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A COMPARISON OF AUSTRALIAN UNIVERSITY OUTPUT USING JOURNAL IMPACT FACTORS

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We weighted the output of SCI items from Australian universities using journal impact factors. This provides us with an accessible quality indicator of science journal publishing, and allow us to scale for institutional size in terms of output and research staff. Use of this indicator for the 20 pre-1987 Australian universities demonstrates that although some universities rank highly on output, when scaled for institutional size they are overtaken by some of the smaller, more recently established universities.

Introduction

There has been much discussion recently on comparative output of science publishing between Australian universities.[1–5] Apart from the work of *Bourke* and *Butler*[1,2] on citations, this discussion has not focussed on the quality of these outputs. In this article we address the following questions: Which Australian university has most publications in quality science journals? What is the quality of output per researcher for Australian universities?

A performance measure often used as an indicator of journal quality is the journal's annual impact factor. This is the average number of citations per article to articles published in that journal in the previous two years.[6] The calculation of impact factors in this study applies only to source journals of the *Science Citation Index* (SCI). However about 75% of all Australian university science articles appear in these journals.[7,8]

There are disadvantages in using journal impact factors as indicators of journal quality. First, there is a distinction between being published in a journal and being cited by that journal. Journal impact factors, as formal averages, do not reflect the skewed distribution of citations to articles in those journals.[9] Secondly, journal impact factors can vary widely between years, so it is difficult to interpret the impact

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factor of a journal as an indicator of a *characteristic* of that journal. Thirdly, impact factors vary from one discipline to another, due in part to differing citation practices. The impact factor as a statistic is skewed towards the biological and medical sciences, and away from engineering and mathematical sciences.

On the other hand, studies have shown that user perceptions of journal prestige correlate with impact factors.[10] Further, an Australian National Board of Education, Employment and Training[11] study (see p. viii) demonstrated that Australian Research Council applicants ranked publication of research results in journals weighted by citation impact as one of seven preferred performance indicators out of the twenty proposed.

In a study of British academic institutions, *Carpenter* et al.[12] used an "influence weight procedure" to weight institutional output. They point out that "...there is a near universal agreement on the need for data not just on numbers of publications, but also on their subsequent scientific impact" (p. 215). However, they indicate that two advantages of weighting output versus traditional citation analysis are (1) that the latter is costly and labour-intensive, and (2) normally there is a lag of several years between publication of an article and a clear record of citations to it. *Carpenter* et al.[12] use the CHI journal-"influence weight" as a surrogate measure of impact of any article published in it, whereas in this study we use the SCI impact factor in a similar way.

Although Australia now has a unified national tertiary education sector, the post-1987 universities generally have a very much lower scientific output than the pre-1987 universities. In this study we have concentrated on the impact factors of science journals containing articles with Australian authors from the 20 pre-1987 universities: University of Adelaide, Australian National University (ANU, including the Institute for Advanced Studies), Deakin University, Flinders University of South Australia, Griffith University, James Cook University, La Trobe University, Macquarie University, University of Melbourne, Monash University, Murdoch University, University of New South Wales (NSW), University of New England, University of Newcastle, University of Queensland, Queensland University of Technology (QUT), University of Sydney, University of Tasmania, University of Western Australia, and University of Wollongong.

Methodology

Data was downloaded from the SCI on CD-ROM (Institute for Scientific Information, 1991–1993). As advocated by *Leydesdorff*[13] we included all types of source items (articles, meeting abstracts, notes, letters, etc.: see *Science Citation*

Index, 1993 Annual). The *year* of an item was taken to be the year of the SCI CD-ROM in which the item was included (as opposed, for example, to publication year). An item was included as coming from a particular Australian university when it had one or more authors who gave their address as that university. This makes a certain amount of overlap necessary when authors from different institutions collaborate. The data on source publications and total source items came from the SCI Comparative Statistical Summary (1991–1993) and the SCI publication data for those years.

Each of the 20 pre-1987 universities was given a *weighted impact sum* for each of the years 1991–1993. The weighted impact sum (WIS) for a particular university, for a given year, was obtained by assigning to each SCI source item with an author from that university, the impact factor for that year of the journal containing the item, and then summing over all such items. A "world annual average impact factor" was calculated using totals from section 1 of the Journal Rankings in the SCI *Journal Citation Reports*.

