0 publications produced by the non-cumlaude group (see Table 2).

"Pure" cumlaude publications averaged 3.2 citations versus 2.5 citations for "pure" non-cumlaude publications, a nearly significant difference ($p < 0.10$), with "mixed" cumlaude/non-cumlaude authored publications scoring somewhat higher (4.1 citations). When mixed publications are taken into account both for cumlaudes and non-

Table 1
Average short-term impact of publications in the five year period around year of graduation

Citation level ⩾	Type of degree of graduate authors of publication							
	Cumlaude		Both L. and non-C. L.		Non-cumlaude			
	C/p	*p*	*C/p*	*p*	*C/p*	*p*	*F*	*p*
0	3.21	(77)	4.07	(30)	2.48	(350)	2.79	0.10
1	3.92	(63)	4.69	(26)	3.61	(241)	0.37	NS
5	10.67	(12)	7.46	(13)	8.22	(63)	3.51	0.065
10	17.00	(5)	10.67	(3)	13.17	(18)	6.41	0.02
15	17.00	(5)	–	(0)	17.75	(4)	0.17	NS
	$\bar{c}$ = 23.06 N = 16				$\bar{c}$ = 10.32 N = 96			

Yg $-2 \leqslant$ Yp $\leqslant$ Yg $+2$; $1972 \leqslant$ Yp $\leqslant$ 1979; Yg = year of doctorate graduation;
Yp = year of publication. Number of publications (p) between parentheses.
C/p = mean number of citations per publication.
$\bar{c}$ = mean number of citations received by authors. N = number of graduate authors.
F = a variance analysis statistic, with significance level p.

cumlaudes, this leads to a somewhat higher average impact per publication for cum-laudes (3.4) than for non-cumlaudes (2.6). However, due to their combined higher productivity and larger impact per publication, the complete oeuvre of cumlaude authors averaged 23.1 citations versus 10.3 citations for non-cumlaude authors in the given publication period.

If all publications without citations in the given period are excluded, cumlaudes appear on average on 5.6 cited publications as author(s) (mixed ones included) with a mean of 4.1 citations each, twice the average of 2.8 cited publications (with 3.7 citations each) obtained by non-cumlaudes. It is evident that publications authored by non-cumlaudes are characterized relatively often (30%) by zero short-term impact compared to cumlaudes-only authored publications (17%) (see Table 2).

Only few publications are cited five times or more in the given period. Numerically, the great majority is still produced by non-cumlaudes (63 out of 98 papers), with 13 'mixed' publications. On the average, however, cumlaudes are involved with 1.6 publications receiving 5 or more citations, versus 0.8 paper for non-cumlaudes. When the inclusion level is raised further, the increasing importance of cumlaudes becomes even more evident. Five out of the nine publications receiving at least 15 citations were authored by cumlaudes. Thus, 4.7% of the publications authored by cumlaudes in the five year period around graduation year received 15 or more citations, versus only 1% of the publications authored by non-cumlaudes.

The previous results were independent of the position of the graduates among the authors of the publications. In physics, however, first authorship is often given to the junior researcher primarily involved in the project. In order to examine the effects of first-authorship, publications were selected which had either a cumlaude graduate or a non-cumlaude graduate as first author (see Table 3). Publications with a cumlaude as first author were significantly higher cited (3.4 times) on average ($p < 0.05$) than publications first-authored by non-cumlaudes (2.4 citations). Whereas

Table 2
Average number of publications per graduate
in the five year period around graduation as graded by short-term impact

Citation level ≥	Cumlaudes	Non-cumlaudes
0	6.69 (100%)	3.96 (100%)
1	5.56 (83.2%)	2.78 (70.3%)
5	1.56 (23.4%)	0.79 (20.0%)
10	0.50 (7.5%)	0.22 (5.5%)
15	0.31 (4.7%)	0.04 (1.0%)

The percentage of all publications reaching an inclusion level is given between parentheses.

