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A METRIC FOR ACADEMIC PERFORMANCE

APPLIED TO AUSTRALIAN UNIVERSITIES 2001-2004[1]

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ABSTRACT:
In a series of papers, published during second half of the 1980s, the Budapest group (Braun, Glänzel, Telcs and Schubert) proposed that bibliometric distributions are to be characterized as Waring distributions. We use their methodology in order to establish a reference value for academic production within macro classes. From this we develop a combined performance model for academic research and apply the model to Australian universities. This model take advantage of, first, field normalized publication rates (the productivity dimension) and, second, field normalized citation rates (the quality dimension). Based on ISI-data the performance of universities and research institutes is depicted in a more resource-efficient way than competing models.
KEYWORDS: performance based funding; formula-based funding, generalized waring distributions; bibliometrics

1.1 INTRODUCTION

Performance-related funding, or formula-based funding, has been under discussion for several years, and different systems have been introduced in several countries. For many years Australia has used a simple metric, only counting the number of publications. When this system was evaluated it was shown to have a detrimental effect on the Australian research system. While publication rates were rising, the impact of Australian research was falling (Butler 2003). The UK Research Assessment Exercise (RAE) has been an alternative evaluation method. Based on peer review, this method is strong in areas of science where “particularism” (Cole 1992) is low and weak in areas where conflicting views are dominant in the field. Due to its fluent use of peers the RAE system has been seen as the alternative to bibliometric models.

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Recently, the UK has signalled that it is considering a model based on metrics instead of the regular assessments of research excellence. In 2005, a quite comprehensive metric model was implemented in Norway. The Norwegian model uses a weighting of publications in two dimensions: first, according to different publication channels (articles in ISSN journals, articles in ISBN books and ISBN books), and, second, according to level of quality of the publication (normal and high). Approximately 90 per cent of all university publications are covered by the documentation system built up for the purpose of formula funding: Thomson/ISI data is to be used together with sources obtained from the National Library of Norway. The advantage of this system is its comprehensiveness. By covering almost all publication channels (including books) the counting procedures has probably become more legitimate from the researchers' point of view.

There are basically two drawbacks to the Norwegian model. Firstly, the use of expected impact at two very crude levels is a short-cut that does not represent the actual level of impact. This was stated by the renowned Norwegian cell biologist and bibliometrician Per O. Seglen in several articles as early as ten–fifteen years ago (Seglen 1992, 1997). We can be sure that this has not changed since then. Accordingly, impact figures should not be used in formula funding schemes for universities. Instead actual citations with a benchmark against world figures – field normalized citation scores (FCS) – are supported by the bibliometric research community (see e.g. Schubert & Glänzel 1996, van Raan 2004). Secondly, the heterogeneity of disciplines when it comes to productivity (and, of course, citations) makes it almost impossible to compare different universities as they will have very different mixes of disciplines. In the long run this might result in a situation where some universities will have to close down or starve to death disciplines with low productivity. But, the low productivity could be in relation to other disciplines, while they might be producing good results and showing fairly good productivity in relation to colleagues in other countries.

2.1 THE NEW AUSTRALIAN MODEL

Australia is now in the process of developing a research quality framework (RQF). The ambition of this framework is to establish the best quality and impact of research. Therefore the proposed system is a complicated matrix of assessments. It includes self-assessment, international and/or national peer review (as qualitative assessment), external endorsement (stakeholder impact) and quantitative metrics (DEST 2007). The last point, research output metrics, includes full reporting of books, book chapters and journal articles or the equivalent (in all, 21 different types of output). According to the available documents, the metrics will be using measures of ranked channels of publications (called outlets), i.e. channels will be classified into tiers according to pre-determined distributions (A* - top 5%, A - next 15%, B - next 30% and C - next 50%). Standard bibliometric methods will be applied to a number of disciplines, but not to all. In some disciplines "non-standard bibliometrics" will be performed; this would

include citations of books and articles in books. The proposed bibliometric analyses include citations per publication using world and Australian benchmarks.

Although the Australian RQF system can be seen as superior compared to the Norwegian and UK systems, there is still room for criticism of the "Aussie Model". Granted that the citation analysis will be performed by standard bibliometric methods à la Budapest, Leuven or Leiden, there are two problems that concern us: firstly, the productivity aspect, and, secondly, the distribution of funding across areas of science. Of course, these two aspects are dependent on each other to a large extent. Beginning with the first aspect, we find that the Australian panels – of which there will be thirteen organized by discipline, each consisting of twelve to fifteen members – will have no reference values for comparison with actual university performance. The crucial question for these panels will be whether or not the research under study is doing well and the only reference they will have will be the work under review. What if the Australian researchers in one discipline have become low producers? How will the panel know? Or, the other way around, what if one area of research is doing extremely well and producing a high number of papers. As there are no reference values, the panels will have a hard time finding out.

Moreover, moving on to the second issue, it is quite clear that comparisons between areas of research will be almost impossible in the Australian model. Each panel will have their funding envelope or will act according to their "budget", defending their discipline, acting out "their learned professionalism". Studies of peer review provide a number of indications that particularism and "cognitive cronyism" cannot be avoided by panels (Cole 1992, Travis & Collins 1991). Members of panels tend to end up as defenders of their disciplines and advocates of specific lines of research. Therefore, the RQF system might hinder the dynamics of research. While the system is being introduced in order to ensure that taxpayers' money is spent on the best research, it might be a conservative force favouring what are currently the strongest areas of science. But, what happens with the lines of research that could have developed if resources were available and if these resources were not occupied by those performing outmoded research?

In the following we will describe a performance-related model developed for the Swedish university system, but applied here to the Australian universities. This model combines productivity with quality measures and only uses one database – the Thomson/ISI database. Basically, it is a simple system, easily implemented, and without any collection of data from researchers or research groups. Let us recall what the Allen report said about the time-consuming aspect:

Collection of research output data involves several costs. These include:

- *the cost of researchers'/research institutions' time in preparing and providing data – time that could otherwise be directed to training students and conducting research;*

- *the labour and IT systems costs involved for research funding bodies to collate and store output data provided by researchers/institutions; and*
- *the labour and IT systems costs involved for the Australian Government to act in its role as a meta-collector of output data from the publicly funded research system in Australia.* (Allen report p. 44)

3.1 PREFERRED DATABASE

One specific database has the required properties – the Thomson/ISI database *Web of Science (WoS)*. Among the specific features of ISI-data is the classification of journals according to field(s) of research. The classification is the result of an ingenious process where journals are often multi-assigned, i.e. they belong to two, three or more journal categories. Table 1 illustrates the general operation of the ISI classification. In row 1 we find the single assigned journals in the category "Materials Science, Paper & Wood". The next row shows the double-assigned journals all of which are in "Forestry". Some of the journals have three assignments including the former ones and they belong to either textiles or polymer science.