The *Commonwealth Universities Yearbook* for 1994 includes academic science staff and their academic qualifications for the 20 pre-1987 universities for 1993. We used these figures as estimates of science staff over the period 1991–1993: changes in such a small period are likely to be quite minor. For the purposes of this study we counted as science staff those people in traditional science departments, as well as those in Psychology, Environmental Science, and Health Sciences (including Nursing), but not Geography or Environmental Studies.

We counted as "research staff" people whose names were listed as science staff with a PhD or other research doctorate (research MD or D Eng, for example). Such people have generally been hired to carry out research and can reasonably be expected to publish regularly in quality science journals. Staff listed in special centres or research units were not included due to the problem of double counting: they were often listed as members of other faculties. The Australian National University count included the Institute for Advanced Studies (IAS) due to the difficulty of separating them on the basis of their SCI institutional addresses. Further the IAS, unlike the other universities, includes names and qualifications of post-doctoral fellows, so these people were included as "research staff".

The number of "research staff" was used to calculate the weighted impact sum per researcher. The total number of academic staff is more readily available from the Department of Employment, Education and Training, (Higher Education Series, report No. 22, 1994). However, use of this total number entails an assumption that the ratio of science staff to non-science staff is constant across Australian universities. This assumption does not seem to hold even for the pre-1987 universities. Since we are counting only publications in SCI source journals it makes sense to include only research qualified staff working in science faculties and departments. In doing this we may have missed counting some people in non-science departments who publish in science journals, but the number is likely to be extremely small.

Results and analysis

The weighted impact sums per item, and the number of items, for each of the 20 pre-1987 universities for 1991–1993 is presented in Table 1, below.

Table 1
Weighted impact sums per item, items, and research staff, 1991–1993
(Note that table rows are sorted, in descending order, by total number of items)

University	1991 WIS/ item	1991 Items	1992 WIS/ item	1992 Items	1993 WIS/ item	1993 Items	1991–1993 Total items	1993 Research staff
Sydney	2.141	1006	2.124	1119	2.065	1244	3369	657
Melbourne	2.064	993	2.477	1023	2.391	1169	3185	456
ANU	2.304	895	2.379	958	2.597	966	2819	663
N SW	1.865	727	1.894	861	1.986	923	2511	702
Queensland	1.761	755	1.924	777	1.857	828	2360	615
Monash	2.141	579	2.099	648	2.248	704	1931	513
Western Aus	1.72	587	1.711	592	1.781	689	1868	375
Adelaide	1.863	575	1.999	580	1.895	654	1809	319
Flinders	1.893	344	2.767	354	2.642	354	1052	148
La Trobe	1.767	253	2.364	267	2.061	305	825	216
Newcastle	1.928	253	1.807	271	1.737	294	818	195
Tasmania	1.873	170	1.648	208	1.693	236	614	168
New England	1.261	193	1.556	185	1.676	212	590	146
Macquarie	1.754	174	2.082	166	1.935	147	487	192
Murdoch	1.105	143	1.122	119	1.394	167	429	113
James Cook	1.3	106	1.912	141	1.575	177	424	133
Wollongong	1.26	118	1.264	146	1.431	148	412	177
Griffith	1.666	124	1.373	128	1.541	105	357	142
QUT	1.248	62	0.993	99	1.294	98	259	150
Deakin	1.492	51	2.113	82	1.588	75	208	90
All Australia	1.959	12586	2.067	13546	2.098	14866		
WORLD	1.635	590306	1.717	639198	1.756	652532		

The table also includes the number of research staff for 1993. We have also included the figures for the world and for all of Australia. "All Australia" includes output from not only universities but all Australian science research institutions (such as CSIRO, Walter and Eliza Hall Institute of Medical Research, and so on).

Correlation of weighted impact sums with output

For each of the years 1991–1993 the weighted impact sum of the universities correlates very highly with the total number SCI source articles from the universities. The correlation coefficients are: 0.982 for 1991, 0.968 for 1992, and 0.967 for 1993.

