THE IMPACT OF AUSTRALIAN SCIENCE

Possible reasons for the perceived decline in the Australian share of scientific citations in the international literature

Discussion paper

The Australian Academy of Science
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FOREWORD

The question mark at the end of *A crisis for Australian science?*, the review by Paul Bourke and Linda Butler of Australia's 'impact' among the published citations of research papers, 1985-92, was a challenge that an academy of science could hardly refuse to take up. With the financial support of the Australian Research Council, another interested party, the Academy's Council in February 1995 commissioned our Secretary for Science Policy, Dr Keith Boardman, and other distinguished researchers constituting the project's Steering Committee, to test the trends evident in the citation analysis and the hypotheses advanced to explain them.

The trend in the citation impact of Australian papers was not uniform across disciplines, so Dr Boardman and his Steering Committee chose some that had been part of the trend and some that stood out from it. To help find suitable ways of testing the hypotheses that had been advanced to explain the observed trends the Committee consulted the Academy's National Committees, relevant scientific societies and the Institution of Engineers, Australia. Their advice was essential in distinguishing the top-ranked journals in each selected discipline, on the basis of which Professor Bourke and Ms Butler conducted a further analysis of the citation data base. Fellows of the Academy also responded readily with insights to guide interpretation of the citation data.

In the outcome, the hypotheses that this report enumerates were defined and tested, within the limits of the data available to the Committee. The firmest conclusions were negative, but useful none the less. The likeliest cause of declining impact, although certainly not the only factor, was found to be an attenuation of the networks connecting Australia's younger researchers with their leading colleagues overseas. Combining this evidence with the obvious importance of such contacts to leading-edge research, we have grounds for recommending that further ways be found of promoting international links. To this and other evidence of the study the Academy will pay more attention in the months ahead.

I am very grateful to the Australian Research Council for supporting this work, and especially to its Chair, Professor Max Brennan, who played an active role on the Committee. The Australian Academy of Technological Sciences and Engineering was ably represented on the Committee by Professor Frank Larkins. Dr Keith Boardman was, as usual, a wise counsellor for the Academy, and Dr Lyn Grigg an experienced guide through the imperfectly mapped territory. Indeed, this study provides further evidence, if it is needed, of the value of data about the research enterprise, and the importance of making sure that it is collected and analysed systematically and consistently across time and institutions. Many more hypotheses than we could examine should be open to study in future.

I look forward to further debate on the issues raised in this report. The Academy would be grateful for comments and further evidence on them.

G J V Nossal
President
Australian Academy of Science

THE IMPACT OF AUSTRALIAN SCIENCE

POSSIBLE REASONS FOR THE PERCEIVED DECLINE IN THE AUSTRALIAN SHARE OF SCIENTIFIC CITATIONS IN THE INTERNATIONAL LITERATURE

1. INTRODUCTION

1.1 Background

Recent systematic and sophisticated analyses of the bibliometric[1] evidence related to research performance agree that while Australia's research effort is 'excellent and prolific' for a country of its size, accounting for just over 2 percent of the world's research (Bureau of Industry Economics (BIE) Report, 1996b), we may have reached a watershed in terms of visibility and performance level within some fields (BIE Report,1996b; Bourke and Butler, 1993). This latter thesis, based on strong evidence of a declining share of world citations in a large number of fields of Australian research since the mid- to late- 1980s, has led to a call-to-arms within sections of the scientific community to examine possible reasons for the general decline in Australia's research impact.

The purpose of this discussion paper, therefore, is to do just that - present possible hypotheses for the decline in citation share, and to examine the evidence available for each hypothesis. It is not the interest of this paper to reassess the careful and important data produced by *Science Watch* (1993), Bourke and Butler (1993), or the BIE (1996a and b). Rather, this paper aims to provide at least some preliminary information regarding particular contexts surrounding the Australian research enterprise, together with accompanying policy implications, and to do this in a setting where pivotal government decisions are about to be made regarding the future funding of the research system.

1.2 The range of possible reasons for declining citation share

Both the Bourke and Butler study and the BIE Report (1996b) consider a range of possible factors for the declining citation data, including a diminution of research resources for Australian scientists; structural changes in the fields of science, with a reorientation to fields with lower citation impacts; poor access to international networks by Australian academics; the ageing of the scientific population; a shift from basic to applied research; uniform displacement in the Institute for Scientific Information (ISI) by other countries; foreign library policy with regard to the journals used by Australian researchers for publication; data errors; and an exodus of quality researchers.

[1] The statistical analysis of published research papers

In turn, the above studies also reject many of these hypotheses as being unlikely to explain the results, or as having data relating to them that are insufficient to develop firm conclusions, or impossible to interpret. For example, the BIE Report notes that Australia's case of falling citation share is not exceptional, with other countries like Denmark, Norway and Sweden showing similar patterns of reduction. What is exceptional in Australia, however, is the very large number of fields in which the decline appears to be occurring. In addition, both the BIE Report and Bourke and Butler provide evidence that Australia is probably not being displaced by the newly industrialised countries, some of whom are also experiencing a decline.

There is also little evidence that changes in the field structure of Australian science from high impact to low impact areas has had anything more than a slight effect on the citation data (BIE, 1996b). The 'ageing scientific population' is also rejected as implausible by the BIE, although this continues to remain a popular hypothesis in many scientific circles.

