A ten year citation analysis of major Australian research institutions

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The introduction of the Excellence in Research for Australia scheme has heightened debate amongst research institutions over the use of metrics such as citations, especially given the ready availability of citation data. An analysis is presented of the citation performance of nine Australian universities and the Commonwealth Scientific, Industrial and Research Organisation (CSIRO) that indicates that Australian Institutions perform significantly better than the global average. That said, the question is raised as to whether we are setting the bar too low. Finally, a tentative link between citation performance and application to innovation is noted.

The importance of measuring research and development (R&D) performance

Public funding of research and development in most countries is seen as being of great value to the economy by both direct and indirect contributions. Many studies have estimated the benefits and while there is no clear cut figure, it is generally seen that the public benefit well outweighs the cost of publically funded R&D (Industry Commission, 1995). The links between public spending on R&D and innovation are documented and were analysed in depth in two major national studies for the Australian Government (Batterham, 2000; Cutler, 2008).

The Australian Bureau of Statistics in 2008 found that the total funding on innovation was estimated at $29b. Even acknowledging the benefits, given that funds are always limited, obvious questions arise. Are we investing enough or too much? How much should be in mission-oriented R&D versus unconstrained R&D? Should excellence be the prime determinant for government funding? Should research be prioritised? None of these questions is simple, and one of the most significant challenges is the measures that can be used to gauge the effectiveness of R&D.

Performance measures for R&D

Leaving defence and matters of national security aside, most government funded research is published ultimately in the open literature. It is hardly surprising then that measurements based on publications feature so strongly in funding schemes or that there are clear calls for funding to be related to performance (Industry Commission, 1995).

Many countries take direct measurements in the form of research assessment schemes. Others use the indirect route, e.g. the National Science Foundation in the USA, and the Australian Research Council and the National Health and Medical Research Council in Australia rely on peer review assessment for selection of projects. Peer review itself is heavily influenced by publications. Any other system would be open to the criticism of *insider knowledge* being the main determinant of funding.

It is interesting to note that at the country level, there are several analyses that show the relativity between countries and use this to justify arguments around the level of funding. The work of King (2004) on the scientific wealth of nations set a benchmark that was followed by Mashelkar (2009) in India who used a novel approach of rating publications per head against GDP per head, thereby showing the monetary advantage of doing research in certain countries, India in particular.

A similar international approach at a sectoral level was published recently to show that in the field of nanoscience, Europe and the USA publish a similar number of papers but the citation rate for the USA is over twice that for Europe. The suggestion was made that this may be due to the higher proportion of mission oriented work in the USA through the Department of Energy funded Government Laboratories (Roco, 2010) than in Europe.

It is hardly surprising that excellence features in any appraisal as much as the number of publications. Excellence is seen as a key driver in and of itself in that research judged to be excellent is seen as more likely to have a greater impact and to be more likely to attract collaborators. Given the availability of citation analysis for most publications, it appears inevitable that citations and the resulting *impact factors* will feature more and more in the allocation of funds, despite comments highlighting the limitations of assessment schemes (Nature Publishing, 2010a, b, c; Van Noorden, 2010).

Ultimately, the most significant measure of the effectiveness of R&D is its impact. It has long been recognised that this is the most difficult measure of all. The challenges include the length of time between discovery and application; the relative contribution of translational work, Intellectual property protection; development and scale up; marketing and speed to market.

Whether the final user is in the public domain, e.g. in health education or the private domain, the chain between R&D and innovation involves multiple steps and multiple players making impact measurement a real challenge. While impact is currently not in the *Excellence in Research for Australia* (ERA) scheme, it is now under trial in several universities in the UK for their *Research Assessment Scheme* (Higher Education Funding Council for England 2010).