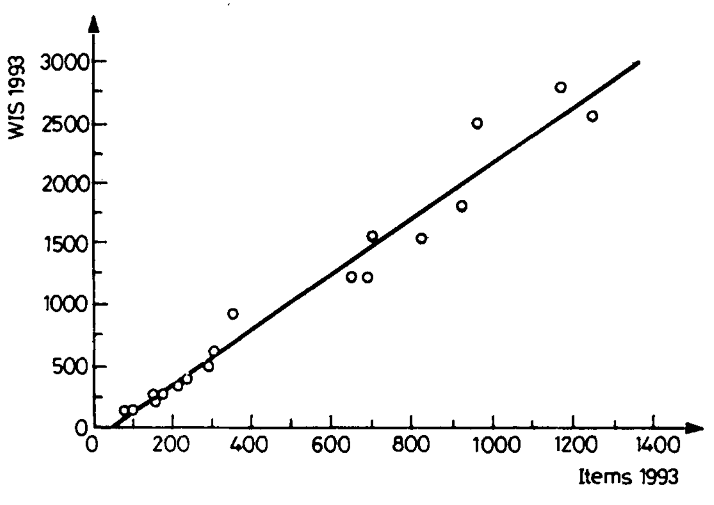

Fig. 1. Weighted impact sum *versus* items, 1993: $r^2 = 0.967$

This might give comfort to those who argue for institutional quality by output rather than taking into account added quality indicators such as numbers of citations or journal impact factor. However, the weighted impact sums allow us to scale for size of output: something we cannot do with output alone.

Correlation of total items with research staff

The total number of items for 1991–1993 correlates moderately well with the number of research staff as can be seen from Fig. 2.

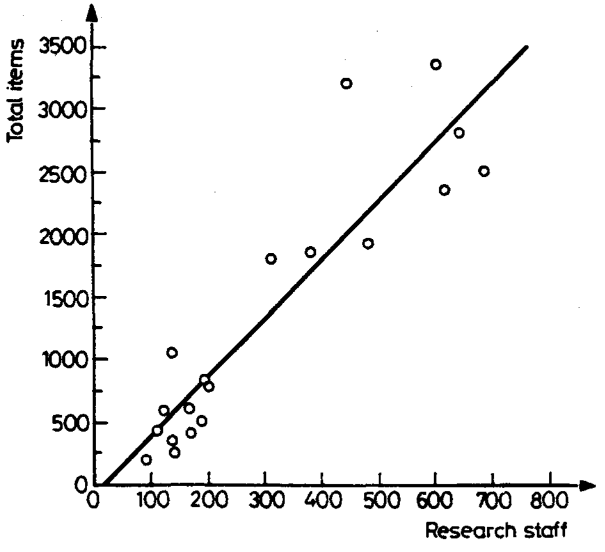

Fig. 2. Total items 1991 – 1993 *versus* research staff 1993. $r^2 = 0.855$

The items per research staff range from 1.73 to 7.11, with a mean of 3.97.

Table 2
Items per research staff

University	Total items research staff	University	Total items research staff
Flinders	7.11	Murdoch	3.80
Melbourne	6.98	Monash	3.76
Adelaide	5.67	Tasmania	3.65
Sydney	5.13	N SW	3.58
Western Aus	4.98	James Cook	3.19
ANU	4.25	Macquarie	2.54
Newcastle	4.19	Griffith	2.51
New England	4.04	Wollongong	2.33
Queensland	3.84	Deakin	2.31
La Trobe	3.82	QUT	1.73

Distribution of weighted impact sum per item

How do the weighted impact sums per item for the 20 pre-1987 universities compare over this 3 year period? To make a sensible year-by-year comparison we need to adjust for a changing mean world impact factor: 1.635 in 1991, 1.717 in 1992 and 1.756 in 1993. This is a general annual inflation in citations and we need to take it into account before we can compare one year with another. We first scaled for this annual inflation, and then averaged these scaled weighted impact sums per article from 1991 – 1993. The results are shown in Fig. 3.