Neither is it the case that Australian scientific publication patterns have a local/regional rather than an international focus, thus affecting the visibility of Australian science. A recent study by Bourke, Butler and Biglia (1996) reports a 'strikingly international orientation in the publication patterns of Australian basic research, especially in science' (p.56), with 75 percent of all Australian science journal articles appearing in the ISI data base.

A recent Dutch policy statement (NWO, 1996) has highlighted *systemic* problems in the Dutch university sector thought to be having a negative impact on research. Many of the problems listed in the document bear a strong resemblance to the situation in Australia. For example:

- the decline in student numbers in certain disciplines, and the effects this may have on the amount of research in those disciplines;
- reduced job opportunities for post docs at a time when there is actually an urgent need for new blood;
- the danger that it will not be possible to retain the best of the younger generation;
- administrative structures and terms of employment that make it difficult to take decisive action;
- forms of competition between universities which are less than healthy;
- government financial cuts; and
- fading political support. (p.11)

The current study has considered these and other hypotheses, largely generated by Bourke and Butler (1994) and the BIE Report, in terms of their credibility and data availability. The hypotheses focussed on for this report, together with a brief discussion of the data pitfalls involved in interpretation and in reaching conclusions, are described in the following sections.

1.3 The hypotheses examined

A recent paper by Linke (1995) has reviewed the literature surrounding those factors thought to have the potential to systematically affect research performance. The paper groups the factors under two broad headings - personal factors, such as the characteristics and background of individual researchers, and environmental factors defining the circumstances in which researchers operate. While performance *per se* is not the major issue here, the hypotheses below contain elements related to the personal characteristics of researchers, such as age and background issues, specifically, international experience; and environmental factors such as the funding of disciplines, funding per researcher, shifts from basic to applied research, and library practices. In addition, further hypotheses related to bibliometric explanations for the citation data are also examined.

Data have been gathered (or accessed) to examine the following hypotheses:

1. The visibility of Australian science has declined because of a reduction by Australian scientists in the tapping of international networks.

2. There has been a 'greying' of Australian science.

3. There has been a shift from 'basic' to 'applied' research activity.

4. There has been an inadequate funding of research so that researchers do not have adequate resources to undertake high quality science.

5. Foreign libraries have policies and practices related to the management of international journals that may impact on the visibility of Australian science.

6. Various bibliometric[2] hypotheses:
    - There has been a decline in the proportion of Australia's publications that are very highly cited ('big bangs'), leading to a decline in citation shares;
    - Australians are finding it harder to publish in the 'top' journals and this is a major contributing factor to the decline in Australia's citation shares; and,
    - Australians may be publishing fewer review articles, leading to a reduction in citation shares.

As mentioned previously, while many hypotheses have been put forward to explain the Bourke and Butler and the BIE data, the credibility of each hypothesis, together with the availability of reliable data, played a major role in the selection of reasons for consideration in this preliminary report. Even so, data problems abound, particularly in the collection of time series data dating back to the early 1980s, part of the time period of interest in this study. In addition, a recent NBEET/ARC Report (in press) notes that while national data sets such as those collected by the Australian Bureau of Statistics (ABS) and the Department of Employment, Education, Training and Youth Affairs (DEETYA) have improved in recent years,

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[2] Further bibliometric analyses are included within discussion of other hypotheses. All the bibliometric analyses are reported in detail in Appendix 2.

> *...there are still some difficulties in making direct comparisons between the different collections. For example, academic organisational units, to which staff are identified, do not correspond with fields of research against which research income and publication output are identified. In addition, fields of study, against which post-graduate students are identified, reflect yet another order of reporting.* (*p.x)*

This report goes on to say with regard to national data sets that,

> *...although they do suggest areas where changes in patterns of research may be occurring, they have not been in place, with consistency for sufficient time to reliably document such change. Nor are the national data sets adequate for assessing the characteristics of Australian researchers across different fields or institutions. (p.5)*

To add to the difficulties, the problems associated with the use of OECD Higher Education Statistics have also recently been highlighted (OECD Workshop, Restricted Report, 1995), particularly in relation to the use of OECD data to make international comparisons. The findings of the OECD Report suggest that the error margin in much of the Higher Education R&D statistics is quite high, leading to queries being raised regarding the robustness of findings based on OECD statistics, including the recent BIE Reports' findings (ARC, 1996).

Because of the serious problems involved in producing meaningful international comparisons noted by both the BIE (1996a) and the ARC (1996), this discussion paper refrains from making such comparisons, even though the ideal situation would suggest that international comparisons provide an appropriate context for discussions of this type.

With these provisos in mind, the following sections describe data that may in some way point to possible reasons for Australia's declining citation shares, or alternatively, help discard popularly held assumptions.