Table 1. The ISI multi-assignation system

Journal	SC1	SC2	SC3
1	Materials Science, Paper & Wood		
2	Forestry	Materials Science, Paper & Wood	
3	Materials Science, Paper & Wood	Forestry	Materials Science, Textiles
4	Materials Science, Paper & Wood	Materials Science, Textiles	Polymer Science

There are 250 different journal categories in use and, therefore, the number of combinations is huge. Accordingly, the ISI database is superior for field normalization of productivity and citation data.

Scale neutrality is another point to be discussed. A university with a lower number of publications should not be treated unfairly. The procedure of field normalization of citation rates developed by CWTS and ISSRU, (CPP/FCSm according to CWTS nomenclature, e.g., Moed et al, 1995 or the field Normalised Mean Citation Rate NMCR by ISSRU, see Braun and Glänzel, 1990), relating the citation rates of one article to other articles within that journal category, is one way of handling that problem. In addition, field normalization seems to take care of the gender neutrality problem. Empirical studies show (Xie & Shauman 1998, Sandström & Hällsten 2007a and Sandström & Sandström 2007b) that female researchers have fewer publications but higher relative citation rates. In general, there are no scale-dependent advantages for larger universities or larger entities (van Raan 2006).

The Thomson/ISI database is also preferred because it covers almost 9,000 different journals or conference proceedings. Even if there are other databases, e.g. Scopus, that have higher coverage the problem is that these do not offer the qualities of the ISI database. Certainly, the ISI is a commercial database, but we should remember that there is a procedure for inclusion of journals, which states that a journal should meet a

number of specified criteria in order to be indexed (peer review, editorial policy etc.). The coverage of humanities and social science is lower than other areas of science (Moed 2005, Butler & Visser 2006). This might be a problem if we are going to compare productivity and citation rates, but in our understanding this problem has largely been overstated. The humanities tend to use books, monographs and anthologies for their publications. This implies that they do not make use of peer review to the same extent as other fields. There might be other quality processes inside humanities but these are not institutionalized in the same way as in other areas of scientific inquiry. The number of journals is very high in some of the humanities categories. One example is "History", which is the largest single journal category, if we count number of journals. Accordingly, there might not be many more humanist journals to be indexed by Thomson/ISI.

Of course, articles in the "History" category are not as numerous as historical journals do not publish as frequently as journals in other categories. In order to develop the scientific methods of social science and humanities, so as to enhance the quality of research, we should not adapt to the present-day workings of these disciplines. Instead, we might learn from how natural science, engineering and many social science areas have developed over time. National journals have been rejected and these areas have gone through a process of internationalization (in short, journal peer review). In the world of scientific journals there are a number of research fronts, each journal with its specific set of "discourses". Potential authors with articles to publish will have to relate to these discourses since the experts on the problems under discussion (research fronts) are to be found in those journals. If scientists avoid these journals, neglect them or simply do not send in manuscripts, they put themselves in a position outside of academic science (Hemmings et al. 2007).

4.1 THE PRODUCTIVITY ASPECT

One would think that it should be easy to find out which university has the highest productivity. Actually, that is quite a tricky problem. We would need a list of all researchers at universities and a list of all the papers written by these authors. This cannot be accomplished as there is a small deficiency in the database – it is impossible to align all authors of multi-authored papers to corporate addresses.

Therefore, we propose a simplifying strategy of using first author (AU) and reprint (RP) author addresses only. In 70 per cent of cases (as regards Nordic university articles) we find that first author is the same as the reprint author. We also accomplish other things by using the combination of first author and reprint author. An important aspect is that in many cases the RP author is the responsible author, and most probably a representative of the university that should be credited for the article.

The next step is to check the names so that all homonyms and similar problems have been taken care of. We have done this for the Nordic universities and found 51,000 unique authors for the period 2001–2004. Addresses were harmonized at the same

time. The publication behaviour of 51,000 authors is an interesting question that can be used to reduce the number of journal subject categories (SC). By using a hierarchical clustering technique we have found that 23 macro classes can be a suitable number that represents areas of science that are distinct from each other. The clustering was carried out using the publishing behaviour of authors, i.e. if an author publishes in subject category A, he or she is also prone to publish in categories B and C. Another author mainly publishes in category D, but also in E and F. This gives us two different clusters. Figure 1 show the result of a clustering carried out for ISI subject categories and visualizes the basic idea of how this clustering works.[2]

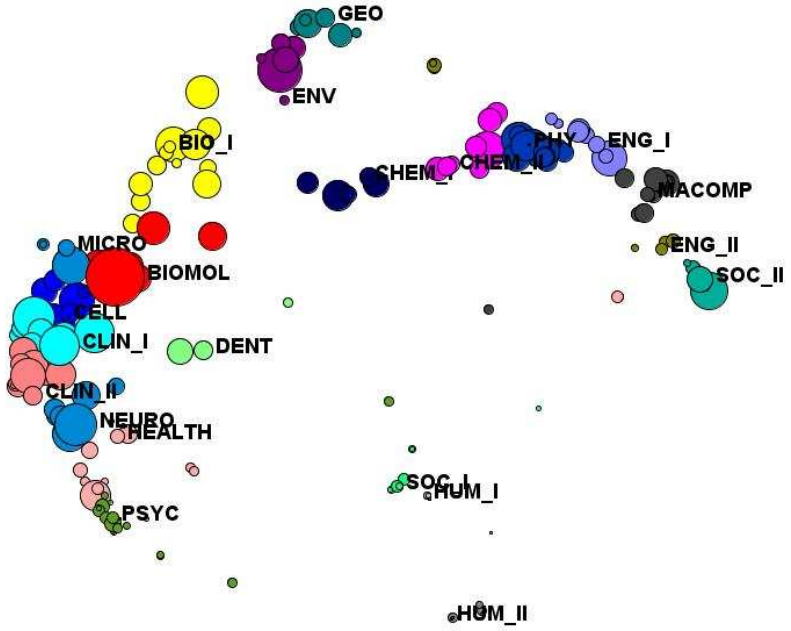

Figure 1. Macro classes of subject categories.

Each author has to be placed in one main macro class according to our methodology. An example: if an author has three articles in Engineering and one article in Social Science he will be placed in the Engineering group. In the following application of the model to Australian universities we will base it on our clusters, but will add information from classifications suggested by Hicks and Katz (1997) at SPRU combined with suggestions from Glänzel & Schubert (2003), plus categorizations used by Thomson ISI in their Essential Science Indicators.[3]

Next, we ask how these authors are distributed by number of articles during the period (2001–2004). As expected we find highly skewed distributions. A high portion of names (approximately 50–70 % depending on area) have only one article. The head of the curve is high and the tail is long, i.e. we are dealing with power-law distributions. Accordingly, there is no room for treating this material as normal distributions with

[2] We acknowledge the influence from Klavans & Boyack (2006).

[3] The classification can be found at http://www.forskningspolitik.se/default.asp?Page=english.

mean values or even median values. Instead, we are entering a specific area of bibliometric interest. Ever since Lotka (1926) published his “inverse square law” it is well known that productivity distributions follow a particular pattern. This aspect has been studied by many scholars and different hypotheses have been invoked to explain the skewed distributions. In the context of this paper we are interested, first, in finding an accurate description of the empirical bibliometric distributions and, second, in establishing a reference value for each area under study.

