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The efficacy of different modes of funding research: perspectives from Australian data on the biological sciences

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Abstract

In this paper we set out to investigate whether there was variance in the impact of research publications in relation to their mode of funding. We allocated relevant publications to sectors on the basis of the institutions undertaking the research, the duties of the researchers, and the providers of the major source of funding. To undertake a bibliometric analysis, we used the Research Evaluation and Policy Project database containing all Australian ISI-indexed publications since 1981, and a database of publications constructed from the final reports of the recipients of Australian Research Council large grants in the biological sciences. Our results indicate that rather than the mode of funding, the nature of the researcher's appointment appears to be the most significant determinant of impact. We found that researchers appointed to full-time research positions in the biological sciences, irrespective of their source of funds, achieved higher visibility for their research than did researchers with significant other duties, such as undergraduate teaching or clinical practice.

Keywords: Bibliometric analysis; Funding; Research appointment; Biological sciences

1. Introduction

Although policymakers and researchers have strong views on the subject, it is noteworthy that very little is known about which of the standard modes of funding research secures the 'best' result in terms of the impact and visibility of the research. The issue is raised most acutely in systems where there exists a variety of modes: for example, full funding of whole institutions or centres, leaving maximum discretion to the institution to determine projects worthy of support; direct project funding where external funding agencies identify projects and researchers to support, leaving infrastructure provision to the institution; direct funding where external funding agencies identify projects and researchers to support and provide infrastructure support. Alongside these issues is the question of the productivity and visibility of work associated with full-time researchers, however funded, and researchers who have duties other than research, such as teaching and administration.

There is a good deal of 'in principle' advocacy of these various approaches or combinations of them in the policy literature on research in various systems. For example, in the 1997 discussions preparatory to the report of the Dearing Committee, there was lively debate in Britain between exponents of a system in which research funding would increasingly be vested in direct granting processes and others who

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wished to see greater institutional autonomy in the support of research projects and programs by universities themselves (Bourke, 1997). The British university system offers an ideal site for serious work on this. It should, in principle be possible to develop a project in which comparisons are made between research outputs flowing from operational grants secured via Research Assessment Exercise processes and outputs deriving from direct funding processes associated with the research councils. We are not aware of any work of this kind, however. In this paper, we set out to offer some purchase on these larger policy issues through fine-grained work on Australian data. Our intention is to outline the methodology employed and some general results, showing their implications for policy. We will refer principally to a study of grant and fellowship recipients in the biological sciences but also make some use of a second project on acknowledgment patterns in biomedical science.

2. Methodology

2.1. Studies utilised

Two studies were utilised for this research. In the major project the Research Evaluation and Policy Project (REPP) was funded by the Australian Research Council (ARC) to undertake a bibliometric analysis of publications that were attributable to large grants made by the ARC in the biological sciences. Every grant recipient is required to lodge a final report which purport to detail all publications resulting from work funded by the grant. REPP was given access to the final reports for grants commenced in the period 1991 to 1993 and extracted all publication details together with demographic details of chief investigators. The study was extended to recipients of full-time ARC research fellowships in the biological sciences. The journal articles identified were then matched to the REPP database and a bibliometric analysis was undertaken comparing the citation performance of these articles with those resulting from alternative funding arrangements, for example from fully funded institutions ineligible for ARC support and from university operating grants. Data was obtained from 277 large grants and 31 fellowships, which reported 1846 articles of which 1015 ultimately formed the basis for one sector in our analysis.

The second project was funded by the National Health and Medical Research Council (NHMRC) and involved collaborative work with the Policy Research in Science and Medicine unit (PRISM) at the Wellcome Trust. PRISM extracted from its Research Outcomes Database (ROD) of funding acknowledgments details for all 1993 and 1994 Australian biomedical articles (Jeschin et al., 1995). Of Australia's 13,620 biomedical publications, 8048 were identified in the ROD database with funding acknowledgments. With this information, we were able to analyse the funding sources of the different sectors in our biological sciences study and thereby determine the distinctiveness of the comparators for the ARC supported research.