As most of the basic research conducted in Australia occurs in the higher education sector, it is here that we focus our investigation. However, because of the time period under investigation in the Bourke and Butler study, which prompted this investigation, and issues related to time lags in citations and so on, the data collection has been restricted where possible to that related to the pre-1987 universities. Similarly, not all fields of research have been included. The fields and sub-fields of research were chosen to be representative of the range of performances noted in the Bourke and Butler study. That is, fields are represented whose citation trends were found to be rising or holding steady, or were declining over the time period. For the field of Medical and Health Sciences, the sub-fields chosen were all found to be experiencing a declining trend in the Bourke and Butler study. The Medical Sciences feature very highly in the overall size of Australian research output, and any change in this area has a noticeable impact on the whole. The universities, and the fields of research are listed in Appendix 1.

2. HYPOTHESIS 1: *The visibility of Australian science has declined because of a reduction by Australian scientists in the tapping of international networks*

International scientific collaboration and the flows of academic talent among nations are seen as good *per se* and as integral factors in stimulating and maintaining a healthy national science system (see, for example, NBEET, 1995; Colombo, 1995; Luukkonen, Persson, & Sivertsen, 1992; NBEET, 1994; Saha & Klovdahl, 1979). It has also been argued that international collaboration has a particular role to play in enhancing the visibility of aspiring young scientists (Beaver & Rosen, 1979). In many nations, international scientific collaboration has become a political imperative (Bourke & Butler, 1995; Luukkonen, Persson & Sivertsen, 1992).

As noted by Colombo (1995):

> *The communal nature of scientific exploration is a feature of the post war world, when the individual scientist gave way to the team. The team is now giving way to the network, and, electronically linked by ever more sophisticated technologies, these networks make it possible to draw upon expertise across continents. (p.27)*

A recent NBEET report (1995) has also made the point that the understanding of a nation's international links may have less to do with formal policy-driven international collaborations than with informal networks developed through the free market of scholarship. Such a view places the focus on *individuals* in the development of international links. The NWO (1996) has recently highlighted the increasing importance of a focus on individuals within the instruments used to raise the profile of Dutch research.

> *Academic research always revolves around individuals... . Top-class researchers need to be offered ample opportunities at* ***all*** *stages of their careers. (p.28)*

While Australian 'instruments' for fostering the profile of research have a strong focus on structural support (university infrastructure, large equipment concentration, research schools and specialisms (as in the Institute of Advanced Studies, and CSIRO), and centres of research excellence of various types including ARC Special Research Centres, and the Co-operative Research Centres), instruments with a focus on individuals such as in the Dutch system while they do exist here (for example, the NH&MRC's C.J. Martin Fellowship, and the ARC's Australian Research Fellowships Scheme) seem to be less obvious. Certainly, specific funding opportunities for Australian researchers to engage in international postdoctoral or other study programs are scarce.

However, informal networking by individuals can be fostered in a variety of ways, and the Bureau of Industry Economics has recently suggested the following avenues:

- *Australian postgraduate students and post-doctoral researchers abroad;*
- *sabbatical leave;*
- *incoming high quality foreign scientists and postgraduate students;*
- *shared use of facilities;*
- *participation in conferences and seminars;*
- *informal discussion groups between scientists; and*
- *mobility between universities and other institutions. (BIE,1996b, p.46)*

Several of these are examined to varying degrees (dependent on data availability) below.

2.1 The origin of Australian academics' qualifications

One method of obtaining information on the structure and quantity of academic networks is to examine the actual amount of talent flow between countries and specific universities. This has been done on a number of occasions by examining the recruitment patterns of Australian universities (see, for example, Saha & Klovdahl, 1979). Saha and Klovdahl found that for the period 1961-1974, there was little variation in the proportion of appointments in Australian universities from overseas, and this proportion hovered between 40-50 percent. Their 'overseas' component, however, also included Australians returning from overseas. The actual proportion of overseas-born academics in Australian universities in 1970 was reported as being around 20 percent. The proportion of 'overseas' appointments who were actually Australians returning to academic appointments from overseas was around 45 percent for the same year.

A recent study (Anderson, 1993) has examined the qualifications profile of academic staff in Australian higher education institutions, both the university and the previous college sector, for the years 1978, 1987, and 1992, and for different fields of study.

The study found, among other things, that more than one-third of university academics gained their highest qualifications from overseas, and that one-quarter of university academics had their first and highest qualification from overseas ('foreign recruits'). These patterns changed little over the period under scrutiny. Moreover, fields with the most foreign recruits were humanities, social studies and engineering.

The Anderson study provides useful aggregate information regarding the academic profile, and also became a useful reference point for data collection for the current study. However, for the purposes of this investigation, data collection needed to start in 1970, and more years needed to be sampled. The focus of this data collection was also on PhD location rather than other types of higher degrees. In addition, while the Anderson survey examined fields of *study*, fields of research were of interest here.

Analysis

The sample of universities used in the current analysis were those 19 universities that existed prior to 1987. Many of these universities now have components added from the former college sector. The time period scrutinised was from 1970 to 1994, and in particular the years 1970, 1973, 1976, 1979, 1982, 1985, 1988, 1991, and 1994.

Field of research was classified according to the ABS Australian Standard Research Classification and the fields examined are at Appendix 1.

Information for the study was obtained from university calendars for the entire population of academic staff members recorded in the calendars as holding PhDs and as being members of departments/schools able to be readily classified into one of the fields of research. (See Appendix 1 for the list of departments.)