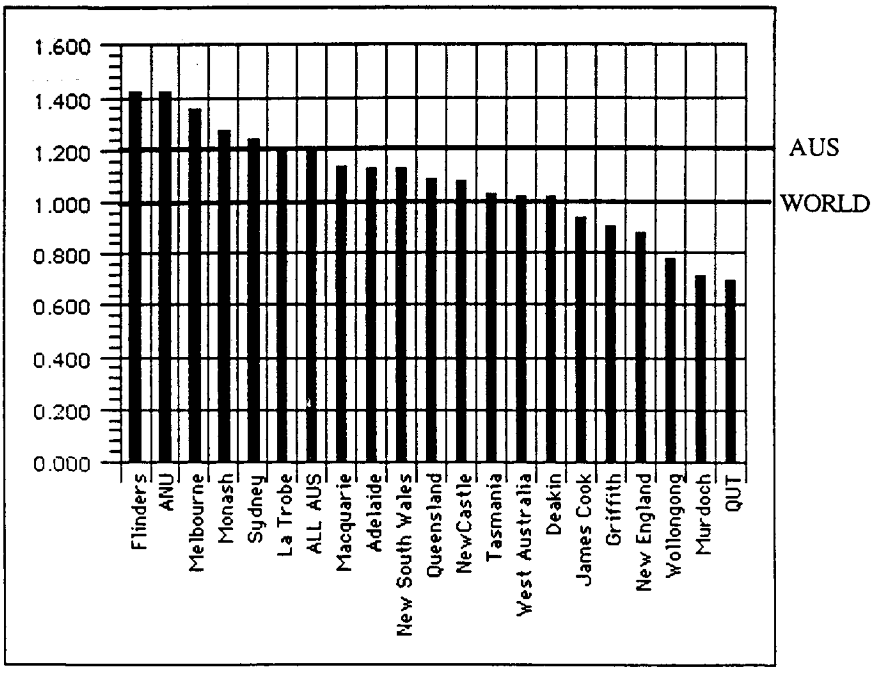

Fig. 3. Mean weighted impact sum per item, scaled for world inflation, averaged over 1991 – 1993. Average for the 20 pre-1987 universities = 1.071. Note: "ALL AUS" denotes the figure for all Australian science

Variation of the fractional weighted impact sum with fraction of items

For each of the 20 pre-1987 universities we plotted the fractional weighted impact sum versus the corresponding fraction of items for 1993. In doing this we started from the items in journals with highest impact factor, working down to those with lowest impact factor.

The graphs have a similar appearance – approximating a square root function. A log-log plot shows this to be the case. A table of correlation coefficients and slopes of the corresponding log-log plots is given below for each of the 20 universities for 1993.

Table 3

Slopes and correlation coefficients of log(fraction of weighted impact sum) versus log(fraction of total items), 1993. Estimated using linear regression

University	Slope	r^2
Adelaide	0.496	0.987
ANU	0.459	0.959
Deakin	0.5	0.986
Flinders	0.521	0.982
Griffith	0.581	0.975
James Cook	0.36	0.965
La Trobe	0.57	0.989
Macquarie	0.507	0.995
Melbourne	0.549	0.984
Monash	0.515	0.98
Murdoch	0.586	0.976
New Engl.	0.381	0.962
Newcastle	0.647	0.982
Queensland	0.447	0.986
QUT	0.618	0.967
Sydney	0.502	0.984
Tasmania	0.488	0.993
Western Aus	0.477	0.982
Wollongong	0.453	0.997
Mean:	0.508	0.981
Stdev:	0.070	0.010
All Aus:	0.479	0.974

The plots of the fractional impact sums versus the fraction of items are shown below for those universities with the lowest and highest slopes for the log-log plots, James Cook and QUT respectively.

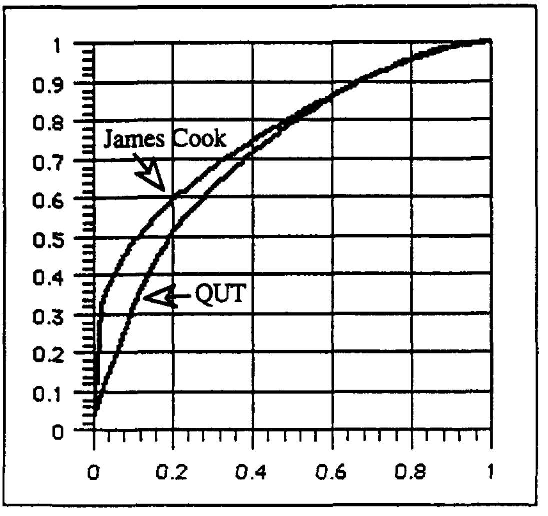

Fig. 4. Fractional weighted impact sums *versus* fraction of items for James Cook and QUT, 1993

Weighted impact sum per researcher

We can use the weighted impact sums to take account of institutional size by calculating the average weighted impact sum per research staff. *Moulden*[5] has argued that the output per academic staff member can be used as a measure of efficiency or research intensity. We use weighted impact sums instead of output although, as we pointed out above, they correlate highly. Instead of simply counting *all* academic staff we take into account the research qualified science staff: those with a PhD or other research doctorate. The weighted impact sum, averaged over 1991-1993, per research staff member for each institution is shown in Fig. 5.