2.2. The REPP database

The REPP database was created from data files purchased from the Institute for Scientific Information (ISI) for the period 1981–1995. It captures all publications with an Australian address in the three major ISI Indices: Science Citation Index (SCI), Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (A&HCI). The database also contains the yearly counts of citations in ISI indexed journals to each of these Australian publications. The REPP database as it now stands contains over a quarter of a million records of Australian publications. This database has been well documented in several of our published studies (for example, Bourke and Butler, 1993), and a description is available on the Internet. [1]

2.3. The ROD database

In 1993 PRISM established the Research Outputs Database to cover all UK biomedical research papers. The papers to be included in the database were identified on the basis of journals classified as biomedical, and an address keyword filter for multi-

[1] http://coombs.anu.edu.au/Depts/RSSS/REPP/repp.htm.

disciplinary and fringe journals. The database now covers articles from 1988 to 1995, and for 2 years (1993 and 1994) also includes Australian biomedical articles. In addition to basic bibliographic details, ROD includes information relating to all funding acknowledgments given in each article. This information was obtained by an inspection of each original research article.

2.4. Locating ARC publications in the REPP database

Most of the ARC publications extracted from final reports could be readily identified in the REPP database using their bibliographic details. The most time-consuming part of this task was the matching of articles where incomplete details were available. In these cases, we searched the REPP database for unique matches on the limited information. A match was accepted where the details we had could be matched by only one article in the REPP database. In some instances we knew a match was very unlikely because the article was:

- a 1996 publication (outside the scope of the REPP database);
- appearing in a journal not indexed by ISI;
- 'in preparation' or for which journal title details were not given.

The full results of the matching process are given in Table 1.

The success rate for matching publications (after excluding those articles that were in non-ISI journals) was over 90% for articles published between 1991 and 1994, but only 69% for articles published in 1995. The low matching success for 1995 publications was due to two factors: first, since 1995 tape year data was the latest we had received when the analysis started, some 1995 publications were missing and would not be added to the database until the 1996 update was processed; second, a far higher proportion of 1995 publications lacked some essential bibliographic details. Because of the low success rate in matching 1995 publications, the analysis was limited to articles published between 1991 and 1994 rather than between 1991 and 1995, as originally intended.

Table 1
The match of articles in ARC final reports to the REPP database

Year	Unmatched				Matched	Total
	Non-ISI	Out of scope	Incomplete details	Full details		
1990	2	6				8
1991	20			4	99	123
1992	59		1	12	215	287
1993	47		4	12	344	407
1994	54		26	8	357	445
1995	28		63	13	171	275
1996	9	86				95
1997		3				3
n/a	47	2	118		36	203
Total	266	97	211	49	1223	1846

2.5. Definition of sectors

Discussions with the ARC led to the elaboration of eight separate sectors for analysis, each with relatively distinct characteristics. They are listed below as a continuum from primarily full-time fully funded research to primarily part-time research.

(1) *ARC Centres*: Fully funded single focus research centres, of 6 to 9 years duration, located within universities and employing full-time researchers.

(2) *Cooperative Research Centres (CRCs)*: Fully funded single focus research centres, of up to 7 years duration, primarily located within universities, and employing full-time researchers.

(3) *Medical Research Institutes (MedRI)*: Fully funded medical research institutes, comprising the Australian Association of Medical Research Institutes and employing full-time researchers.

(4) *Multidisciplinary Research Institutions (MultiRI)*: Two fully funded multi-disciplinary research institutions employing full-time researchers, specifically the Commonwealth Scientific Industrial and Research Organisation (CSIRO) and the Institute of Advanced Studies (IAS) at the Australian National University.

(5) *ARC Grantees*: Recipients of ARC large grants of 3 years duration, retaining teaching and administrative duties within their institutions, and recipients of full-time ARC research fellowships of 3 to 5 years duration.

(6) *Government*: Full-time and part-time researchers located in Australian and State government departments and agencies.

(7) *Hospitals*: Full-time and part-time researchers funded principally through hospital general operating grants or state health commissions.

(8) *Universities*: Part-time researchers retaining teaching and administrative responsibilities funded principally through university general operating grants, ARC small grants or NHMRC project grants.

The CRC sector, a relatively recent development in Australia, was subsequently excluded from the citation analysis as it contributed a very small number of publications clumped heavily in the more recent years of the period being analysed.

In constructing the sectors, we had three goals: (i) to identify sectors that contained research comparable to that undertaken by recipients of ARC large grants in the biological sciences; (ii) to create sectors with distinctive funding and research-time characteristics; and (iii) to make sectors as distinct as possible by avoiding where feasible the double counting of articles in more than one sector.

To help achieve these goals, we made two methodological decisions: one relating to the treatment of collaborations and the other relating to the selection of publications when constructing the sectors.