A relation between citations and innovation

Given the difficulty of measuring impact, it is informative to note the work of Breitzman (2001) who investigated the published science that underpins the prior art disclosed in patents. He showed that where the prior art involved higher citation rankings, the companies' stock-price outperformed other companies by a large margin over a ten year period. This is one of the few examples of a demonstrated connection between the quality of R&D as measured by citation impact and innovation as measured by patent activity and ultimately the stock price of companies. Schwartz (2004) also noted the same trend using a similar procedure in 2004. An analysis along these lines for Australia could be interesting.

Recent citation analyses of Australia's R&D performance.

Of several analyses of Australian performance at the institutional level, that from the Forum of European-Australian Science, Engineering and Technology Discussion Paper (Matthews *et al.* 2009) shows that overall, Australia performs above the world average but that when international collaboration is involved, the citation impact is markedly increased (see Figure 1 from Mathews *et al.*, 2009). From a simple minded view of economic efficiency, one might argue that if citation impact were the primary goal, then some of the funding spent within Australia should be redirected to offshore collaboration.

The other recent analysis that looks at the totality of Australia's performance is the Australian Innovation System Report by the Australian Department of Innovation, Industry, Science and Research (2010). This report acknowledges the difficulty of measuring innovation performance and focuses on R&D capacity as an essential element of the national innovation system. Given that the Government has a target of increasing the number of research groups performing at world class levels, the proxy of performance is taken as the number of research fields with higher than world average citation rates over the period 2004-2008. The report suggests Australia achieved this level in 19 of the 22 fields.

Given that excellence can be linked to greater levels of international collaboration as well as a higher

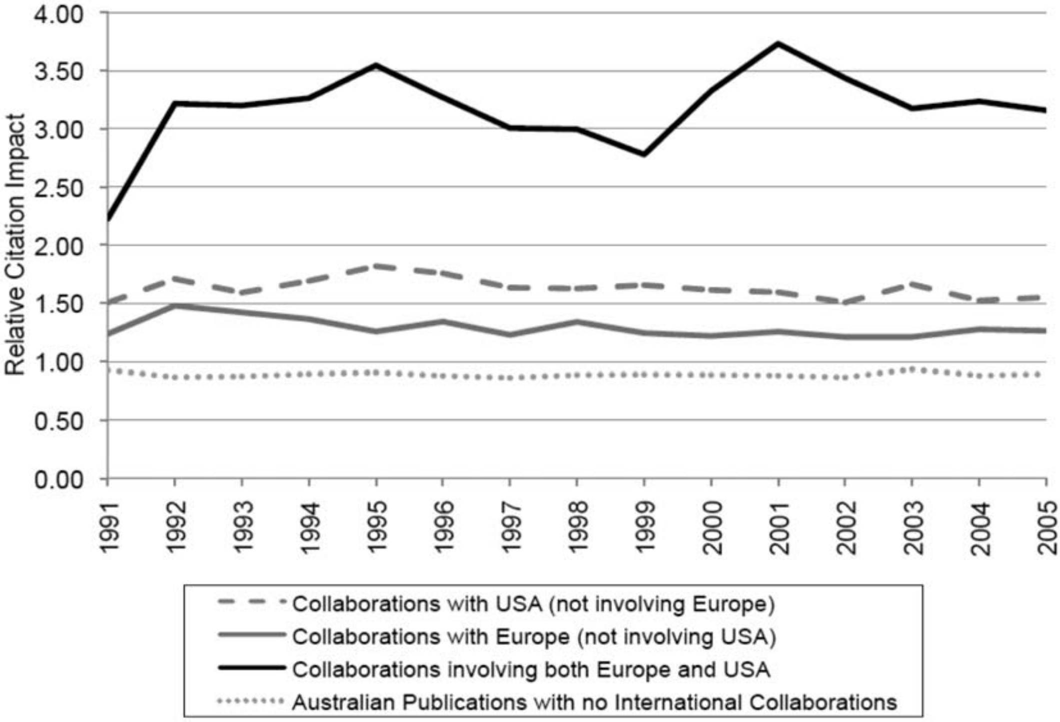

Figure 1 Relative citation impact of science citation index publications 1991-2005

impact in innovation through the support of patents, we may well question why being "above average" is adequate. For a nation that publishes of order two or three per cent of the world's publications, one might argue that the target should be much higher.