In Figures 3 and 5 we ranked institutions by "weighted impact sum per item" and "weighted impact sum per research staff" respectively. There is a moderate correlation between these two institutional rankings, as shown in Fig. 6.

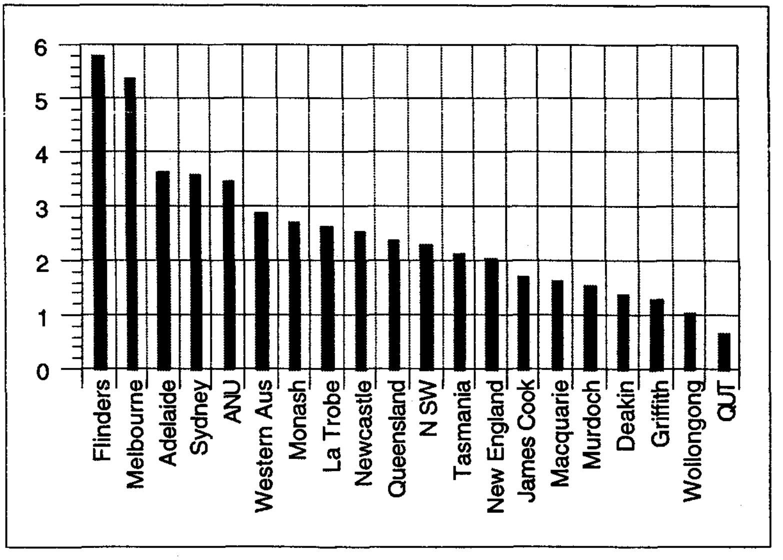

Fig. 5. Average weighted impact sum (1991 – 1993) per research staff. Mean = 2.532

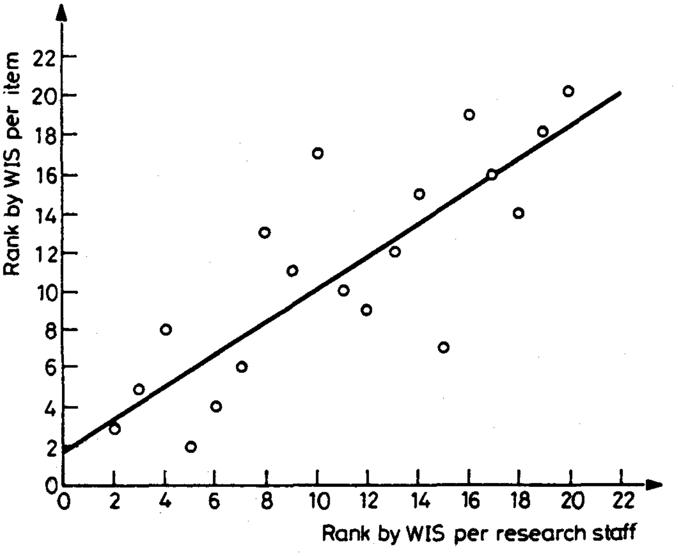

Fig. 6. Rank by weighted impact sum per item *versus* rank by weighted impact sum per research staff. $r^2 = 0.709$

Discussion

Weighted impact sums and citations

In this article we have tried to gauge quality of output scaled for institutional size. The need to weight output by some quality indicator, such as citations[1] or journal impact factors as we have done here, has been discussed by a number of commentators. *Osborne*[14] stated that: "What is needed is a clear understanding that performance indicators for research must be appropriately sophisticated and also give some indication of quality." (p. 9). In discussing institutional size *Moulden*[5] said:

> "It should come as no surprise to discover that the University of Sydney, with more than 2000 academics, published nearly 5000 (SCI) scientific papers in 1989–92, while Flinders University, whose academic staff complement is about a third that of Sydney, published just over 2000 in the same period. ...One measure of efficiency (if you are a funding agency) or research intensity (if you are a dean) would be some index of the research output per academic staff member."

We are not advocating our measures as a replacement for Bourke and Butler's[1] citation studies, but rather to complement the picture on Australian university science publishing provided by them. A necessary part of being cited is first to be published. The impact factor has a gatekeeper effect: it is generally more difficult to get published in journals with high impact factor, so these journals offer a higher potential for citation to individual items. Further, impact factors are available relatively quickly and are a preferred indicator of Australian Research Council applicants, as well as being associated with journal prestige.