Publications that involved collaboration between sectors were identified and handled in the following way:

- collaborative publications involving the ARC Centres and ARC Grantees sectors were excluded from all other sectors; and
- collaborative publications involving the MultiRI and MedRI sectors were excluded from the remaining three sectors.

The selection of publications within sectors was done using two different criteria:

- all publications from organisational units coded to the biological sciences; or
- biological sciences publications (as defined by journal sets) from organisational units which did not have a field descriptor.

Journal output resulting from research in the biological sciences does not always appear in journals classified to the biological sciences (Butler et al., 1999). To undertake a complete analysis of the output of biological sciences research would involve identifying all publications from projects undertaken in that field. We did this for ARC Grantees and ARC Centres by extracting details of all publications from biological sciences final reports, irrespective of the field of the journal in which they appeared. For universities and research institutions (University, MedRI and MultiRI sectors) we were able to identify organisational units that were classified to biological sciences and were also able to analyse the full journal output of these units. In the remaining sectors, however, it was not possible to identify a discrete biological sciences organisational structure and for these we employed journal sets. For example, biological sciences were not necessarily the main focus of research in institutions within the MedRI, Government and Hospital sectors. To include all their publications would have been misleading, so the publications for these sectors were limited to those appearing in journals classified to biological sciences or in our multidisciplinary biomedical journal set.

Although these decisions are not without problems, in particular the treatment of collaborative publications between sectors, the discussion of the methodology that follows will show that we experienced success in creating sectors with quite distinctive profiles.

3. Discussion of the methodology

As a main focus of this paper is the relative impact of publications produced from research funded by different modes, it is important to determine the success achieved in defining the sectors. We pursued this point in two ways: first, we determined the degree of duplication between sectors; and second, we analysed additional data to test how successful we were in segregating sectors in relation to different types of funding.

3.1. Duplication and collaboration

Due to the methodology used in the construction of sectors, the only duplications involving ARC publications that were possible were between the two ARC sectors, Centres and Grantees, and the degree of overlap was less than 10%. There were a small number of duplications between the MultiRI and

Table 2
Percent distribution of publications by sector and funding characteristics (1993–1994)

	Existence of funding acknowledgments			% in both databases	Funding body	
	Funded	Unfunded	Unmatched		ARC	NHMRC
ARC grantees	86	8	6	52	68	15
ARC centres	79	15	6	49	25	43
MultiRI	76	14	10	34	10	10
Hospitals	56	32	11	73	2	28
Government	81	13	5	20	12	5
MedRI	86	5	10	79	4	54
Universities	73	21	6	37	23	25

MedRI sectors, but our procedure ensured that there were no duplications between either of those two sectors and any of the remaining sectors. These four sectors therefore can be regarded as comprising discrete sets of publications. The Hospital, University and Government sectors did involve a number of duplications, however, the extent of overlap did not present a serious problem. For example, in the University sector the maximum potential for duplications was only 10%. [2]

We are confident that the methodology we employed has resulted in the construction of sectors with distinct sets of publications. However, this could only result in a useful analysis if we could demonstrate that these sets of publications also resulted from quite distinctive patterns of funding.

3.2. Sources of funding

The steps taken to this point did not ensure that the sectors constructed necessarily corresponded to discrete modes of funding. Collaborative publications were in many cases assigned to a single sector, but nonetheless could have been the result of a research project funded through a number of different funding mechanisms. In addition, even where a publication involved no inter-sectoral collaboration, it may have been based on multiple funding modes.

To gain some purchase on this point, we made use of the collaborative project between REPP and PRISM, which examines the funding acknowledgments of Australia's biomedical publications. This enabled us to seek a match between substantial parts of the sectoral database constructed for our ARC biological sciences project and the sources of funding for publications in these sectors. Table 2 shows some characteristics of the distribution of funding acknowledgments for those publications present in both databases.

It is important to emphasise that authors do not always acknowledge all (or any) sources of funding (Jeschin et al., 1995), and that not all the publications in the REPP biological sciences study were in the PRISM database. The distribution shown in Table 2 is, therefore, by no means definitive. In addition, the PRISM database is aimed primarily at the biomedical fields and does not include journals from those sub-fields of the biological sciences focused on botany, zoology and ecology. This is reflected in the high coverage in the PRISM database for publications from the Hospital and MedRI sectors (around 75%), but a lower coverage for those sectors with a high proportion of their output in the three named sub-fields, in particular the Government sector.