An analysis of ten institutions in Australia for the period January 1999 to November 2009

In this paper we consider ten institutions in Australia, chosen in terms of the highest numerical score for either publications or citations totalled across all 22 of the fields in the Thompson ISI Essential Science Indicators (ESI). At the outset one notes that to be classified in any field, an institution must have had at least one paper published in the ten year period that is in the top one per cent of cited papers in that field.

The independent medical research institutions warrant comment. First, ESI analyses institutions as they appear on the author lists. Thus, despite close connection with universities, the independent institutions may not appear in the associated university numbers. Equally, as these medical research institutions tend to publish in a limited number of fields, they won't appear in this analysis as the selection of the ten institutions for analysis in this paper is based on the total publications and citations for all twenty-two ESI fields for that institution. As an example, data for the Walter and Eliza Hall Institute in Melbourne, Australia is noted at the end of the paper.

The ten institutions ranked by citation are shown in Table 1. As expected, this ranking is somewhat different to the oft repeated league tables e.g. the Times Higher Education World University Rankings and the Shanghai Jiao Tong University's Academic Ranking of World Universities, and is because the analysis is based only on citations and covers a ten year period.

Using a scale measure such as the total number of publications or citations is not an absolute measure of quality. An institution might put out a large number of mediocre publications that would nevertheless attract a significant number of citations. Against this, a small institution might have a stellar performance in terms of citations per paper but be too small to feature in this analysis. Interestingly, while there is a gradation in citations/paper across the ten institutions, it is hardly marked.

Next let us consider where these citations sit as against the rest of the material indexed in the Thomson Essential Science Indicators (see Table 2). The rankings for each field are based on the number of Institutions

Institution	*Citations*		*Papers*		*Number of Fields*		*Citations per Paper*
	Number	*Rank*	*Number*	*Rank*	*Top 10%*	*Top 10*	
University of Melbourne	365,427	97	28,582	65	2	-	12.8
University of Sydney	354,109	99	29,847	55	4	-	11.9
University of Queensland	308,191	121	25,777	83	4	-	12.0
UNSW	242,937	173	21,249	125	1	-	11.4
ANU	240,425	177	18,394	153	2	-	13.1
Monash University	235,937	178	20,137	131	2	-	11.7
CSIRO	216,123	205	15,603	207	4	3	13.9
UWA	190,737	233	16,214	194	1	-	11.8
University of Adelaide	142,250	312	13,156	248	-	-	10.8
University of Newcastle	60,138	603	6,540	505	-	-	9.2

Table 1: Top 10 institutions in Australia ranked on the basis of total publications and citations listed in the Thomson Essential Science Indicators

that are in absolute terms in the top 10 institutions in the world as well as a column showing where the ranking fits as a percentage (the top 10 per cent of all institutions in the field, 25 per cent, 50 per cent and >50 per cent).

Of the 22 fields, Australia at an institution level is above average in nineteen of the fields as stated in the Australian Innovation System Report 2010 but more interestingly, if we define world class as in the top 10 per cent, Australia is world class in six of the fields with clinical medicine and plant and animal science being quite extraordinary results.

Equally meritorious is that CSIRO at the institution level is the only institution in Australia that is ranked as being in the top 10 institutions in the world (absolute) and does so in three of the fields, none of which involve a particularly small number of institutions worldwide which would then inflate the likelihood of being in the top 10.

The relatively large number of institutions publishing in particular fields and ranking well below world average performance raises interesting questions. Uncomfortable and all as the question is, should our limited research funds be used this way or are we better targeting bringing those near the top (say the top 25 per cent) up to the top 10 per cent?