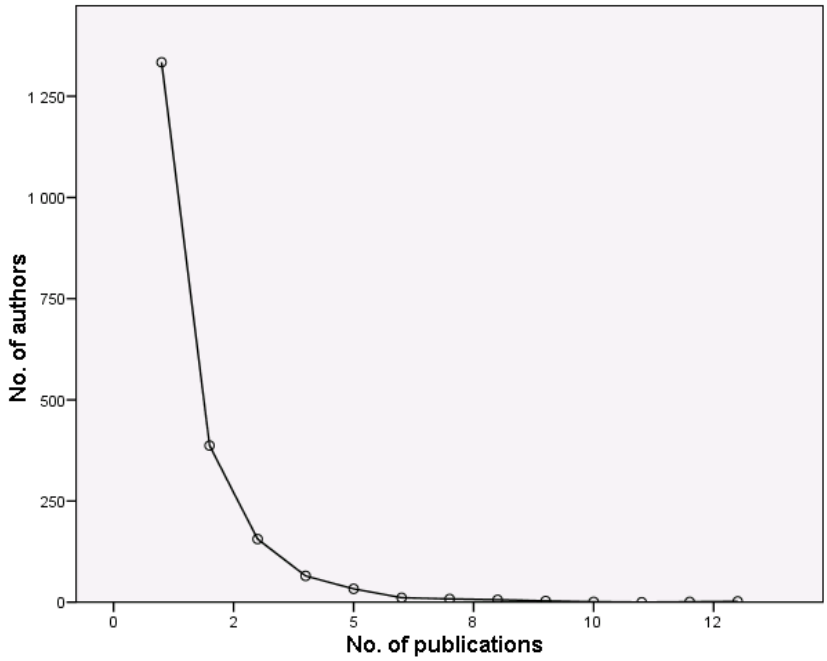

Fig 2. Frequency distribution in macro class AGR based on Nordic data.

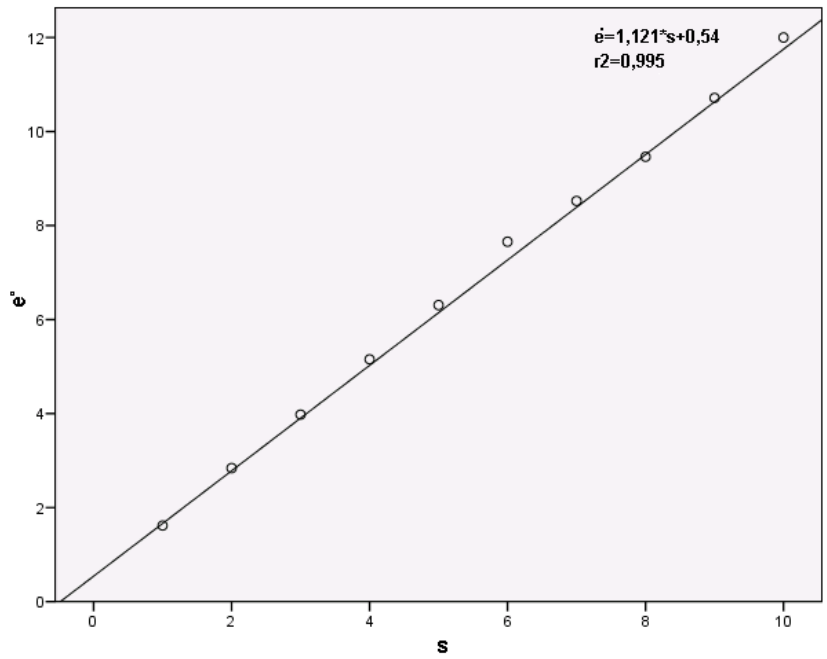

Fig 3. Left truncated sample mean values for AGR (Nordic data).

Obviously, our approach is based in mathematical statistics and a theoretical discussion can be found in papers by Braun, Glänzel, Schubert and Telcs during the second half of the 1980s. Inspired by Irwin (1963) they showed that bibliometric materials could be characterized as Waring distributions. A straight line should be obtained by plotting the truncated sample mean of these distributions (Telcs et al 1985). The intercept of this line is an expected value for the average productivity of the full research population (Braun et al 1990). In our model this value is used as a reference value.

From this it follows that we can establish reference values for each of the 23 macro classes. Table 2 shows the reference values and mean values per macro class. Agriculture and Humanities are two of the largest areas of research in Australia according to this analysis. In Table 2 we also display summations of number of fractionalized articles, Waring and the combined Waring and CPP/FCSm per macro class (CPP/FCSm is explained further in the next section).

By using the number of articles per university divided by the reference value we obtain the Waring value for each university and each macro class. This is the relative **quantity of production** performed by the university in each macro class. Simply, by multiplying the Waring value per macro class and university by the calculated field normalized citation score (CPP/FCSm) we can establish a combined value incorporating production and quality of production. The general model for citation scores is discussed in the following section.

Table 2. Macro classes and field normalization vaues 2001–2004 (Waring values and CPP/FCSm).

KLASS	SUM (Waring* CPP/FCSm)	SUM (Waring)	No frac articles	CPP/-FCSm	Waring-Ref	Mean	Median
AGR	4891	3880	3725	1.26	0.48	1.60	1
BIOL	3834	3398	3976	1.13	0.59	1.62	1
BIOMOL	929	1045	1379	0.89	0.66	1.69	1
CELL	1739	1936	2498	0.90	0.65	1.71	1
CHEM	1090	967	3105	1.13	1.61	2.30	1
CLIN	3432	3105	4223	1.11	0.68	1.75	1
CLIN_II	2135	1923	3077	1.11	0.80	1.87	1
COMPMATH	3959	4198	3778	0.94	0.45	1.53	1
DENT	372	373	474	1.00	0.64	1.69	1
ECON	926	1224	967	0.76	0.40	1.42	1
ENG	2631	2010	2593	1.31	0.65	1.73	1
ENV	2093	2148	1998	0.97	0.47	1.61	1
GEO	2359	1875	2101	1.26	0.56	1.56	1
HEALTH	1982	1982	1388	1.00	0.35	1.48	1
HUM	4710	4710	1460	1.00	0.16	1.19	1
IMMUN	1016	935	1328	1.09	0.71	1.73	1
MATSCI	2614	2189	3940	1.19	0.90	1.96	1
MULTI*	198	185	245	1.07	0.60*		
NEURO	820	873	1589	0.94	0.91	1.93	1
PHARM	404	403	834	1.00	1.04	2.05	1
PHY	1549	1389	2765	1.11	1.00	2.12	1
PSYC	2166	2297	2963	0.94	0.65	1.68	1
SOC	4301	4294	2577	1.00	0.30	1.33	1

Note: Number of articles is fractionalized values. Open citation window until 2007.
**Multi is an average value of all classes.*
WaringRef, Mean and Median values are the average of (2001-2002)+(2003-2004)/2

5.1 RESEARCH QUALITY

The Australian RQF includes what is called “standard bibliometric methods”. This refers to the Leiden methodology with benchmarks of citation levels related to the ISI subject categories (see van Raan 2004, Moed 2005). Therefore, it is not necessary to go deeper into the methods for citation analysis. Basically, reference values are established for each subject category, per type of article (article, letter or review) and in our version per year. Type of article is important as citation rates for reviews might be higher compared to articles. Also, reference values should be designed for each year.