Table 3
Average short-term impact of first-authored publications of graduates in five year period around graduation

Citation level ⩾	Type of degree of graduate authors of publication							
	Cumlaude		Both C. L. and non-C. L.		Non-cumlaudé			
	C/p	*p*	*C/p*	*p*	*C/p*	*p*	*F*	*p*
0	3.40	(57)	4.16	(25)	2.41	(274)	3.94	0.05
1	4.04	(48)	4.73	(22)	3.54	(186)	0.72	NS
5	13.25	(8)	8.10	(10)	8.06	(48)	7.81	0.0009
10	17.00	(5)	10.67	(3)	12.57	(14)	15.80	0.0002
15	17.00	(5)	–	(0)	15.50	(2)	1.29	NS
	$\bar{c}$ = 18.62				$\bar{c}$ = 7.95			

Yg −2 ⩽ Yp ⩽ Yg +2; 1972 ⩽ Yp ⩽ 1979; Yg = year of doctorate graduation;
Yp = year of publication. Number of publications (p) between parentheses.
C/p = mean number of citations per publication.
$\bar{c}$ = mean number of citations received by authors.

84% of cumlaudes' first-authored articles were cited at least once, this was only the case in 68% of non-cumlaudes' publications. Also, 8.8% of the publications first-authored by cumlaudes were cited at least 15 times, compared to 0.7% for non-cumlaudes. In general, although the results are somewhat more pronounced, the pattern of results did not differ much with that of Table 1, which might be due to the fact that in total 78% of the publications in which a graduate is one of the (co)-authors is first-authored by them.

A special point of interest is the impact of articles produced and published during the period in which the graduate research work was conducted, as this may reflect the impact of the doctorate thesis research of the candidates to a considerable extent. These are the publications which may have influenced members of the graduation committee in their decision about the award of a cum laude degree. Therefore, the short-term impact of articles published in the three years before graduation, as well as the year of graduation itself, was computed (see Table 4). In this four-year period, cumlaudes produced 5.1 publications on average, compared to 3.0 publications in the case of non-cumlaudes. These publications received a mean number of 21.7 citations in the case of cumlaudes, and 8.7 citations in the case of non-cumlaudes. The average number of citations per publication was 4.3 for cumlaudes, and 2.9 for non-cumlaudes. Eighty-nine percent of publications with at least one cumlaude author was cited at least once, versus 77% of the papers with at least one non-cumlaude

Table 4
Average short-term impact of publications 0 to 3 years before year of graduation

Citation level ⩾	Type of degree of graduate authors of publication							
	Cumlaude		Both C. L. and non-C. L.		Non-cumlaude			
	C/p	*p*	*C/p*	*p*	*C/p*	*p*	*F*	*p*
0	4.58	(52)	3.63	(29)	2.88	(279)	8.58	0.004
1	5.17	(46)	3.95	(22)	3.79	(212)	4.67	0.04
5	10.00	(16)	7.00	(9	8.68	(57)	1.17	NS
10	15.29	(7)	10.00	(1)	13.67	(18)	1.36	NS
15	17.00	(5)	–	(0)	17.40	(3)	0.06	NS
	$\bar{c}$ = 21.67				$\bar{c}$ = 8.74			
	N = 15				N = 102			

Yg $-3 \leqslant$ Yp $\leqslant$ Yg; 1973 $\leqslant$ Yp $\leqslant$ 1981; Yg = year of doctorate graduation;
Yp = year of publication. Number of publications (p) between parentheses.
C/p = mean number of citations per publication.
$\bar{c}$ = mean number of citations received by authors. N = number of graduate authors

Table 5
Medium-term impact of publications 0 to 3 years before year of graduation

Citation level ⩾	Type of degree of graduate authors of publications									
	Cumlaude			Both C. L. and non-C. L.			Non-cumlaude				
	C/p	*p*	*M*	*C/p*	*p*		*C/p*	*N*	*M*	*F*	*p*
0	9.13	(52)	3.47	7.42	(24)		5.27	(245)	2.40	11.92	0.0006
1	10.11	(47)	3.13	8.09	(22)		6.15	(210)	2.06	10.75	0.002
5	14.06	(31)	2.07	12.00	(13)		10.50	(102)	1.00	4.42	0.04
10	24.69	(13)	0.87	15.25	(8)		17.05	(39)	0.38	7.97	0.007
15	28.70	(10)	0.67	17.40	(5)		22.20	(20)	0.20	4.51	0.05
20	33.14	(7)	0.47	–	(0)		24.64	(14)	0.14	6.42	0.02
30	44.33	(3)	0.20	–			37.0	(1)	0.01	0.95	NS
	$\bar{c}$ = 43.53						$\bar{c}$ = 14.40				
	N = 15						N = 102				