Course	*Number of Institutions*					*Total for world*
	Top 10	*Top 10%*	*Top 25%*	*Top 50%*	*Top 100%*	
Clinical medicine	0	6	9	10	10	3047
Plant & animal science	1	6	7	9	10	877
Environment/ecology	1	2	5	9	9	541
Geosciences	0	2	3	6	10	443
Engineering	0	1	9	10	10	1084
Social science	0	1	6	9	10	681
Agricultural sciences	1	1	5	6	8	438
Chemistry	0	0	5	8	10	941
Biology and biochemistry	0	0	4	9	9	714
Computer Science	0	0	4	8	8	335
Materials science	0	0	4	5	7	631
Psychiatry/psychology	0	0	3	7	9	385
Pharmacology & toxicology	0	0	3	4	5	388
Neuroscience & behaviour	0	0	2	5	8	458
Microbiology	0	0	2	4	7	329
Immunology	0	0	1	6	7	305
Physics	0	0	1	5	7	681
Molecular biology & genetics	0	0	0	2	9	423
Mathematics	0	0	0	2	5	194
Space science	0	0	0	1	4	134

Table 2: Ranking of Australian Institutions by field against the rest of the world

Data on individual fields and universities

Sitting behind the analysis in Table 2 of overall Institution rankings for each of the 22 fields is the data that corresponds to the performance of each Institution in each of the 22 fields. Appendix 1 shows the ranking by citation for each field for each of the top ten institutions. Within each field, one finds different numbers of Institutions on a worldwide basis, e.g. there are 3047 Institutions in Clinical Medicine but only 877 for Plant and Animal Science. To simplify the presentation and facilitate comparisons, the absolute rankings are converted to a percentage ranking. As an example, the University of Sydney citations for the field of Clinical Medicine rank 73 from 3047 institutions worldwide reported in the Web of Science. This is shown on the diagram for Clinical Medicine as Sydney, 2.4 per cent as the rank has been converted to a percentage.

The data in Appendix 1 graphically confirm the pre-eminence of some Australian institutions. To this analyst, it suggests the question that if higher citations imply more impact and innovation, as argued above, should Australia concentrate more of its research funding on those that are performing at the higher levels, e.g. the top 25 per cent of their peers in the world?

Data for the independent medical research institutions

The analysis in this paper used citations and publications across all twenty-two fields of the ESI and then took the top ten institutions. This absolute scale misses the smaller but prestigious institutions such as the medical research institutes. Consider as an example the Walter and Eliza Hall Institute (WEHI). For a ten year period from January 2000, the Institute had 55189 citations covering seven of the twenty-two fields, thereby just missing out on the analysis in this paper. On a specific field-basis, say immunology, their citations of 12580 put them just behind the University of Melbourne (15226) and Monash University (13139) but ahead of all other institutions in Australia.

Most meritorious is that WEHI has 37.2 citations per paper for immunology against a world average of 20.4.

Conclusion

An argument is outlined that high rankings on citations are an indicator of more effective innovation. The analysis of a ten year performance window for ten of the top publishing institutions in Australia certainly supports the claim that Australia's performance is well above average.

An unanswered question logically follows of how much better could we do and whether this entails focusing effort on our top performers and those that are close to the top. This is a topic that demands a deeper analysis than this paper, with its aggregation at an institutional level.