Field in this context refers to the subject categories used by Thomson/ISI in their classification of journals. The FCS indicator is based on the citation rate of all papers published in all journals of the field(s) in which the university is active, and not only in the journals in which the researchers publish their papers. Normally publications in prestigious journals generate an impact above the field-specific average (which is the logic behind Journal Impact Figures delivered by Thomson/ISI in their Journal Citation Reports).

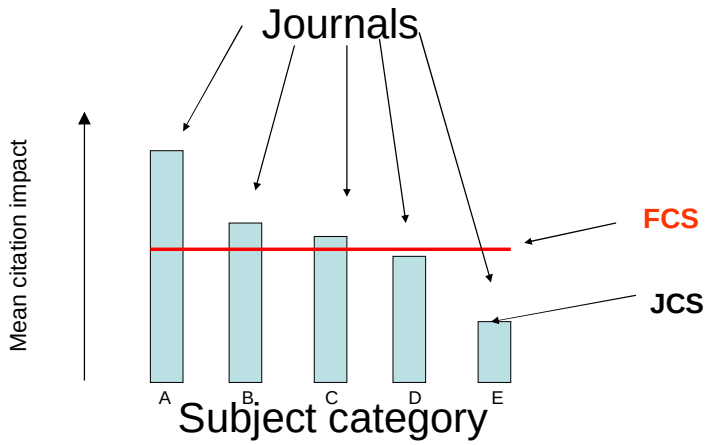

Figure 4. The normalization procedure for journal and field citation scores.

Here, in Figure 4, the subject category consists of journals A–E. For each of these journals a JCS (journal citation score) can be calculated. This is the journal mean citation level for the year under investigation. A specific article might have actual citations (CPP) above, below or on a par with this mean level. All journals in the subject category together form the basis for the FCS (field citation score). Accordingly, a specific article might have a CPP above or below the FCS mean level. A researcher publishing in journal A will probably find it easier to reach the mean FCS level than a researcher publishing in journal E. Note that the mean number of journals in a subject category (first classifications) in the Web of Science (full version) is about 40 journals. For a full picture we should add that most journals are multi-assigned, so with the help of almost 250 subject categories ISI/Thomson can accurately cover the content of journals.

Universities are active in a number of fields. In such cases a weighted average value is calculated. Normally the weights would be determined by the number of papers published in each field. For example: if a university has 100 articles in one subject category (SC1) with a CPP/FCS of 1,5 and 50 in another (SC2) with a CPP/FCS of 1, the weighted average (CPP/FCSm) would be 1.33 ((100*1.5+50*1)/150). The logic behind this is, of course, that a larger field at the university should have a stronger influence on the end result. However, the number of articles might not be representative to the size of the field. If, for example, the articles in SC1 are publications from a medicine department and the articles in SC2 are from a social science department, the social science department might be larger (more researchers) since researchers in social science on average produce a smaller number of articles per capita. As a “side-effect” our method gives a solution to this problem. By using the Waring values as weights, which would be more accurate size indicators, we also receive a more accurate way of calculating the general field normalized citation score. In the example above the CPP/FCSm would then probably be closer to 1.25.

Remember that the FCS indicator represents a world average in a specific (combination of) field(s). If the ratio CPP/FCSm is above 1.0, the impact of the papers

exceeds the field-based (i.e., all journals in the field) world average. With this type of advanced bibliometrics we are very close to a representative picture of each university using field normalized citations rates.

For an analysis that includes all areas of science (also humanities and social sciences) an open citation window is preferred. As journals in the Humanities and Social Sciences normally have fewer articles per number and fewer issues per year the peak for citations comes later than in Science and Medicine. To handle this citations are measured from the year of publication until June 2007. An article published in 2002 will receive citations until June 2007. Accordingly, an article from 2005 will have a shorter citation window, but is compared to other articles from 2005.[4]

One controversial point is whether we can apply citation analysis to the humanities. Most bibliometricians think that citation levels are too low and unevenly distributed in the humanities, and we are, of course, in agreement. Accordingly, field normalization does not work in an adequate way and, therefore, we have to find a second best solution. As this is an exercise in method we take the view that all aspects should be open to discussion. Our way to handle this problem is to give the humanities an overall score of 1 in CPP/FCSm so that what counts is their productivity alone. With established processes for peer recognition also this area of research should, in due time, develop into more scientific practises.

According to the RQF preparatory work the process will also include non-standard bibliometrics, i.e. citations of other material like books and chapters in books. This is an interesting approach and so far reports from investigations have given positive results (Butler & Henadeera 2007). At the same time it is obvious that there is at least one serious problem: the lack of international benchmarks. In relation to this it could be said that the panels and their 12-15 members will provide the benchmark. But, the panels are organized by discipline, while research is organized in so many different ways. A study of all political scientists in Sweden 1998–2005 that included non-standard bibliometrics showed that political scientist are active in several different policy areas (Sandström 2007). Half of their articles were written outside of the major subject categories for the discipline (Political Science; International Relations; Public Administration). Instead, policy-related issues are discussed in relation to environmental and climate policy, social issues, labour market policy, etc. The panel for “social sciences and politics” will perhaps contain two or three political scientists, and the question is whether they will be able to assess and benchmark even the diversity of political sciences. Another problem with panels is the nepotism factor pointed out by two Swedish researchers (Wennerås & Wold, 1997). In a follow-up study, ten years later, it was shown that although gender discrimination had

[4] For academic purposes we have downloaded Swedish and Australian data from the Internet Web of Science. Downloads performed in May, 2007.

disappeared nepotism was still the single most important factor explaining the distribution of funding (Sandström & Hällsten 2008).

6.1 APPLICATION TO AUSTRALIAN UNIVERSITIES

We have chosen to apply the proposed method to Australian universities. The reasons for this are manifold and can be summarized in a few words: Australia has had a system for formula-based funding for many years; moreover right now it is moving into a new and complex system. Therefore, Australia is used to counting publications and Australian researchers can be expected to be more prudent with their addresses than many other university researchers.

In this implementation of the model we use ISI data covering the period 2001–2004. In order to account for the mobility of researchers between universities and different structural phenomena related to the number of researchers per area we have decided to perform the analysis split into two periods: 2001–2002 and 2003–2004.[5] A mean of these two periods is then used for the summation of Waring values.