Yg $-3 \leqslant$ Yp $\leqslant$ Yg; 1973 $\leqslant$ Yp $\leqslant$ 1979; Yg = year of doctorate graduation;
Yp = year of publication. Number of publications (p) between parentheses.
C/p = mean number of citations per publication.
$\bar{c}$ = mean number of citations received by authors. N = number of graduate authors.
M = mean number of publications per graduate author.

author. Cumlaudes averaged 1.67 papers with at least 5 citations, versus only 0.65 in the case of non-cumlaudes. Cumlaudes, although representing only 13% of the total candidates, were authors in 5 out of the 8 papers receiving more than 15 citations in their first three years.

It is conceivable that the above results were to some extent due to the particular, short-term, citation period choosen. Therefore, additional comparisons were made both with regard to the medium-term impact (0 to 4 years after publication year) and the long-term impact (0 to 6 years) of the research articles published during the years of graduation.

The medium-term impact of the total of publications with at least one cumlaude author was 43.5 citations per cumlaude, three times as much as the 14.4 citations obtained by publications with at least one non-cumlaude author (see Table 5).

Ninety-one percent of the publications with cumlaudes were cited at least once during the five year citation period versus 86% for non-cumlaudes. On average, cumlaudes were author of 1.4 publications with at least 10 citations, versus only 0.46 articles for non-cumlaudes.

When a 0–6 year citation window was used (therefore only for publications produced six years before 1983, the most recent year for which citation data were

Table 6
Long-term impact of publications 0 to 3 years before graduation

Citation level ⩾	Type of degree of graduate authors of publication									
	Cumlaude			Both C. L. and non-C. L.		Non-cumlaude				
	C/p	*p*	*M*	*C/p*	*p*	*C/p*	*p*	*M*	*F*	*p*
0	14.61	(33)	3.3	11.8	(17)	7.48	(171)	2.9	11.88	0.0007
1	15.55	(31)	3.1	11.8	(17)	8.15	(157)	2.7	11.69	0.0008
5	18.68	(25)	2.5	15.4	(12)	12.86	(90)	1.5	4.53	0.04
10	29.85	(13)	1.3	18.1	(9	18.91	(45)	0.8	6.92	0.02
15	38.0	(9)	0.9	22.4	(5)	26.04	(23)	0.4	5.15	0.04
20	40.5	(8)	0.8	23.5	(4)	29.35	(17)	0.3	3.69	0.07
30	54.0	(4)	0.4	–	(0)	35.44	(9)	0.15	5.29	0.05
	$\bar{c}$ = 68.3 N = 10					$\bar{c}$ = 25.1 N = 59				

Yg $-3 \leqslant$ Yp $\leqslant$ Yg; $1973 \leqslant$ Yp $\leqslant$ 1977; Yg = year of doctorate graduation;
Yp = pear of publication. Number of publications (p) between parentheses.
c/p = mean number of citations per publication.
c = mean number of citations received by authors. N = number of graduate authors.
M = mean mean number of publications per graduate author.

Table 7
Short-term impact and productivity of cumlaude and non-cumlaude graduates in physics over time

Publication blocks	Cumlaudes			Non-cumlaudes		
	C/a	*P/a*	*C/p*	*C/a*	*P/a*	*C/p*
Yg-5 to Yg-3	2.31	1.08	2.14	1.99	0.81	2.43
	(2.92)	(1.31)	(2.23)	(2.09)	(0.85)	(2.45)
Yg-4 to Yg-2	10.93	2.36	4.64	3.66	1.23	2.98
	(12.00)	(2.86)	(4.20)	(3.83)	(1.31)	(2.92)
Yg-3 to Yg-1	14.13	2.73	5.17	5.49	1.74	3.16
	(15.67)	(3.47)	(4.52)	(5.71)	(1.84)	(3.10)
Yg-2 to Yg	13.12	3.06	4.29	6.99	2.37	2.95
	(17.12)	(4.06)	(4.22)	(7.61)	(2.52)	(3.02)
Yg-1 to Yg + 1	12.79	3.68	3.47	8.41	3.01	2.79
	(13.79)	(4.26)	(3.24)	(8.58)	(3.11)	(2.76)
Yg to Yg + 2	9.33	3.22	2.90	6.26	2.57	2.44
	(11.28)	(3.89)	(2.90)	(6.59)	(2.68)	(2.46)
Yg + 1 to Yg + 3	5.93	2.73	2.17	3.96	1.89	2.09
	(6.60)	(3.00)	(2.20)	(4.07)	(1.93)	(2.11)