The scheme used for analysis is that used by Anderson (1993) and the categories considered are depicted in Table 1. Anderson makes an important point regarding the interpretation of the statistical trends which is worth noting here:

> *...statistical trends over the period of the study are 'muted' because the data are for all staff, not new staff. Thus differences that appear in the tables...are due to incremental changes on a body of data comprised largely of the same individuals. (p.3)*

Table 1. Location of first qualification by location of highest qualification[1]

	Location of highest qualification	
Location of first qualification	**Australia**	**Overseas**
Australia	A (true blue)	B (adventurers)
Overseas	C (migrants)	D (foreign recruits)

[1] Anderson, 1993

Results

Tables 2(a) and 2(b) give an overview of the academic profile for the sample population. The four rows in each table show for each of the years examined the total number [2(a)] and percentage of the total [2(b)] who fell into one of the four groups indicated in Table 1: both qualifications in Australia (Aust-Aust), the first in Australia and PhD overseas (Aust-O'seas), the first overseas and PhD in Australia (O'seas-Aust), and both qualifications overseas (O'seas-O'seas). These data are also graphically depicted in Figures 1(a) and 1(b).

Table 2(a) Location of first and highest qualification for selected years and sample disciplines[1] for pre-1987 universities - number

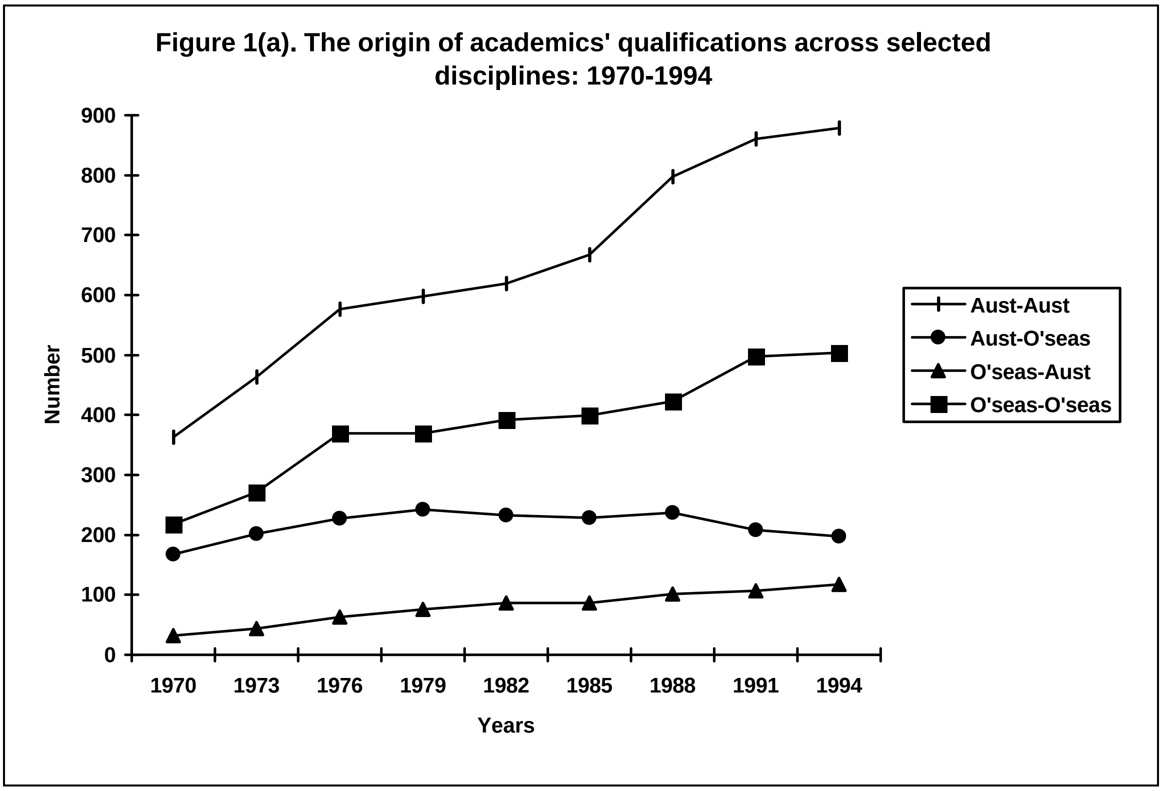
Location of qualification: First-Highest	1970	1973	1976	1979	1982	1985	1988	1991	1994
Aust-Aust	363	463	576	598	619	667	797	861	879
Aust-O'seas	168	202	227	242	233	229	237	208	198
O'seas-Aust	32	44	63	76	87	87	101	107	117
O'seas-O'seas	218	271	369	369	392	399	423	497	504
Total	781	980	1235	1285	1331	1382	1558	1673	1698