6.2 PROCEDURE

When we applied this model to Sweden we had a corrected and (unified) database of names of all first and reprint authors connected to a university by address. In the Australian application of the model we will use the Swedish universities plus the uncorrected data from Australian universities. This is due to time constraints, but this is, of course, nor a preferred procedure. Best results would require a unification of author names also for the Australians.

Another shortcut is that we will use the macro classes proposed based on the Nordic investigation mentioned above. Of course, it would have been preferable to have a clustering performed on the behaviour of Australian researchers and/or comparable countries.

The number of articles per university and macro class is divided by the reference value – the Waring reference value – for that macro class. This gives us a figure for how many researchers the actual number of articles represents (ten highly productive researchers might publish as much as a normal group of twenty researchers). We then add these values together to obtain a sum of “producers”, i.e. the number of researchers that corresponds to the number of articles.

Field normalized citation scores per macro class and university have been calculated. All articles incorporating an Australian university address have been used for this procedure, not only articles with a reprint author address connected to the university.

[5] Cf. Schubert & Telcs 1989.

Finally, we join these values together. Through a simple multiplication of Waring values and CPP/FCSm per macro class and university we obtain the combined value of production and quality. All values per university are shown in Appendix A.

Table 3. Results for Australian universities

	A	B	C	D	E	F	G	H
UNIV	SUM(Waring* CPP/FCSm)	SUM (Waring)	No frac articles	CPP/FCSm	AVG WaringRef	Column A %	Waring %	Articles %
SYDNEY UNIV	5575	5021	5769	1.11	0.57	11.12	10.61	10.89
MELBOURNE UNIV	5160	4673	5260	1.10	0.56	10.29	9.87	9.93
QUEENSLAND UNIV	4709	4441	5068	1.06	0.57	9.39	9.38	9.57
AUSTRALIAN NATL UNIV	4256	3549	3876	1.20	0.55	8.49	7.50	7.32
NEW S WALES UNIV	4011	3716	4304	1.08	0.58	8.00	7.85	8.12
CSIRO	3503	2676	3059	1.31	0.57	6.98	5.65	5.77
MONASH UNIV	3426	3349	3857	1.02	0.58	6.83	7.08	7.28
WE AUSTRALIA UNIV	2891	2687	3141	1.08	0.58	5.76	5.67	5.93
ADELAIDE UNIV	2201	2196	2651	1.00	0.60	4.39	4.64	5.00
NEWCASTLE UNIV	1437	1334	1449	1.08	0.54	2.87	2.82	2.74
MACQUARIE UNIV	1281	1140	1132	1.12	0.50	2.55	2.41	2.14
TASMANIA UNIV	1164	1290	1352	0.90	0.52	2.32	2.72	2.55
LA TROBE UNIV	1104	1233	1107	0.89	0.45	2.20	2.61	2.09
GRIFFITH UNIV	1000	1125	1179	0.89	0.52	1.99	2.38	2.22
QUEENSLAND UNIV TECH	981	945	1107	1.04	0.59	1.96	2.00	2.09
WOLLONGONG UNIV	931	890	1110	1.05	0.62	1.86	1.88	2.10
CURTIN UNIV TECHNOL	900	884	853	1.02	0.48	1.79	1.87	1.61
FLINDERS UNIV	874	940	1026	0.93	0.55	1.74	1.99	1.94
UNIV N QUEENSLAND	820	832	922	0.99	0.55	1.64	1.76	1.74
DEAKIN UNIV	795	912	929	0.87	0.51	1.58	1.93	1.75
MURDOCH UNIV	690	754	773	0.92	0.51	1.38	1.59	1.46
TECHNOL SYDNEY UNIV	573	651	652	0.88	0.50	1.14	1.37	1.23
S AUSTRALIA UNIV	558	570	633	0.98	0.55	1.11	1.21	1.19
RMIT UNIV	517	632	786	0.82	0.62	1.03	1.33	1.48
SWINBURNE UNIV TECH	396	432	520	0.92	0.60	0.79	0.91	0.98
WE SYDNEY UNIV	395	468	471	0.84	0.50	0.79	0.99	0.89
	50149	47340	52978			100	100	100

Applying this metric would give the universities of Sydney and Melbourne the highest share of government floor funding (see Table 3, column A). As a general trend it seems clear that the larger universities do well from a formula-based funding of the proposed type. This is partly because of the quality dimension (displayed in column D, Table 3) which is given a heavy weight in this model. ANU has fewer articles than New S Wales Univ, but in the end the summation of Waring value and CPP/FCSm gives ANU a higher figure. Obviously, the research institutes of CSIRO, receive the highest relative citation scores. This produces a high figure, almost seven percent of the total (column F), although the institutes produces less than six percent of articles (column H).

Obviously, the Appendices sections give the most detailed information. There we show results for all universities per macro class. First, in Table 5, the number of articles per macro class is displayed. Sydney, Melbourne and Queensland are the largest producers according to our analysis based on article count and with no specific unification of addresses. Table 6 show the effects of the Waring method. While the order between the largest producers are stable there are several changes in the big

group of universities with approximately 900 – 1.200 publications during the period. Putting in citations, Table 7, produces even more changes: As mentioned, CSIRO and ANU are gaining ground with this specific part of the procedure and they are, in the final combination of measures, the units that reveal the best relative performance in relation to all other units.

Compared to Swedish results there is much less Australian research in the Medical Sciences. Another striking feature is the high figures for the Humanities and the Social Sciences in the Australian case. The estimated Waring values should be good approximations of each areas relative size, but remember that we employ reference values based on articles from Australian and Swedish universities. The language factor is important if we are to explain the differences between the countries especially regarding international publishing in the humanities and social sciences. Our figures (appendices) indicate that the humanities employ a large share of Australia's scientific workforce. If the reference values were established with countries like New Zealand, England and the Netherlands we would most probably have higher reference numbers. Therefore, in this case we do have too high figures for the humanities, but, in our opinion, as a matter of showing the Waring effects in weighting of areas it is quite instructional.

7.1 DISCUSSION

We have described a simple model for metrics of academic science. Compared to the time-consuming efforts that will have to be utilized for the Australian model our model is more time-efficient. In short, it would save much effort that can be put into research rather than assessments.

This paper is a methodological paper and we do not claim to have accurate Australian figures. There are a number of steps in the methodology that should be adjusted to the specific country. Unification of names and addresses is just one point, clustering of subject codes another.

However, the method does give interesting results. Research production from very different areas of science is made comparable. The productivity of researchers differs a lot between universities and this is a working component of the methodology. With this methodology a university will get paid for its activities according to its production and the quality of this production. Governing bodies of universities will try to find ways to support researchers who produce fair numbers of publications, given that these papers are cited. The more papers a university produces the more citations it will receive assuming that the peer community find the papers interesting and worthy of referencing.

While finishing this article (mid September, 2007) Australian researchers are awaiting the Final RQF Submission Specifications. In March 2008 they are supposed to submit their work to panels for review and each group will receive their metrics values. With

the level of detail the RQF is much more precise, but the process is laborious. In November 2008, when the Australian Minister announces the outcomes of the RQF, we will be able to compare figures for universities with the overall Waring model.