C/a = average number of citations per author;
P/a = average number of publications per author;
C/p = average number of citations per publication. Between parentheses, results are given which incorporate "mixed publications" of cumlaude and non-cumlaude authors.
Yg = year of graduation.

available), the total published graduation work of cumlaudes was cited 68.3 times on average, 2.7 times as much as the 25.1 citations received by non-cumlaudes (see Table 6). Ninety-six percent of the publications with at least one cumlaude author was cited at least once, compared with 92.5% of the papers produced by non-cumlaudes. Seventy-four percent of the publications authored by cumlaudes received at least 5 citations, versus 54% of the publications by non-cumlaudes. Fourty-four percent of 'cumlaude publications' were cited at least ten times, versus 29% of non-cumlaude publications, with 28% were cited at least 15 times (versus 15%), 24% (versus 12%) at least 20 times, 8% (versus 4.8%) at least 30 times, and two publications (versus none) exceeded 50 citations (average 94.5: citations) Notwithstanding their higher production, publications by cumlaudes are cited considerable higher on average than those of non-cumlaudes, independent of the particular 'citation window' choosen.

In order to examine the comparative changes in productivity and impact of cumlaudes and non-cumlaudes over time, Table 7 was constructed. The impact of publica-

tions authored over a period of time several years before graduation, around graduation, and some years after graduation was computed, the period being divided in partially overlapping consecutive three year blocks, starting with the first three year block 5 to 3 years before graduation until 1 to 3 years after graduation. This type of longitudinal study is to be preferred above simple life work citation counts.[7]

Citation windows were used consisting of citations received in the year the paper was published, as well as in the two subsequent years. Summarizing the measuring method, blocks were formed consisting of three consecutive publication years, each having its own 0–2 year citation window.

Although some graduates have authored publications many years before graduation, the rate of publication is still comparatively low in the first block five to three years before graduation. During these three years, cum laude graduates-to-be produce only about one publication on average. The production of non-cumlaudes is virtually the same (0.8 publication). Also, publications of both groups are cited relatively low (see Table 7). Both publication and impact rates rise considerably in the next, partially overlapping, three-year block extending from four to two years before graduation. Especially, publications of cumlaudes increases fast both in number and impact. Their productivity more than doubles from 1.1 article to 2.4. These publications are cited on average 4.6 times instead of 2.1 times each in the preceding period. As a result, the published work of cumlaudes is cited almost 11 times on average, a considerable increase from the 2.3 times in the previous period. It should be noted that both publications and citations in this second block are potentially visible for members of the graduation committee, as the last year in which the publications (published in the second year before graduation) can be cited is the year of graduation. Comparatively, both the increases in publications and impact for non-cumlaudes-to-be are small, as the number of publications increases with 50% (from 0.8 to 1.2), and the average impact per publication increases from 2.4 citations to 3.0 citations. For the first time, productivity and impact figures of non-cumlaudes are significantly below those of cumlaudes.

Both productivity and impact continue to increase during the next three-year publication block, which extends from the third to the first year before graduation, and part of which also may have influenced the graduation committee. In this period, the mean short-term impact per publication peaks at 5.2 citations (see Fig. 1) for cumlaudes, and significantly lower, at 3.2 citations for non-cumlaudes. Productivity increases modestly for cumlaudes with 0.3 publications to 2.7 publications, and relatively strong (with 0.5) to 1.7 publications for non-cumlaudes. This period shows also a peak for cumlaudes as regards the total short-term impact of their publications, which reaches 14.1 citations, as compared to only 5.5 citations for non-cumlaudes.