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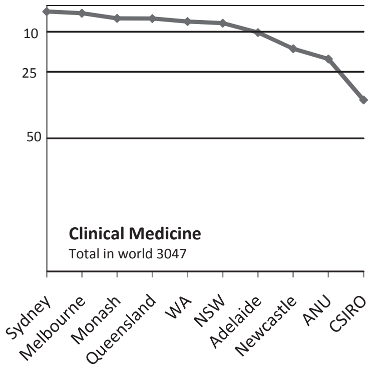
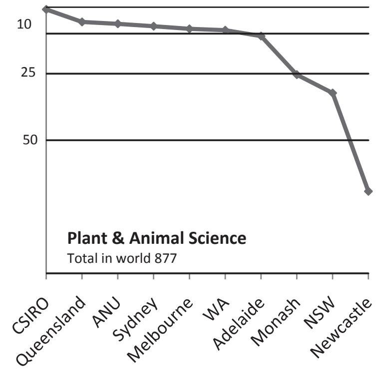
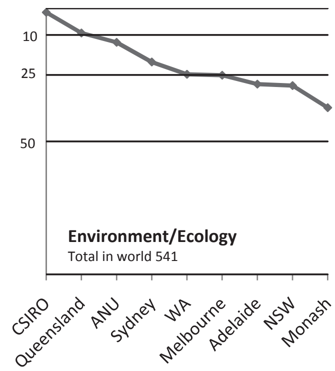
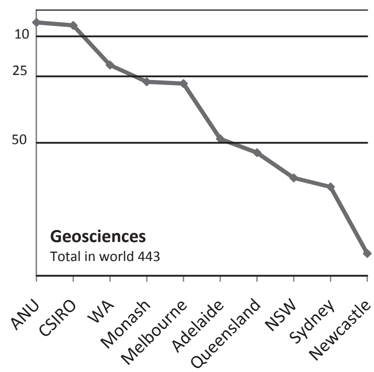
Appendix 1

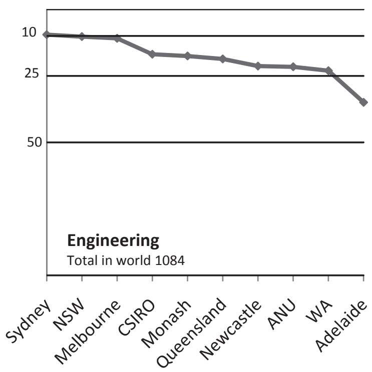
Ranking by citation as a percentage. The number in the box refers to the total number of institutions in a particular field.