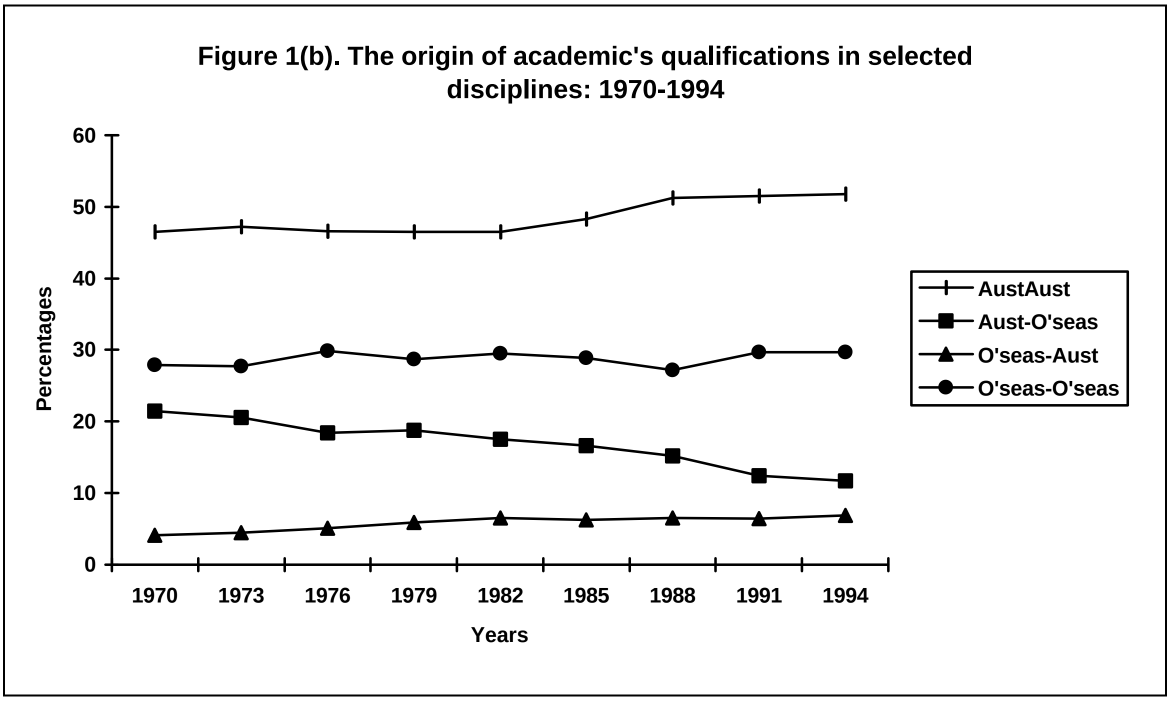
[1] See Appendix 1

Table 2(b) Location of first and highest qualification for selected years and sample disciplines[1] for pre-1987 universities - percentages

Location of qualification: First-Highest	1970	1973	1976	1979	1982	1985	1988	1991	1994
Aust-Aust	46.5	47.2	46.6	46.5	46.5	48.3	51.2	51.5	51.8
Aust-O'seas	21.5	20.6	18.4	18.8	17.5	16.6	15.2	12.4	11.7
O'seas-Aust	4.1	4.5	5.1	5.9	6.5	6.3	6.5	6.4	6.9
O'seas-O'seas	27.9	27.7	29.9	28.7	29.5	28.9	27.2	29.7	29.7
Total	100	100	100	100	100	100	100	100	100

[1]See Appendix 1





For the period under examination, the proportion of academics in Australian universities who received both their undergraduate and PhD education at an Australian university ranged from 46.5 percent in 1970 to 51.8 percent in 1994. This represents an increase of 11.4 percent, and has been largely at the expense of academics who travel overseas from Australia for their PhD training. This group's share has decreased by 45.6 percent between 1970 (21.5 percent) and 1994 (11.7 percent). This result will be examined in more detail later in this report. Australia as a location for internationally mobile scientists (both qualifications overseas) has remained as attractive in 1994 as it was in 1970 with a slight increase in the proportion of this group of 6.5 percent. This is in line with immigration data in a recent Bureau of Industry Economics report (BIE, 1996) which suggests that Australia is a net gainer of scientific personnel. The proportion of personnel with an overseas undergraduate and Australian PhD has increased substantially from a low base over the period (68 percent), although this group's share of academic places remains quite low (4.1 percent in 1970 to 6.9 percent in 1994).

Overall, the findings generally mirror those of Anderson (1993) (see Table 3), with the most noticeable difference being in the Australia-Overseas group with the proportion of personnel in this group in the Anderson study reducing by 31.5 percent over the time period (1978-1992) and as mentioned previously, by 45.6 percent in this study.

Table 3. Patterns of recruitment: Comparison of Anderson[1] (1993) study (whole university system) and current study (selected science and engineering departments)

	1978/79		1987/88		1992/94	
Location of : First qual. - Highest qual.	**Anderson**	**Current**	**And.**	**Current**	**And.**	**Current**
	%		%		%	
Australia-Australia	50	46.5	49.1	51.2	54.9	51.8
Australia - Overseas	18	18.8	15.7	15.2	12.5	11.7
Overseas - Australia	7	5.9	7.5	6.5	7.4	6.9
Overseas - Overseas	26	28.7	27.7	27.2	25.3	29.7

[1]Anderson study also included Masters (Research) qualifications

The variations among research fields, as well as the change over time between 1970 and 1994 can be seen in Tables 4(a) and 4(b). In 1994 the proportion of completely Australian educated academics (Aus-Aus) ranges from 44 percent in Engineering to 69 percent in the Medical Sciences. This latter finding reflects that reported by Anderson (1993).