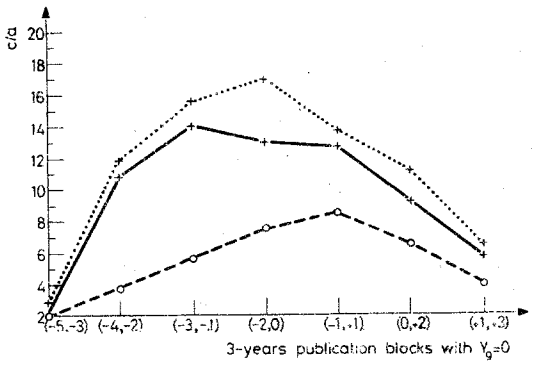

Fig. 1. Citations per author for cumlaudes and non-cumlaudes over time. Curves —— + —— cumlaudes, . . . + . . . cumlaudes corrected, – – – o – – – non-cumlaudes corrected

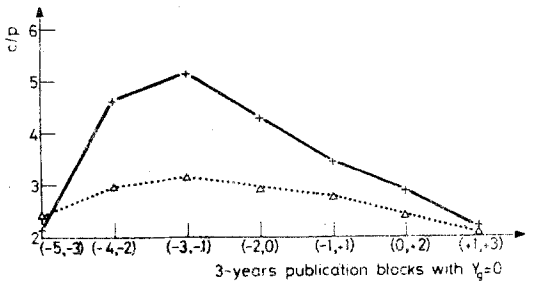

Fig. 2. Short-term impact per paper for cumlaudes and non-cumlaudes. Curves: —— + – – cumlaudes, . . . Δ . . . non-cumlaudes

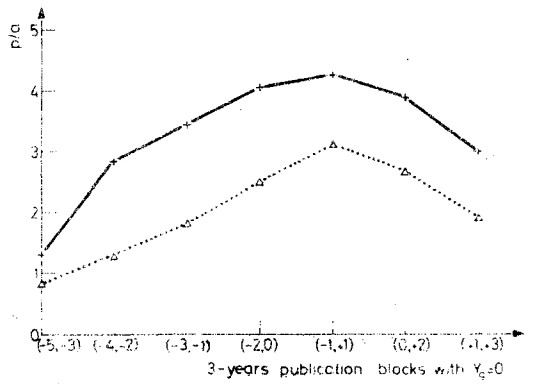

Fig. 3. Publications per author for cumlaudes and non-cumlaudes. Curves: —— + ——cumlaudes, . . . Δ . . . non-cumlaudes

In the subsequent three-year block, extending from two years before graduation to the year of graduation, the average impact per publication decreases for cumlaudes from 5.2 citations to 4.3 citations, although the decrease is somewhat less sharp and not significant (from 4.5 to 4.2) when also articles published together with a non-cumlaude graduate are taken in account. For non-cumlaudes, the decrease in impact per publication is not significant. The number of publications still increases for both groups, but again relatively more important for noncumlaudes (from 1.7 to 2.4 articles) than for cumlaudes (from 2.7 to 3.0), although cumlaudes have co-authored on average an additional publication with non-cumlaudes.

In the three-year block centering around the year of graduation, the average number of publications per author still continues to increase for non-cumlaudes (from 2.4 to a peak of 3.0 publications), but virtually nonsignificant for cumlaudes (from 4.1 to 4.3, after correcting for publications coauthored with non-cumlaude graduates). However, the small increase in productivity of cumlaudes cannot make good for the decrease in impact per publication (from 4.2 to 3.4 citations), resulting in a total impact of only 12.8 citations (13.8 corrected), which is somewhat below the level of the previous two periods considered. For non-cumlaudes, the total impact rises from 7.0 citations to 8.4 citations, as their increase in productivity still offsets their significant decrease in impact per publication (from 2.9 to 2.8 citations). For the first time, impacts per publication of cumlaudes and non-cumlaudes are no longer significantly different.

Productivity and impact levels deteriorate clearly during the block which includes graduation year and the two years thereafter (see Figs 1, 2 and 3). The average short-term impact per publication decreases for cumlaudes to 2.9 citations, while productivity declines to 3.2 (3.9 corrected) articles per author. Non-cumlaudes show similar declines in impact and productivity. Finally, further declines are apparent 1 to 3 years after graduation. Although cumlaudes continue to publish on average one publication more with a Leiden address than non-cumlaudes, both their absolute and relative impact per paper has deteriorated sharply, and is now almost exactly that of non-cumlaudes, and on the level as produced 5 to 3 years before graduation, far below all other periods. Even though in all previous blocks (except the first) long-term impact of articles by cumlaudes is significantly higher than of those published by non-cumlaudes, this difference in long-term impact is no longer significant 1 to 3 years after graduation.