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APPENDICES: RESULTS PER UNIVERSITY AND MACRO CLASSES

TABLE 4. ARTICLES PER UNIVERSITY AND MACRO CLASS

No of articles	CLASS																						
UNIV	AGR	BIOL	BIOMOL	CELL	CHEM	CLIN	CLIN_II	COMPMA	DENT	ECON	ENG	ENV	GEO	HEALTH	HUM	IMMUN	MATSCI	MULTI	NEURO	PHARM	PHY	PSYC	SOC	TOTAL
SYDNEY UNIV	305	399	149	267	314	601	611	284	61	40	369	218	86	229	176	144	439	30	238	90	287	220	217	5769
MELBOURNE UNIV	293	206	192	309	226	589	451	294	110	147	164	143	120	107	185	251	238	26	306	94	292	302	220	5260
QUEENSLAND UNIV	384	345	208	378	241	499	171	311	85	51	189	93	133	160	139	117	341	25	246	166	255	332	205	5068
NEW S WALES UNIV	94	152	107	202	275	352	238	383	43	93	397	190	100	57	110	121	469	9	87	36	216	383	196	4304
ANU	197	264	111	190	316	119	42	340	4	127	52	144	315	47	111	93	343	33	59	13	493	126	343	3876
MONASH UNIV	54	139	143	141	404	460	283	307	25	125	226	86	133	69	132	152	266	9	128	141	89	154	196	3857
WE AUSTRALIA UNIV	327	204	101	120	155	356	322	197	24	51	122	66	172	119	46	118	166	4	104	36	100	157	78	3141
CSIRO	929	512	59	184	118	25	60	83	5	19	146	334	156	6		54	234	18		20	91	2	10	3059
ADELAIDE UNIV	281	168	73	118	143	281	294	77	82	21	123	94	98	39	46	64	66	17	83	65	216	121	88	2651
NEWCASTLE UNIV	44	40	20	32	68	93	91	145		15	179	57	63	47	56	27	166	10	25	38	64	97	78	1449
TASMANIA UNIV	183	371	25	47	95	52	31	46	3	12	13	41	145	19	43	11	19	4	37	20	21	39	81	1352
GRIFFITH UNIV	49	140	16	59	92	38	25	81	2	37	52	78	8	42	23	5	95		14	9	31	156	133	1179
MACQUARIE UNIV	20	144	16	81	20	28	11	135	1	18	12	62	118	7	64	26	101	12	18		72	105	66	1132
WOLLONGONG UNIV	8	70	23	12	95	29	47	118	2	13	76	21	57	18	15	5	288	14	44		26	77	56	1110
QUEENSLD UNIV TECH	14	23	4	33	95	55	94	138	14	22	90	36	33	48	16	28	75		5		143	78	65	1107
LA TROBE UNIV	55	109	36	74	28	122	34	106	2	25	5	27	23	98	86	19	29	6	20	6	40	84	77	1107
FLINDERS UNIV	12	84	31	54	54	137	69	37	1	9	6	22	13	45	41	38	27	5	79	25	40	128	75	1026
DEAKIN UNIV	19	83	18	14	67	63	85	97		7	25	35	13	37	47	10	87	3	6	3	11	130	72	929
UNIV N QUEENSLAND	56	330	9	15	22	103	14	17		5	45	27	121	14	15	17	29	10	11	9	4	19	36	922
CURTIN UNIV TECH	37	29	10	16	30	19	34	88		37	53	27	137	70	34	12	67	1	7	6	26	55	63	853
RMIT UNIV	34	5	5	24	119	58	36	118	3	8	46	26	9	9	15	6	118	2	8	13	73	18	39	786
MURDOCH UNIV	197	102	13	50	25	47	9	43	3	5	22	42	5	10	24	9	44	1	26		31	25	44	773
TECH SYDNEY UNIV	18	32	7	24	23	25	8	137	5	45	54	37	10	21	19	2	86	1	4	26	15	11	48	652
S AUSTRALIA UNIV	12	16	2	12	29	59	13	92	3	20	36	23	33	41	4	2	47	3	5	22	80	33	51	633
SWINBURNE UNIV TEC	8	2	3	35	19	7	5	64	1	6	55	63		3	9	1	93	3	33		49	53	13	520
WE SYDNEY UNIV	103	13	3	13	36	12	4	47		15	43	14	7	32	9	3	15	2	2	1	6	64	33	471
TOTAL	**3725**	**3976**	**1379**	**2498**	**3105**	**4223**	**3077**	**3778**	**474**	**967**	**2593**	**1998**	**2101**	**1388**	**1460**	**1328**	**3940**	**245**	**1589**	**834**	**2765**	**2963**	**2577**	**52978**