Table 4(a) Location of first qualification by location of Phd for selected disciplines: 1970

Field	No.	A Aus-Aus	B Aus-O'seas	C O'seas-Aus	D O'seas-O'seas
		%	%	%	%
Physics	207	47.4	15.9	3.9	32.9
Chemistry0	272	47.1	23.5	3.3	26.1
Earth Sciences	92	42.4	21.7	3.3	32.6
Electrical Engineering	47	34.0	31.9	6.4	27.7
Agricultural Sciences	62	48.4	29.0	4.8	17.7
Medical Sciences	83	53.0	18.1	4.8	24.1
Computer Science	18	44.4	16.7	11.1	27.8

Table 4(b) Location of first qualification by location of PhD for selected disciplines: 1994

Field	No.	A Aus-Aus	B Aus-O'seas	C O'seas-Aus	D O'seas-O'seas
		%	%	%	%
Physics	310	49.0	11.6	7.1	32.3
Chemistry	315	52.4	15.9	4.4	27.3
Earth Sciences	260	45.0	11.5	10.8	32.7
Electrical Engineering	170	44.1	10.0	6.5	39.4
Agricultural Sciences	179	59.8	12.9	7.8	19.6
Medical Sciences 1	223	69.0	7.2	4.9	18.8
Computer Science	241	45.2	10.8	7.1	36.9

1 (Immunology, Neurosciences, Physiology, and Pharmacology)

Conversely, the group receiving both undergraduate and PhD education overseas (O'seas-O'seas), ranges from 19 percent in the Medical Sciences to 39 percent in Electrical Engineering. This result for Electrical Engineering is contrary to the result found by Anderson for the Engineering field as a whole where in 1992 only 27 percent of academics are reported as having both undergraduate and postgraduate qualifications from overseas.

All fields have relatively low proportions of Australians undertaking PhD training overseas (Aus-O'seas), and 'migrants' (O'seas-Aus) coming to Australia for PhD training.

As discussed previously (Table 2(b)), the proportion of academics from the 'foreign recruits' (O'seas-O'seas) category remained very stable over the time period under scrutiny. Saha and Klovdahl (1979) in their study of international networks and flows of academic talent between 1961 and 1974 found a similar stable pattern for this group and suggested the following:

> *This pattern might signify that there is a maximum number of overseas scholars which universities can absorb or tolerate, or that there exists a finite pool of potential overseas recruits who would merit appointment over local talent (assuming, of course, a meritocratic appointment system). In either case, there appears to be a saturation point in overseas recruitment beyond which there is a greater reliance on local candidates to fill staff vacancies. (p.62)*

If, as it appears, the proportion of international talent from recruiting (talent *to* Australia) has remained static, then in the interests of maintaining the flow of international values and knowledge and the corresponding networking behaviour, other avenues of international talent flows (talent *from* Australia, and back) become even more significant.

Where Anderson's study placed quite a deal of emphasis on the proportion of 'foreign recruits' in Australian universities (O'seas-O'seas), of major interest to this study is the change in the pattern of behaviour of 'Australian' academics (both Aus-Aus and Aus-O'seas). International collaborations and continuing (though limited) international networks based on Australians travelling overseas to gain PhDs have been reported as important as launching both a publications career, and a foray into the international literature and other networking possibilities (NBEET, 1995).

Table 5 contains information on that proportion of the sample regarded as of Australian origin and the location of their PhDs. Place of first degree is used as a measure of nationality, as it has been found to correlate highly with country of birth (around 90 percent accuracy reported in Saha & Klovdahl, 1979). The data are also depicted in Figure 2.

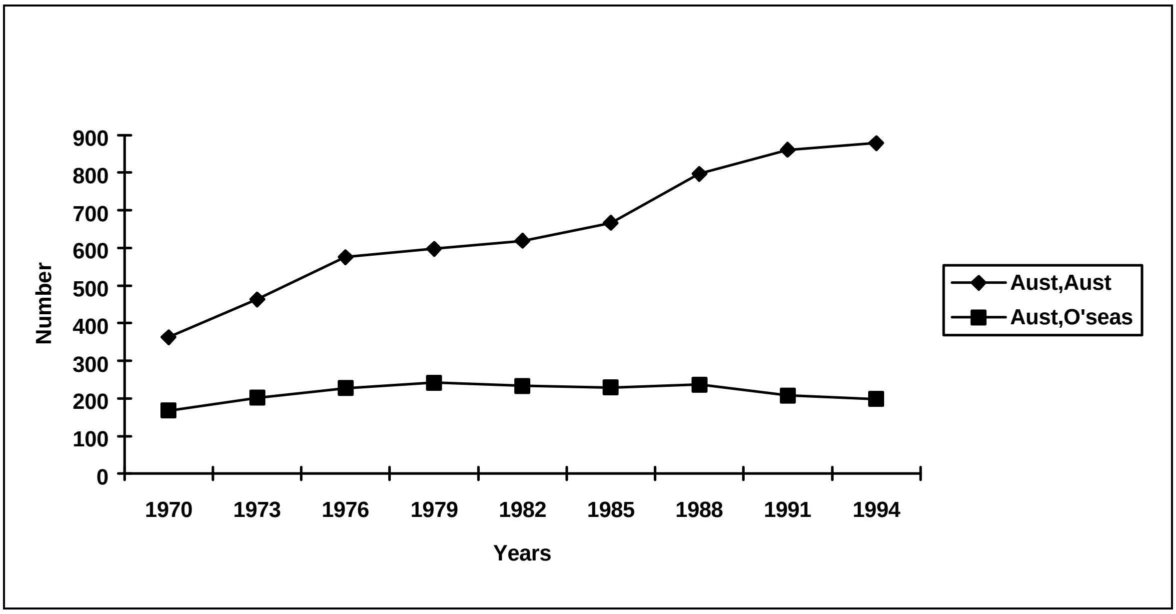
There has been a 142 percent increase in the number of Australian academics with both qualifications from Australia (from 363 in 1970, 879 in 1994). On the other hand the actual number of Australians travelling overseas to obtain PhDs has only increased by 17.8 percent in the same time period (from 168 in 1970, to 198 in 1994).