A final analysis was performed to gain insight into the average impact of journals in which papers are published. Therefore, an analysis was made with regard to 'journal citation scores', which are computed by taking the mean number of citations publications receive in the second year after publication in the particular journal (see Ref.[4]) In order to exclude effects of random fluctuations in the journal

citation scores as much as possible, scores were over three years (the year of publication–two years after publication). The three-year publication blocks offered similar results as the previously discussed analysis of the number of citations per publication (see Fig. 4), with significant differences found in the publication blocks (–4, –2), (–3, –1), and (–2, 0).

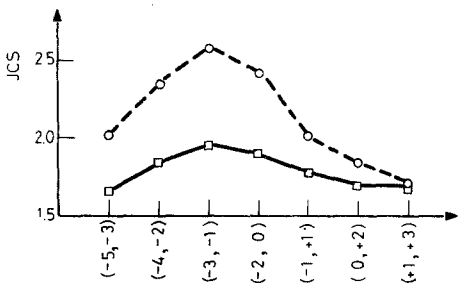

Fig. 4. Journal citation scores of cumlaudes and non-cumlaudes over time (JCS = Journal Citation Scores. Yg = year of graduation)

In general, journal citation scores of cumlaudes exceeded those of non-cumlaudes, yielding significant differences in the three blocks (–4, –2), (–3, –1), and (–2, 0). More specific analyses, not shown here in detail, show that journal citation scores of cumlaudes were especially high in the third year before graduation, and were also significantly, or nearly significantly higher than those of non-cumlaudes in the subsequer three years. After graduation, cumlaudes and non-cumlaudes published in journals with similar impacts as measured by the journal citation scores.

Discussion

In this study a comparison was made between the results of a peer review process, namely the awarding of a cumlaude degree to doctorate candidates in physics, and bibliometric indicators regarding the work of both award and non-award recipients before and after graduation. It was hypothesized that, starting a few years before graduation, publications authored by cumlaudes would show a larger short-term and long-term impact than publications authored by non-cumlaudes published in journal theories regarding scientific quality judgments and merit distribution among scientists will be compared regarding their predictions.

In order to get an overall view, publications in a five year period, including the year of graduation (as well as the two years before and after that event), were examinec

with regard to their short-term impact. All publications carried the address of the university awarding the cumlaude degree, which makes it unlikely that research conducted after graduation at another institution influences the results. Cumlaude degree recipients were much more productive than non-award recipients, as cumlaudes produced 70% more publications on average than non-cumlaudes. In addition to their greater productivity, publications authored by cumlaudes were cited, on average, more often per article than publications authored by non-cumlaudes during the first three years.

Compared to non-cumlaudes, cumlaudes received more than twice as many citations overall for their publications, which were all given by scientists outside their alma mater. Furthermore, cumlaudes produced disproportionally more publications with a high short-term impact than non-cumlaudes. Results were even somewhat more pronounced when only publications with a graduate as first author were considered.

When a period was choosen which represented most of the early productivity and impact of the graduates, extending from three years before graduation to graduation, results were comparable to those previously discussed with differences in productivity of publications and especially short-term impact being still more in favor of cumlaude graduates. Also, when a medium-term (0 to 4 years) or a long-term citation window (0 to 6 years) was used, results did not change essentially. These results support the hypothesis that cumlaudes score better on bibliometric measures than non-cumlaudes.

Perhaps most importantly, impact and productivity were studied over time by examining seven consecutive partially overlapping three-year blocks extending from five years before graduation to three years after graduation. In the first three year period, productivity and short-term impact of cumlaudes and non-cumlaudes-to-be were highly similar. However, in the four years before graduation, both productivity (as measured by published research articles) and short-term impact per publication and per author showed huge differences between cumlaudes and non-cumlaudes, with the former exceeding the latter by factors of two and three. There were also clear differences in patterns of productivity and impact. Cumlaudes peaked fairly soon in both average short-term impact per publication and in total number of publications published in a three year period, already reaching in the second block (4–2 years before graduation) levels of impact never to be reached by non-cumlaudes, and also levels of productivity equalled only three blocks later by non-cumlaudes. In contrast, the average short-term impact per publication changed hardly at all during the first six of the three-year blocks for non-cumlaudes, and the average number of their publications increased steadily but relatively slowly toward their graduation year. Thus, non-cumlaudes seem to develop their publishing and research skills considerably later than cumlaudes, without, on the average, ever quite catching up, especially with regard to publication rates. Another possible explanation will be discussed further on.