That said, the data does indicate that the sector created for ARC Grantees is consistent with our perception that it is comprised of articles based principally on ARC-funding. As expected, the MedRI sector is heavily reliant on funding from NHMRC, with little from the ARC. Funding acknowledgments in the Hospital sector are much lower, but like the MedRI sector, also involve NHMRC rather than ARC funding. The MultiRI institutions, in line with their full funded status, acknowledge only a small amount of support from ARC and NHMRC.

[2] The actual proportion is likely to be lower as some of the collaborations would have involved more than one other sector.

This analysis of the sectors demonstrates that while it is impossible to create sets of publications reporting research resulting from a single mode of funding, it is possible to create sectors that have sufficiently distinct characteristics (in relation to funding sources, institutional type and the nature of researchers appointments) for a meaningful bibliometric analysis to be undertaken.

3.3. Publication year window

When analysing the distribution of publications from the ARC Grantees sector across the years of study, it became apparent that a problem existed. While the publications from the other sectors showed similar distributions across the years, those from the ARC Grantees sector were much more heavily concentrated in 1993 and 1994. This had an obvious effect on their comparative citation rates. In an attempt to allow a more realistic comparison with other sectors, we 'normalised' the data for the ARC Grantees sector. This was accomplished by giving their 1991 publications a weighting of 3 and their 1992 publications a weighting of 1.33. Results for both the 'normalised' and original data were given in the analysis.

4. Measures used in the analysis

We briefly list here specifications adopted for tabulations in this analysis: [3]

- the types of publications counted were limited to articles, notes and review articles;
- data was compiled on a publication-year basis, not a tape-year basis;
- the publication window was 1991–1994;
- the citation window was 1991–1995;
- at the sector level, the analysis was based on whole publication counts;
- the analysis was limited to articles published in journals found in the SCI.

[3] For a discussion of the effect caused by the choice of different options, the literature written on the decline or otherwise of British science in the 1980s provides an excellent overview (see Martin, 1994).

The analysis drew on indicators that we have routinely used in a number of our reports, where they are described more fully (most recently Butler et al., 1997). In brief, we have used here: (1) *citation per publication* (cpp) rates; (2) numbers of most *highly cited publications* (in the top 1% and 5% bands for Australian publications). This measure focuses on articles published in 1991 and 1992, as more recent publications have had little time in which to attract citations; (3) a comparison of *actual and expected citation rates*, based on the average number of citations actually received by the publications of a sector compared to the average number of citations achieved by all publications in the journals carrying the articles of that sector; and (4) the classification of articles using the Computer Horizons Incorporated (CHI) four point scale from basic through to applied (Narin, 1976).

This article is restricted to an analysis of the field of biological sciences, though the full report also contains analyses undertaken at the sub-field level (Butler et al., 1999). Fields were delineated using journal set analysis based on the translation of the SCI's subject categories into the fields of the Australian Standard Research Classification (ASRC). For each set of indicators, comparisons were made between the performance of the ARC publications identified with award recipients and the performance of biological sciences research attributed to the other sectors.

In addition to analyses at the sub-field level, the full report also analysed selected demographic characteristics to determine whether differential citation performances could be identified, using the indicator of actual vs. expected citation rates.

5. Results

In this section, we present the results from our major study of the biological sciences that are particularly relevant to the issues being examined in this paper. The following analyses cover the aggregate data for the whole field of biological sciences, though we also refer in the discussion to relevant points arising from analysis at the sub-field level. After the presentation of the results obtained using three dif-

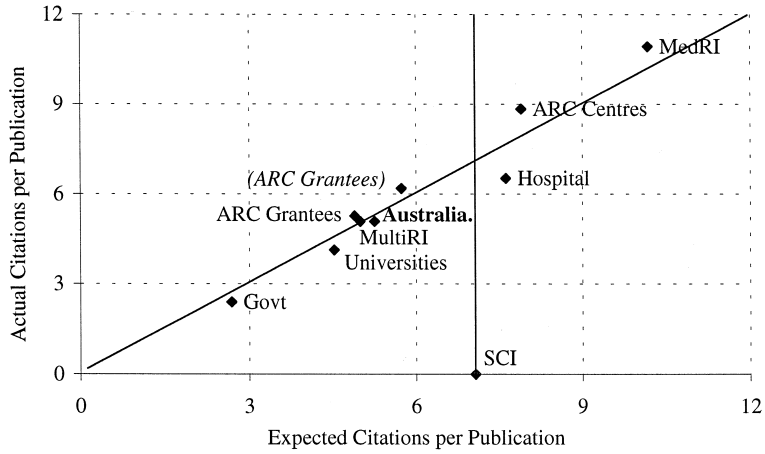

Fig. 1. Actual and expected citation rates (1991–1994).

ferent bibliometric measures, we examine some of the characteristics of sectors that may provide explanations for their differential performances.