Table 5 Location of PhD qualification of those academics in australian university departments whose first qualification is Australian[a]

	Year								
Location of qualification	**1970**	**1973**	**1976**	**1979**	**1982**	**1985**	**1988**	**1991**	**1994**
Australia	363 (68.4)[b]	463 (69.6)	576 (71.7)	598 (71.2)	619 (72.7)	667 (74.4)	797 (77.1)	861 (81.0)	879 (81.6)
Overseas	168 (31.6)	202 (30.4)	227 (28.3)	242 (28.8)	233 (27.3)	229 (25.6)	237 (22.9)	208 (19.0)	198 (18.4)
Total	531	665	803	840	852	896	1034	1069	1077

[a] Sample - see Appendix 1
[b] Percentages in brackets

Figure 2 Location of PhD qualification of those academics in selected university departments whose first qualification is Australian



Tables 5(a)-(e) contain information on Australian academics within the specific disciplines. The pattern of the ‘Australianisation’ of academia is repeated for all disciplines, with only small increases reported in the number of Australians receiving overseas PhDs in most areas. However, while there has been a small increase in the number of overseas-educated Australians, all fields show a change in the *balance* in the academic staff profile, with an increasing proportion of academics with Australian-Australian qualifications.

Table 5(a) Location of PhD qualification of those academics in Australian *Physics* whose first qualification is Australian

Location of highest qualification	1970	1973	1976	1979	1982	1985	1988	1991	1994
Australia	98 (74.8)[1]	116 (72.0)	137 (74.5)	146 (74.5)	144 (74.6)	136 (74.7)	152 (77.9)	172 (78.5)	152 (80.1)
Overseas	33 (25.2)	43 (28.0)	47 (25.5)	50 (25.5)	49 (25.4)	46 (25.3)	43 (22.1)	47 (21.5)	36 (19.9)
Total	131	159	184	196	193	182	195	219	188

Table 5(b) Location of PhD qualification of those academics in Australian *Computer Science* whose first qualification is Australian

Location of highest qualification	1970	1973	1976	1979	1982	1985	1988	1991	1994
Australia	8 (72.7)[1]	10 (71.4)	17 (80.0)	24 (82.8)	40 (80.0)	49 (79.0)	71 (81.6)	78 (86.7)	109 (80.7)
Overseas	3 (27.3)	4 (28.6)	4 (20.0)	5 (17.2)	10 (20.0)	13 (21.0)	16 (18.4)	13 (23.3)	26 (19.3)
Total	11	14	21	29	50	62	87	91	135

Table 5(c) Location of PhD qualification of those academics in Australian *Chemistry* whose first qualification is Australian

Location of highest qualification	1970	1973	1976	1979	1982	1985	1988	1991	1994
Australia	128 (66.7)[1]	163 (70.3)	185 (70.9)	181 (70.4)	179 (71.9)	173 (72.3)	201 (76.4)	203 (79.6)	165 (76.7)
Overseas	64 (33.3)	69 (29.7)	76 (29.1)	76 (29.6)	70 (28.1)	64 (27.7)	62 (23.6)	52 (20.4)	50 (23.3)
Total	192	232	261	257	249	237	263	255	215

[1] Percentages in brackets

Table 5(d) Location of PhD qualification of those academics in Australian *Agricultural Sciences* whose first qualification is Australian

Location of highest qualification	1970	1973	1976	1979	1982	1985	1988	1991	1994
Australia	30 (62.5)[1]	41 (60.3)	53 (62.4)	48 (65.7)	43 (56.6)	66 (71.7)	78 (70.3)	79 (73.8)	107 (82.3)
Overseas	18 (37.5)	27 (39.7)	32 (37.6)	25 (34.3)	33 (43.4)	26 (28.3)	33 (29.7)	28 (26.2)	23 (17.7)
Total	48	68	85	73	76	92	111	107	130

Table 5(e) Location of PhD qualification of those academics in Australian *Medical Sciences* (Immunology, Pharmacology, Physiology and Neurosciences) whose first qualification is Australian