A remarkable point is the decline in short-term impact per publication and total number of citations received, which is already quite early observable for cumlaude graduates. Even before graduation, the short-term impact per publication of cumlaudes is declining, a decline which continues in all subsequent periods which have been observed, finally reaching the level of non-cumlaudes. One to three years after graduation, even the long-term impact of publications authored by cumlaudes was no longer significantly higher than those written by non-cumlaudes.

It is interesting to compare these results with the predictions made on the basis of various theories regarding the allocation of scientific merit. The 'Matthew-effect' predicts little difference between cumlaude and non-cumlaude graduates before graduation, as there seems little basis for those outside the particular university to be able to distribute merit according to observable distinctions. In fact, this pattern is only observable in our earliest measurement point, five to three years before graduation. The Matthew-effect can not explain the sudden increase in citations given to little known graduates, except perhaps when it is assumed that not so much the contributions of the graduate authors are rewarded with citations, but only the visibility and distinctions of the co-authors, which often include the mentor or more senior faculty. However, in the present situation, both cumlaudes and non-cumlaudes share the same mentors and faculty, so the presence of the mentor as co-author does not explain much, the more so as cumlaudes are more or less evenly divided among mentors. Another possibility, which cannot be checked with our present data, is that the cumlaudes-to-be collect the first effects of a Matthew-effect due to earlier awards received by them, as for instance a cum laude undergraduate degree. However, this advantage (if any) is of short duration, as the average number of citations per publication drops after the second year before graduation. This pattern does not point to a persistent cumulative advantage due to earlier awards. The Matthew-effect even seems to be completely contradicted by the results obtained after graduation, which show less citations per publication being given to those awarded with a cumlaude than before they accumulated some merit. After graduation, citation rates of cumlaudes even decline to the level of non-cumlaudes. Although it might be the case that publications of cumlaudes based on their work elsewhere are more heavily cited than average (which we are planning to study on a later occasion), even then it is not clear on basis of the Matthew-effect why some of their work is less cited after reception of the award than before. In addition, the Matthew-effect is of little help in explaining the large variability of citations given to work of the same author, published at the same institution, and in the same period of time. Thus, we have to conclude that a Matthew-effect is generally not visible in our results.

According to the Ortega-hypothesis, a relatively large share of citations and highly cited publications would be obtained by the relatively 'mediocre' non-cumlaudes. In

general, although outnumbering cumlaudes by a factor 6, non-cumlaudes account jointly for only 2 to 3.5 times the number of citations obtained by cumlaudes. On the other hand, still a large number of citations is received by non-cumlaudes, indicating the impact of their work. Therefore, a lot of useful research would probably be lost when only cumlaudes-to-be would be allowed to do research. However, it is important to notice the interesting finding that the majority of the citations received by non-cumlaudes is given to a small subgroup. For instance, out of the 1279 citations received by 59 non-cumlaudes (for 171 publications in the four year period closed by the graduation year) 499 were given to only 17 publications, each receiving 20 or more citations in the seven year period following publication. In comparison, out of the 683 citations received by 10 cumlaudes for 50 publications, 418 were given to the 12 publications cited 20 or more times in the same period. Thus, the Ortega-hypothesis seems not very viable, as the evidence shows small elite groups receiving most of the citations (see also Ref.[10])

It has been assumed here that bibliometric measures reflect, or at least monitor, the impact of scientific performance. Another stance has recently been taken by sceptics like *MacRoberts, MacRoberts.*[11] These sceptics claim that citations offer only a very partial reflection of the influence of a paper, if at all. However, it remains unclear then, why cumlaude graduates are much more heavily cited than non-cumlaudes, and are especially likely to produce articles with high impact. Thus, this point of view also has little to offer to the clarification of the present results.