TABLE 5. WARING VALUES PER UNIVERSITY AND MACRO CLASS

Sum of Waring	CLASS																						
UNIV	AGR	BIOL	BIOMOL	CELL	CHEM	CLIN	CLIN_II	COMPMA	DENT	ECON	ENG	ENV	GEO	HEALTH	HUM	IMMUN	MATSCI	MULTI	NEURO	PHARM	PHY	PSYC	SOC	TOTAL
SYDNEY UNIV	318	341	113	207	98	442	382	316	48	51	286	234	77	327	568	101	244	23	130	43	144	170	361	5021
MELBOURNE UNIV	305	176	145	240	70	433	282	327	87	185	127	153	107	153	595	177	132	20	168	45	147	234	366	4673
QUEENSLAND UNIV	399	294	157	293	75	367	107	345	67	65	146	100	118	229	448	82	189	19	135	80	128	257	341	4441
NEW S WALES UNIV	98	129	81	157	86	258	149	425	34	117	307	204	89	81	353	85	260	6	48	17	109	297	326	3716
ANU	205	226	84	147	98	87	26	378	3	161	40	154	281	67	356	65	190	25	32	6	247	98	572	3549
MONASH UNIV	56	118	108	109	126	338	177	341	20	158	175	92	118	98	426	107	148	6	70	68	44	119	327	3349
WE AUSTRALIA UNIV	340	174	77	93	48	262	201	218	19	65	95	70	154	169	148	83	92	3	57	17	50	121	130	2687
CSIRO	967	438	45	143	37	18	37	92	4	23	113	359	139	8		38	130	14		9	45	2	17	2676
ADELAIDE UNIV	292	143	55	91	45	207	184	86	64	26	95	101	88	55	147	45	36	13	45	31	108	93	146	2196
NEWCASTLE UNIV	45	34	15	24	21	68	57	161		19	138	61	56	66	181	19	92	8	13	18	32	75	130	1334
TASMANIA UNIV	191	317	19	36	30	38	19	51	2	15	10	44	129	27	137	7	10	3	20	9	10	30	135	1290
LA TROBE UNIV	57	93	27	57	9	90	21	118	2	32	4	29	20	140	276	13	16	4	11	3	20	65	128	1233
MACQUARIE UNIV	20	123	12	63	6	21	7	149	0	22	9	66	105	10	206	18	56	9	10		36	81	109	1140
GRIFFITH UNIV	51	120	12	45	29	28	16	89	2	46	40	84	7	59	74	3	53		8	4	15	121	221	1125
QUEENSLD UNIV TECH	15	20	3	26	30	40	59	153	11	27	70	39	29	69	52	20	41		2		72	60	108	945
FLINDERS UNIV	12	72	23	41	17	100	43	41	0	11	4	24	12	64	132	27	15	4	43	12	20	99	124	940
DEAKIN UNIV	20	71	14	11	21	46	53	107		9	19	38	11	53	152	7	48	2	3	1	5	101	120	912
WOLLONGONG UNIV	8	60	17	9	30	21	29	131	2	16	59	23	50	26	47	3	160	10	24		13	59	93	890
CURTIN UNIV TECH	38	24	7	12	9	14	21	97		46	41	29	122	100	110	8	37	1	4	3	13	42	104	884
UNIV N QUEENSLAND	58	282	7	11	7	75	9	18		6	34	28	108	20	47	12	16	7	6	4	2	14	59	832
MURDOCH UNIV	205	87	10	38	8	35	6	47	2	6	17	45	4	14	77	6	24	0	14		16	19	73	754
TECH SYDNEY UNIV	18	27	5	18	7	18	5	152	4	56	42	39	8	29	61	1	48	1	2	13	8	8	80	651
RMIT UNIV	35	4	4	19	37	43	22	131	2	9	35	27	8	12	47	4	65	2	4	6	37	14	64	632
S AUSTRALIA UNIV	12	14	1	9	9	43	8	102	2	25	28	24	29	58	13	1	26	2	2	11	40	26	84	570
WE SYDNEY UNIV	107	11	2	10	11	8	3	52		19	33	15	6	45	27	2	8	2	1	0	3	49	55	468
SWINBURNE UNIV TEC	8	1	2	27	6	5	3	71	1	7	42	67		4	29	0	51	2	18		24	41	22	432
TOTAL	**3880**	**3398**	**1045**	**1936**	**967**	**3105**	**1923**	**4198**	**373**	**1224**	**2010**	**2148**	**1875**	**1982**	**4710**	**935**	**2189**	**185**	**873**	**403**	**1389**	**2297**	**4294**	**47340**

TABLE 6. CPP/FCSm PER UNIVERSITY AND MACRO CLASS

Mean of CPP/FCSm	CLASS																					
UNIV	AGR	BIOL	BIOMOL	CELL	CHEM	CLIN	CLIN_II	COMPMA	DENT	ECON	ENG	ENV	GEO	HEALTH	HUM	IMMUN	MATSCI	MULTI	NEURO	PHARM	PHY	PSYC	SOC
CSIRO	1.57	1.17	0.97	0.94	1.81	1.24	1.17	0.92	1.54	1.00	1.41	1.10	1.35	0.60		0.75	1.11	3.15		1.24	1.10	0.78	1.25
ANU	1.52	1.21	0.97	0.96	1.10	0.99	1.14	1.00	2.46	0.82	1.28	1.14	1.68	0.81	1.00	1.20	1.30	1.00	1.05	1.02	1.32	1.04	1.36
MELBOURNE UNIV	1.15	1.16	0.92	0.97	1.11	1.22	1.23	1.13	0.98	0.86	1.60	0.93	1.36	0.89	1.00	1.21	1.45	1.08	1.17	1.13	1.10	1.04	1.00
QUEENSLAND UNIV	0.96	1.16	1.15	1.11	0.96	1.16	1.12	0.87	1.07	0.95	1.44	1.17	0.98	0.95	1.00	1.08	1.46	1.33	0.84	1.06	1.24	0.95	0.97
CURTIN UNIV TECH	1.24	0.67	0.40	0.95	1.05	1.07	0.92	0.54		0.61	1.33	0.71	1.74	0.85	1.00	1.14	0.88	3.64	1.45	0.62	1.07	0.85	1.09
SYDNEY UNIV	1.17	1.22	0.86	0.74	1.12	1.19	1.29	1.09	1.04	0.65	1.57	0.71	0.98	1.11	1.00	1.11	1.34	1.16	0.86	1.03	0.98	0.88	1.23
MONASH UNIV	1.11	1.21	0.85	0.81	1.33	1.25	1.22	0.70	1.21	0.69	1.33	1.00	1.22	0.91	1.00	1.19	1.33	1.28	0.79	1.03	0.84	0.73	0.92
NEW S WALES UNIV	0.95	1.07	0.74	0.97	1.88	1.06	0.91	1.08	0.97	0.76	1.35	1.10	0.70	1.21	1.00	1.04	1.14	0.62	0.96	1.03	1.08	1.30	0.95
WE AUSTRALIA UNIV	1.33	0.98	0.88	0.88	0.98	1.14	1.10	0.95	0.86	0.99	0.98	1.07	1.37	1.06	1.00	1.15	0.95	1.32	0.95	0.95	0.77	1.12	0.95
MACQUARIE UNIV	1.35	1.55	0.72	0.96	1.20	0.92	0.65	1.21	0.61	0.77	1.83	0.94	1.42	0.75	1.00	0.50	0.98	0.57	0.75		1.27	1.02	1.09
QUEENSLD UNIV TEC	1.06	0.78	1.20	0.64	1.04	0.91	0.97	1.23	1.03	0.64	0.90	1.09	1.22	1.26	1.00	0.76	0.89		0.74		1.69	0.63	0.90
MURDOCH UNIV	0.99	0.76	0.60	0.85	0.40	1.74	1.02	0.65	0.39	0.63	0.96	0.49	2.62	1.23	1.00	1.20	1.19	1.03	0.68		0.88	0.62	0.85
NEWCASTLE UNIV	1.41	0.65	0.75	0.71	0.70	0.89	0.89	1.47		0.83	1.30	1.16	1.13	0.86	1.00	1.34	1.17	0.11	0.82	0.81	0.76	0.83	1.12
ADELAIDE UNIV	1.36	1.26	0.89	0.88	0.63	0.87	1.03	0.87	0.88	0.71	1.34	0.98	0.85	0.91	1.00	0.98	0.84	0.95	0.92	0.83	0.96	0.88	0.75
WOLLONGONG UNIV	0.59	1.00	0.87	0.75	0.98	1.18	1.12	1.26	0.37	0.41	1.11	1.27	1.04	1.25	1.00	0.48	1.03	0.48	1.28		1.09	0.82	1.02
GRIFFITH UNIV	0.86	0.95	0.44	0.58	0.72	0.76	0.70	0.82	1.31	0.44	1.41	0.99	0.75	1.04	1.00	1.63	1.10		1.10	0.60	1.06	0.85	0.86
FLINDERS UNIV	1.14	0.88	0.72	0.61	0.67	0.90	0.92	1.85	1.15	0.53	1.21	0.66	0.52	1.01	1.00	1.04	0.80	0.28	0.83	1.17	0.75	0.97	0.86
S AUSTRALIA UNIV	1.54	0.42	0.93	0.84	0.74	0.90	1.02	1.11	0.74	0.42	0.84	0.49	1.45	1.22	1.00	0.74	1.06	0.04	0.83	0.83	1.38	0.71	0.86
TECH SYDNEY UNIV	1.26	1.02	0.99	0.41	0.59	1.08	1.24	0.58	0.61	0.96	1.34	0.76	0.62	0.97	1.00	0.87	1.22	0.67	0.27	1.05	1.06	0.47	0.88
SWINBURNE UNIV TE	0.94	0.57	0.15	0.65	0.40	1.49	0.95	0.78	0.34	0.48	0.97	1.10		2.31	1.00	0.97	1.21	0.26	0.87		0.88	0.65	0.89
LA TROBE UNIV	1.30	1.04	0.82	0.83	0.66	1.14	0.65	0.53	0.57	0.54	0.64	0.50	1.17	0.94	1.00	0.70	0.67	0.83	0.86	0.87	0.83	0.73	0.89
UNIV N QUEENSLAN	0.95	1.20	0.68	0.67	1.22	0.87	0.53	0.25		0.29	0.64	0.75	1.01	0.75	1.00	1.19	0.87	0.81	0.90	0.95	0.79	0.38	1.08
RMIT UNIV	0.94	1.63	0.55	0.71	1.06	1.07	1.15	0.58	0.73	0.43	1.10	1.05	0.19	0.58	1.00	0.76	1.02	0.77	0.41	0.94	0.88	0.38	0.48
DEAKIN UNIV	0.67	1.02	0.82	0.91	0.76	0.88	0.81	0.41		0.58	0.66	0.97	0.81	1.00	1.00	0.45	1.44	0.08	0.61	1.00	0.53	0.93	0.87
WE SYDNEY UNIV	0.87	0.69	0.38	0.70	0.93	0.58	0.47	0.78		0.97	0.86	0.66	1.24	0.96	1.00	0.42	0.39	0.48	0.44	0.65	1.79	0.85	0.80
TASMANIA UNIV	1.08	1.11	0.48	1.01	1.10	0.53	0.75	0.45	1.12	0.46	0.80	0.80	1.08	0.77	1.00	0.55	0.69	0.30	0.90	0.66	0.46	0.37	0.51