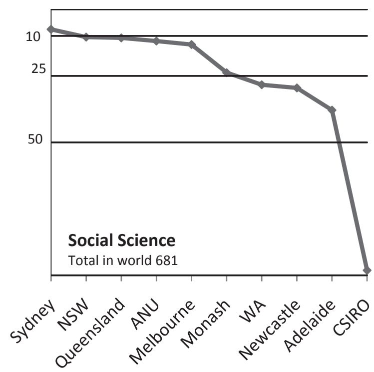


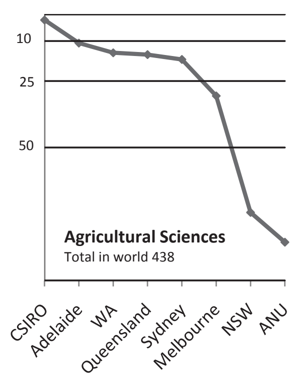


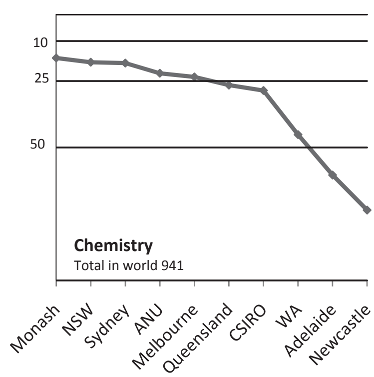


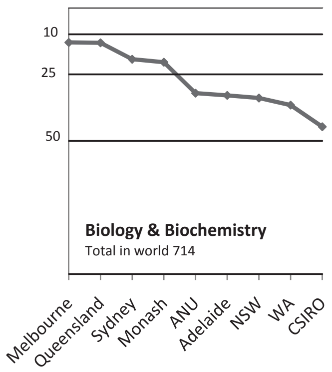








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Total in world 714
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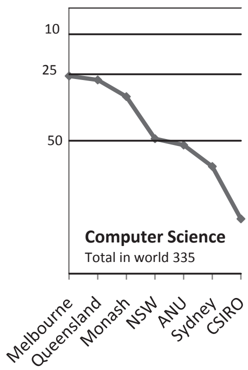
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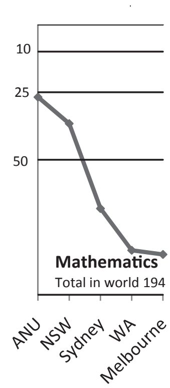
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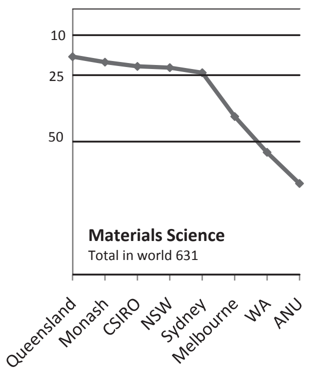
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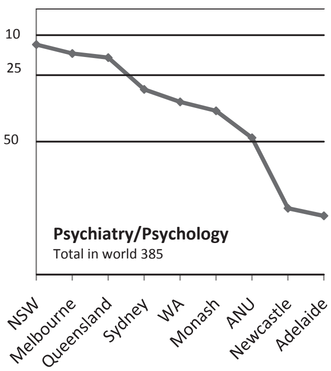
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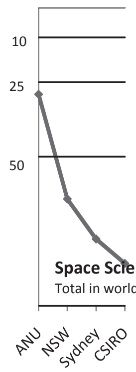
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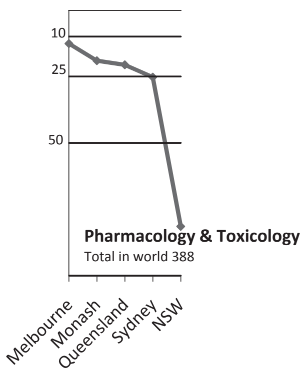
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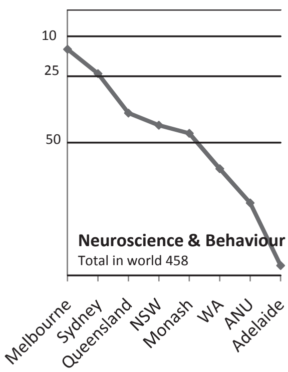
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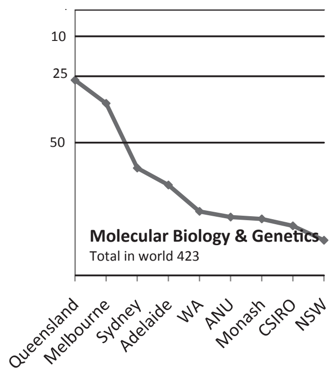
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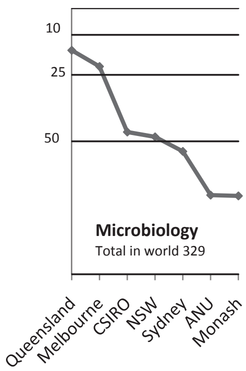
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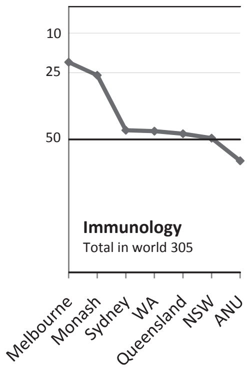
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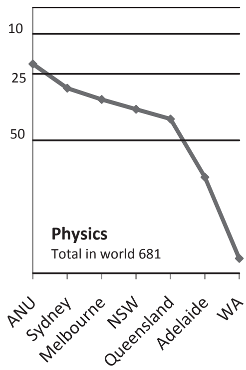
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