Australian science is consistently being published in quality journals[15,16] but, as the *Bourke* and *Butler*[1] data indicates, is not being cited as often. The weighted impact sums indicate that we cannot attribute this fall in citation rate simply to Australian scientists' failure to publish in higher impact factor journals.

Relative rankings

The rankings of institutions by "mean weighted impact sum per item" (Fig. 3) and "weighted impact sum per research staff" (Fig. 5) are moderately correlated (r^2 = 0.709, Fig. 6). However these rankings can tell us quite distinct things about a university's output. For example, Macquarie university is ranked 7th in Fig. 3 and 15th in Fig. 5, whereas the University of Western Australia is ranked 13th and 6th, respectively. For Macquarie University, published items appear in journals that on average are better than the mean for the 20 pre-1987 universities. On the other hand the weighted impact sum per research staff is lower than the corresponding mean. This is consistent with the low items per research staff for Macquarie (Table 2), and the relatively low number of research staff.

Conversely, the weighted impact sum per research staff for the University of Western Australia is better than the 20-university mean, but the journals in which the research staff publish are on average lower than the corresponding mean. This change in ranking should be contrasted with the relatively high number of research staff and high output per research staff for Western Australia.

Of the 20 universities we studied only 6 are at or above the mean weighted impact factor for all of Australia. The non-university science research sector accounts for only 27% of Australian science publications.[17] It is largely responsible for keeping Australia's average weighted impact sum at 120% of the world value. Note that this adjusted average is consistent over a 10 year period.[15-16] On the other hand 14/20 of the universities have a mean weighted impact factor greater than the world average.

The "big seven".

The allocation of research resources to universities has been the subject of debate recently in the Australian media.[14, 18-21] A group of universities, often described as the "big seven", has been singled out for attention. These universities are Adelaide, Melbourne, Monash, New South Wales, Queensland, Sydney, and Western Australia. To quote *Bruce* and *Pockley*[19] "They say they have a special claim on grants that support research because of their large medical, engineering and science faculties". Together with the Australian National University, whose research schools have a separate block grant,[22] they have the highest output in science publishing over 1991–1993: indeed the collective output of the big seven in that period is approximately 2/3 of the total output of the 20 pre-1987 universities.

Using output over the period 1991–1993 (Table 1) these universities, together with ANU, do form a pre-eminent group. However, using weighted impact sum per item and weighted impact sum per research staff, the big seven do not maintain the same rank (Figs 3 and 5). What we find is that there are 6 universities above average on both these indicators: Flinders, Melbourne, ANU, Sydney, Monash, and La Trobe, two of which (Flinders and La Trobe) are not part of the top 7 in terms of output. These 6 universities publish in journals with impact factors above the Australian university average, and have a relatively high weighted impact sum per research staff.

Consequently, despite the smaller size and output of Flinders and La Trobe (the latter the only one of the seven without a medical school or medical research centre) the quality and productivity of these two institutions in science publishing, taking into account the size of their research staff, are markedly greater than some of the "big seven".

Distribution of weighted impact sum by item

The distribution of the fraction of weighted impact sum, W, by fraction of items, I for 1993, is given approximately by a power law $W = AI^D$, where A and D are constants dependent on the university. The indices D vary from 0.36 for James Cook to 0.618 for QUT (Table 3, Fig. 4). Each plot of W versus I produces a curve that passes exactly through the points (0,0), (1,1), and very nearly through (0.5, 0.8). The curves for the universities apart from James Cook and New England also very nearly pass through the point (0.2, 0.5). This provides us with a rule of thumb, which is that:

> *50% of the weighted impact sum is produced by the top 20% of items, and 80% is produced by the top 50% of items.*

This is valid across the 20 pre-1987 universities, except for James Cook and New England where approximately 60% of the weighted impact sum is produced by the top 20% of items.

Conclusion

Weighted impact sums provide us with a quality indicator of science journal publishing which is quick and easy to calculate, allows us to scale for institutional size both in terms of output and research staff, and which produces well-defined power law distributions in fractions of items.

Use of this indicator for the 20 pre-1987 Australian universities demonstrates that although some universities rank highly on output, when scaled for institutional size they are overtaken by some of the smaller, more recently established universities.

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