TABLE 7. SUM OF WARING * CPP/FCSm PER UNIVERSITY AND MACRO CLASS

Sum Waring*CPP/FCSm	CLASS																						
UNIV	AGR	BIOL	BIOMOL	CELL	CHEM	CLIN	CLIN_II	COMPMA	DENT	ECON	ENG	ENV	GEO	HEALTH	HUM	IMMUN	MATSCI	MULTI	NEURO	PHARM	PHY	PSYC	SOC	TOTAL
SYDNEY UNIV	371	415	97	153	109	525	494	345	50	33	450	166	75	364	568	112	327	26	112	45	142	150	444	5575
MELBOURNE UNIV	352	205	134	233	78	529	347	368	85	160	203	142	145	136	595	215	192	21	197	51	162	244	367	5160
QUEENSLAND UNIV	385	342	180	324	72	423	120	298	72	62	210	117	116	218	448	89	277	25	114	85	158	245	329	4709
ANU	312	273	82	141	109	86	30	376	7	132	51	176	471	54	356	79	248	25	34	6	327	101	779	4256
NEW S WALES UNIV	93	138	59	152	161	273	135	458	33	89	414	224	62	99	353	89	296	4	46	18	117	387	310	4011
CSIRO	1522	511	43	134	66	22	44	84	6	23	160	396	188	5		28	144	43		12	50	1	21	3503
MONASH UNIV	62	143	91	88	168	422	216	237	24	109	232	92	144	89	426	128	197	8	56	70	37	87	300	3426
WE AUSTRALIA UNIV	453	172	67	82	47	298	222	208	16	64	93	75	211	180	148	95	87	4	54	16	38	136	124	2891
ADELAIDE UNIV	398	180	49	80	28	180	188	74	57	18	128	98	74	50	147	44	31	12	42	26	104	82	109	2201
NEWCASTLE UNIV	64	22	11	17	15	61	51	237		16	179	71	64	57	181	25	108	1	11	15	24	62	146	1437
MACQUARIE UNIV	27	190	9	61	7	19	4	180	0	17	17	62	149	7	206	9	55	5	7		46	83	118	1281
TASMANIA UNIV	206	352	9	36	33	20	14	23	2	7	8	35	140	21	137	4	7	1	18	6	5	11	69	1164
LA TROBE UNIV	74	97	22	47	6	102	14	63	1	17	2	14	24	132	276	9	11	3	9	2	17	48	114	1104
GRIFFITH UNIV	43	113	5	26	21	21	11	73	2	21	56	83	5	61	74	5	58		8	2	16	102	191	1000
QUEENSLD UNIV TECH	16	15	4	16	31	36	57	188	11	18	63	42	35	86	52	15	37		2		121	38	98	981
WOLLONGONG UNIV	5	60	15	7	29	25	33	165	1	7	65	29	52	32	47	2	165	5	31		14	48	94	931
CURTIN UNIV TECH	47	16	3	12	10	15	20	52		28	55	21	212	85	110	10	33	3	5	2	14	36	113	900
FLINDERS UNIV	14	64	17	25	11	90	39	76	0	6	5	16	6	64	132	28	12	1	36	14	15	96	107	874
UNIV N QUEENSLAND	56	339	5	8	8	65	5	5		2	22	21	109	15	47	14	14	6	5	4	2	5	64	820
DEAKIN UNIV	13	73	11	10	16	41	43	44		5	12	37	9	53	152	3	70	0	2	1	3	94	104	795
MURDOCH UNIV	203	66	6	33	3	60	6	31	1	4	16	22	12	17	77	7	29	0	10		14	12	62	690
TECH SYDNEY UNIV	23	28	5	7	4	20	6	88	2	54	56	30	5	28	61	1	58	1	1	13	8	4	70	573
S AUSTRALIA UNIV	18	6	1	8	7	39	8	113	1	11	23	12	43	70	13	1	28	0	2	9	56	18	73	558
RMIT UNIV	33	7	2	13	39	46	26	76	2	4	39	29	2	7	47	3	67	1	2	6	32	5	31	517
SWINBURNE UNIV TEC	8	1	0	17	2	7	3	55	0	3	41	74		8	29	0	62	1	16		22	27	19	396
WE SYDNEY UNIV	93	7	1	7	10	5	1	40		18	28	10	7	43	27	1	3	1	0	0	5	42	44	395
TOTAL	**4891**	**3834**	**929**	**1739**	**1090**	**3432**	**2135**	**3959**	**372**	**926**	**2631**	**2093**	**2359**	**1982**	**4710**	**1016**	**2614**	**198**	**820**	**404**	**1549**	**2166**	**4301**	**50149**