5.1. Three bibliometric measures

Citations per publication rates are distributed across a wide range, though broadly within three bands. The MedRI and ARC Centres sectors have the highest rates by a distinct margin and the publications from the Government sector have a significantly lower rate. All other sectors have similar rates, close to the Australian average.

Fifty citations were required by an article published in 1991 or 1992 to place it among the 1% most highly cited biological sciences publications in Australia and 26 citations to place it in the top 5%. The MedRI and ARC Centres sectors have a considerable presence in all clusters of highly cited publications. Of particular note is the proportion of their publications in the top 1% band—5% and 4%, respectively. The Hospital sector's presence is also above the Australian average in both clusters. The MultiRI and ARC Grantees sectors have a number of very highly cited publications (top 1% band), but their presence in the other bands is at average levels.

Table 3
Citations per publication (1991–1994)

Sector	Cites	Pubs	cpp
MedRI	10,230	935	10.9
ARC centres	1379	156	8.8
Hospital	5504	844	6.5
(ARC grantees)	(4805)	(777)	(6.2)
ARC grantees	3249	617	5.3
MultiRI	4446	875	5.1
Universities	9856	2390	4.1
Government	4177	1741	2.4
Australia	55,583	10,945	5.1

An examination of Fig. 1 provides additional information to explain the differences in cpp rates noted in Table 3. The MedRI and ARC Centres sectors publish in high impact journals and also receive citations well above the expected level for those journals. [4] The Government sector publishes in low impact journals, attracting citations at the expected level for these. The ARC Grantees, MultiRI and University sectors are also publishing in relatively low impact journals, but while the University sector's publications do not attract citations at the expected level for these journals, the other sectors' publications do. The Hospital sector publishes in relatively high impact journals but does not achieve the expected citation rates (see Table 4).

[4] The vertical line in this figure, labelled 'SCI', represents the average cpp rate for all articles in all journals classified to the biological sciences. Sectors appearing to the left of this line are publishing in journals which have a relatively low impact, while those to the right are publishing in journals of relatively high impact.

Table 4
Most highly cited publications (1991–1992)

	Total number of publications	% Publications in top 1%	% Publications in top 5%
MedRI	402	5	16
ARC centres	48	4	17
Hospital	407	2	8
ARC grantees	190	3	7
MultiRI	452	2	3
Universities	1202	1	3
Government	857	0	1

Top 1% = 50 cites (50 publications).
Top 5% = 26 cites (256 publications).

5.2. Sub-field of research concentrations

It is important to note certain sectoral sub-field variations that are obscured by aggregate totals. The two sub-fields of our classification that are most closely associated with medical sciences, general biology and biochemistry and genetics and cell biology, have average cpp rates significantly higher than the other sub-fields. The sub-field focus of a sector can go a long way towards explaining differential cpp rates for the field as a whole.

The patterns shown in Table 5 suggest three distinct groups. The MedRI and Hospital sectors' publications are concentrated primarily in the medically oriented sub-fields of the biological sciences—the sub-fields with the highest citation impact. The ARC Centres also have a considerable presence in these high impact sub-fields, while the ARC Grantees and MultiRI sectors have a stronger focus on the relatively low impact sub-fields of botany, zoology and ecology and their lower cpp rate is expected. The Government sector's research is also focused on the lower impact sub-fields (botany, zoology, ecology, and other biological sciences) and a low cpp rate is expected, but its position in Fig. 1 indicates that even within these sub-fields it publishes in low impact journals.

The relative performance of sectors in the field of biological sciences as a whole is not necessarily indicative of their performance at the individual sub-field level. When sub-field concentration is further scrutinised, it remains true that the MedRI and ARC Centres perform at higher levels than all other sectors in those sub-fields in which all sectors have a reasonable concentration. These are the two medically oriented sub-fields of general biology and biochemistry and genetics and cell biology. However, the MultiRI sector has the strongest citation per paper rates, and the best citation performance in relation to the expected levels of journals, in the sub-fields of botany and ecology. The performance of the ARC Grantees sector is particularly strong in the sub-fields of botany and zoology. The strength of the performance of these two sectors in their low impact sub-fields is however 'swamped' at the field level by the high citing biomedical sub-fields.