Our data, however, comply rather well with a fourth possibility. According to this hypothesis, the quality of the research project, and not the quality of the particular graduate is the most important determinant of both productivity and impact figures. A possible scenario would be that some PhD graduates are choosen carefully by their mentors to do research in one of the usually rare very promising, interesting and hot research topics currently available. Most others are engaged in relatively less interesting and promising graduate research projects. Some of those participating in the most promising research projects will book almost immediately important results, which are rapidly published and also relatively highly cited. Some graduates, no doubt, fail, and will of course not be awarded with a cum laude. This account would mesh rather nicely with the observed sharp increase both in number of publications by cumlaudes-to-be and in the impact of journals in which these are published, starting in the third year before graduation, and with the fact that graduates in the Netherlands are usually given four years in which to graduate. Given the nature of their research projects, most graduates on the less promising projects booked less important results in general, which also took more time to achieve. This might explain the gradual increase in published output of non-cumlaudes until about the year of graduation.

However, more data would be necessary in order to test these perhaps rather cynical assumptions. In particular, the impact of all of the work done by cumlaudes and non-cumlaudes after graduation, including research done outside the alma mater, would have to be compared, as it is possible that, after graduation, cumlaudes engage in new research at other institutions which continues to show the high impact witnessed before graduation. As the latter scenario would be accurate, the drop in productivity and impact which is evident for cumlaudes almost even before the year of graduation, could be due to the need to publish the less important results of the project after having published the most important early results first. Also, it would be interesting to see if patterns as have been observed with physics graduates can be generalized to other fields of research. We hope to examine these points in the near future.

Finally, although the present data do not allow to make distinctions between the relative importance of the particular research projects and the persons conducting the research, it is clear that oeuvres judged to be important and of high quality by local peers, as witnessed by the relatively rare award of a cumlaude degree, is also cited more extensively on the average by nonlocal scientists than work which is judged locally to be of relatively less importance and less high quality. It should be noted, however, that the work of some non-cumlaudes is cited with approximately the same frequency as that of cumlaudes. As has already been indicated, the judgements of the graduation committee might have been influenced by the early productivity and (some of) the higher impact of earlier work of the graduates. Evidently, the two indicators are not completely independent. Nevertheless, it seems highly unlikely that cum laude degrees were offered only on the basis pf productivity and impact of earlier work. If that would have been the case, it cannot be explained that a considerable number of productive and highly cited graduates were not awarded with a cumlaude.

In general, however, it can be concluded that both indicators of research quality point in the same direction, thus offering support to the concurrent validity of both approaches.

References

1. S. COLE, L. RUBIN, J. R. COLE, Peer review and the support of science, *Scientific American,* 237 (1977) 34; J. R. COLE, S. COLE, Which researcher will get the grant? *Nature,* 279 (1979) 575; S. COLE, J. R. COLE, G. A. SIMON, Chance and consensus in peer review, *Science,* 214 (1981) 881.
2. F. NARIN, *Evaluative Bibliometrics. The Use of Publication and Citation Analysis in the Evaluation of Scientific Activity,* National Science Foundation, 1976.
3. J. IRVINE, B. R. MARTIN, Evaluating big science: CERN's past performance and future prospects, *Scientometrics,* 7 (1985) 281.

4. H. F. MOED, W. J. M. BURGER, J. G. FRANKFORT, A. F. J. VAN RAAN, *On the Measurement of Research Performance. The Use of Bibliometric Indicators,* Research Policy Unit, Leiden, 1983. Monograph: 200 pp. ISBN 90-9000552-8.
5. H. F. MOED, W. J. M. BURGER, J. G. FRANKFORT, A. F. J. VAN RAAN, The use of bibliometric data for the measurement of university research performance, *Research Policy,* 14 (1985) 131.
6. H. F. MOED, W. J. M. BURGER, J. G. FRANKFORT, A. F. J. VAN RAAN, A comparative study of bibliometric past performance analysis and peer judgement, *Scientometrics,* 8 (1985) 149.
7. A. J. NEDERHOF, Evaluating research output through life work citation counts, *Scientometrics,* 7 (1985) 23.
8. R. K. MERTON, The Matthew effect in science, *Science,* 159 (1968) 56.
9. J. ORTEGA Y GASSET, *The revolution of the masses,* New York, Norton, 1932.
10. W. E. SNIZEK, A re-examination of the Ortega hypothesis: The Dutch case, *Scientometrics,* 9 (1986) 3.
11. M. H. MACROBERTS, B. R. MACROBERTS, Quantitative measures of communication in science: A study of the formal level, *Social Studies of Science,* 16 (1986) 151.