5.3. Level of research

The distribution of a set of journals across the four levels of research is another important determinant of citation per publication rates. The fact that basic research journals achieve higher citation rates than applied technology journals in the same field is well documented (Narin, 1976). Nearly three-quarters of all journals in the biological sciences journal set

Table 5
Distribution of publications across sub-fields of the biological sciences

	cpp	ARC grantees	ARC centres	MultiRI	Hospitals	Government	MedRI	Universities
General biology and biochemistry	9.4	31	51	31	46	10	66	25
Genetics and cell biology	10.5	18	33	21	61	7	49	14
Botany	3.5	31	12	15	2	24	0	19
Zoology	2.2	17	3	30	1	30	3	24
Ecology	3.5	13	10	19	0	26	0	21
Other biological sciences	5.7	14	12	2	5	27	4	20
Biological sciences	7.1	100	100	100	100	100	100	100

are classified to the basic research level. Fig. 2 depicts graphically the spread of publications for each sector in our analysis.

There are distinct differences between sectors in the level of research that characterises their publication output. The Hospital sector has the highest proportion of its publications in both the applied research (clinical observation) journals and the engineering/technology (clinical investigation) science journals. With their concentration on clinical sciences in general, this distribution for their biological sciences publications is as expected. This distribution would also lead us to expect lower cpp rates for the sector compared to the MedRI sector which has a similar research focus (the medical aspects of biological sciences) but whose output appears more often in the basic research journals.

Over 80% of publications in the ARC Grantees sector appear in basic research journals. The MultiRI, MedRI and University sectors also publish predominantly in basic research journals. The one sector presenting a counter-intuitive result in this analysis is the Government sector. We had expected this sector to present a profile more in line with the Hospital sector, that is, more focused on applied research. As yet the full explanation for this remains unclear.

5.4. Type of ARC grant

It will be apparent from the data so far discussed that there are differences of some importance between research outputs associated with the MedRI, ARC Centres and MultiRI (within certain sub-fields) sectors, and the outputs from other sectors. This difference suggests, inter alia, a distinction between full-time and part-time researchers and we were able to pursue this point within the ARC system itself. As previously noted, the ARC Grantees sector consists of articles extracted from two types of final reports, those from the large grants scheme involving mainly part-time researchers and those from the recipients of full-time ARC fellowships. We used an analysis of actual and expected citations to determine if any differences could be discerned between the two groups. Fig. 3 depicts the results of this analysis.

The analysis for the fellowship holders shown in Fig. 3 was based on a relatively small number of publications (111). We were concerned to determine whether the high cpp rate for this group was unduly influenced by one (or two) very highly cited articles. We calculated the distribution of each group's publications across different citations bands and found that our concerns are not borne out by the facts. Fellows did not have any very highly cited publications (more than 100 citations), though they did have a higher proportion of their publications in the bands between 40 and 100, hence their higher cpp rate. The difference between the two groups was therefore related to a higher visibility of their publications in general, rather than resting on one or two very highly cited items. We acknowledge, too, that the competition for large grants, with a success rate of 20% of

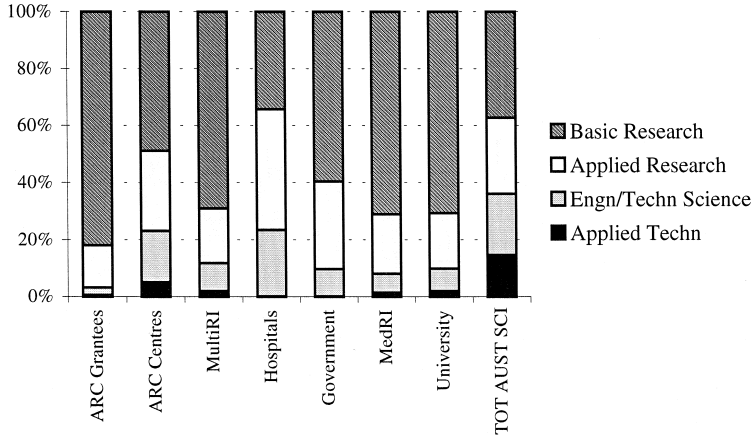

Fig. 2. Level of research by sector (1991–1994).

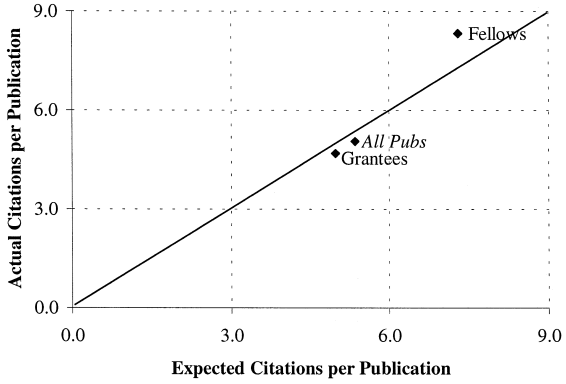

Fig. 3. ARC grantees actual and expected citation rates by type of scheme (1991–1994).

applicants, is a broader sieve than the competition for fellowships, with a 10% success rate. That is, the full-time fellowship holders are drawn from the outstanding applicants in their cohort and constitute a much more highly selected population of researchers.

But, for all these qualifications, the difference in performance between the two groups is far greater than we had anticipated. The articles from fellowship holders have an average impact 50% higher than those from the large grant recipients. In addition, the fellowship articles achieve greater than the expected level of citations for the journals in which they publish, while the grant recipients receive just under their expected level.

6. Conclusion

The general bearing of this study suggests that, on most of these measures, researchers appointed to full-time research positions in the biological sciences, whether from ARC or other modes of funding support, achieve higher visibility for their research than do researchers with significant other duties (such as teaching or clinical work). This is not a result associated per se with differences between modes of funding since any mode of funding can be deployed for full-time or part-time support. But, in practice, it does represent a difference in outcome between funding mechanisms since most full-time research positions in the Australian system are associated with fully funded research entities, such as ARC Centres, medical research institutes, the IAS and CSIRO. In these entities, discretion for the assignment of support to specific projects is vested in a devolved, intramural research management structure.

The explanation for differences between full-time and part-time research outcomes may not be as obvious as it at first sight appears, of course. There is a temptation to see it as a result of the obvious difference in dedicated time available for research activity. We certainly do not dismiss the advantages of full-time research in facilitating simple productivity. More dedicated time available to the researcher should presumably allow for more research to be completed and brought to publication. It is possible to illustrate this by comparing the publication rates of ARC fellows with those of ARC large grant recipients. Table 6 shows the publication numbers per researcher for the period of the grant for the two ARC groups classified by type of publication.

While acknowledging that the data for fellowship recipients is based on a relatively small number of cases, the table presents a clear picture. For all except one type of publication, the productivity of fellowship recipients is significantly higher than that of large grant recipients.

But that difference in capacity for dedicated effort between the two principal groups, large grant recipients and full-time researchers, carries us only part of the way, and perhaps not the most interesting part of the way, to understanding what these results suggest. We have been at pains to emphasise the additional systematic difference between the work associated

Table 6
Publications per researcher

	Large grants	Fellowships
Number of researchers	406	31
Books	0.1	0.2
Book chapters	0.8	2.4
Journal articles	5.6	8.2
Major reviews	0.1	0.4
Conference papers	3.0	4.3
Patents	0.0	0.0
Computer software	0.1	0.8
Unpublished	1.7	1.0
Other	0.8	2.0
Total	12.4	19.3

with large grants in most of the sub-fields and the work of the research entities in terms of the higher impact and visibility of the journals carrying the publications of the full-time researchers. How should we understand this difference? We advance a number of hypotheses here emphasising that to develop some of these would require expert judgment by practitioners of the biological sciences. We suggest the following.

- The considerably longer potential life history of projects conducted in research entities such as ARC Centres and medical research institutes may allow for the identification of research problems of wider and deeper content, closer to 'state of the art' work in the field and accordingly more likely to achieve publication in the major international journals.
- Conversely, the shorter guaranteed trajectory of schemes such as the ARC large grants may predispose researchers to choose lesser problems capable of more predictable and safe completion.
- The shorter trajectory of large grants, in comparison with research entities such as ARC Centres may also predispose researchers, conscious of the need to maintain a steady output in relation to the next large grant cycle, to submit work to journals in which they are more likely to be accepted than to highly competitive journals.

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