Location of highest qualification	1970	1973	1976	1979	1982	1985	1988	1991	1994
Australia	44 (74.6)[1]	51 (72.9)	73 (79.3)	77 (76.2)	95 (82.6)	112 (82.4)	143 (86.1)	156 (90.7)	154 (90.6)
Overseas	15 (25.4)	19 (27.1)	19 (20.7)	24 (23.8)	20 (17.4)	24 (17.6)	23 (13.9)	16 (9.3)	16 (9.4)
Total	59	70	92	101	115	136	166	172	170

Table 5(f) Location of PhD qualification of those academics in Australian *Earth Sciences* whose first qualification is Australian

Location of highest qualification	1970	1973	1976	1979	1982	1985	1988	1991	1994
Australia	39 (66.1)[1]	51 (66.2)	66 (67.3)	68 (63.0)	66 (64.7)	77 (64.7)	92 (68.7)	103 (76.3)	117 (79.6)
Overseas	20 (33.9)	26 (33.8)	32 (32.7)	40 (37.0)	36 (35.3)	42 (35.3)	42 (31.3)	32 (23.7)	30 (20.4)
Total	59	77	98	108	102	119	134	135	147

[1] Percentages in brackets

Table 5(g) Location of PhD qualification of those academics in Australian *Electrical Engineering* whose first qualification is Australian

Location of highest qualification	1970	1973	1976	1979	1982	1985	1988	1991	1994
Australia	16 (51.6)[1]	31 (68.9)	45 (72.6)	54 (71.1)	52 (77.6)	54 (79.4)	60 (76.9)	70 (77.8)	75 (81.5)
Overseas	15 (48.4)	14 (31.1)	17 (27.4)	22 (28.9)	15 (22.4)	14 (20.6)	18 (23.1)	20 (22.2)	17 (18.5)
Total	31	45	62	76	67	68	78	90	92

[1] Percentages in brackets

A University of Sydney academic has recently described six ‘golden threads’ that purport to run through Australia’s first class universities (Jackson, 1995, cited in IDP Report, 1995), one of which is that

> *Australia’s universities recruit staff from Australia and from overseas and do not inbreed. Academics at Australian universities have experience at home and abroad, an international dimension maintained through study leave.*

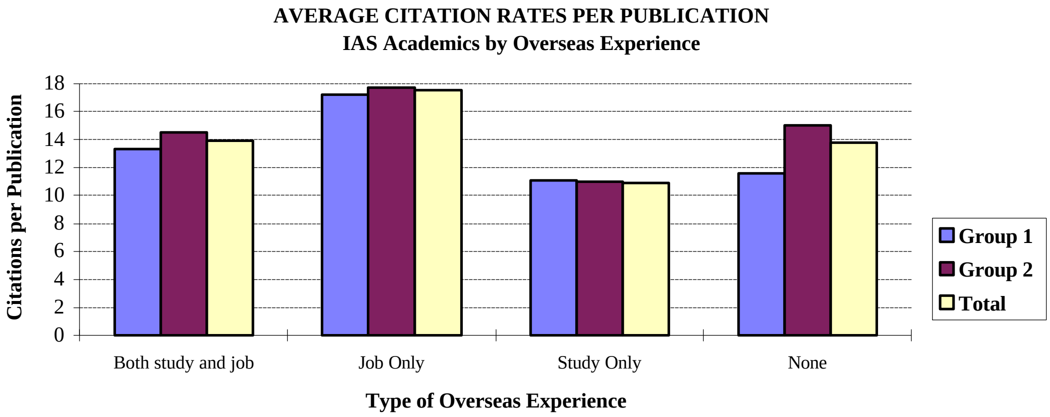
However, what we appear to have here is a picture of academic insularity within Australia’s university system, at least as far as one measure of Australian academic training experiences goes. It should be noted here that fields shown to be strong in the Bourke and Butler study show the same pattern as those shown to be declining in international visibility. It should also be acknowledged that disciplines may differ in terms of the importance they attach to international experience at this level.

An interesting question now is how and if this lack of overseas experience at the postgraduate level, and combined with other measures of international experience, impacts on the visibility of Australian scientists in the international literature. Unfortunately, systematic data on other measures of the international research experience of Australian academics, such as sabbatical leave and overseas postdoctoral training, was not possible to retrieve for the whole system for this study. However, data of this kind were available for staff at the ANU’s Institute of Advanced Studies (IAS), and the next section reports results of an examination of the research performance (as measured by publications and citations) of IAS staff taking into account their international experience. The full report of this data is contained in Appendix 2. In addition, the Graduate Careers Council of Australia (GCCA) was able to provide some very limited data on PhD graduates who were overseas at the time of the GCCA census, and engaged there in full-time work or study, and this data is also presented in the following sections.

2.2 The relationship between international research experience and research ‘visibility’.

In the previous section the data are clear in showing that the proportion of Australian academics who travel overseas to obtain a higher degree has significantly declined in recent years. Whether or not lack of international experience at this level impacts on citation rates is not known. No system-wide data is available to address this question. Neither does a change in the networks mean a decline in the quality of research. Bourke and Butler (see Appendix 2) have derived a data base for Institute of Advanced Studies staff that allowed an analysis to be conducted on 343 academics categorised according to the location of their higher degree, whether or not they had worked (had a postdoctoral position) overseas prior to appointment at the IAS, and their level of appointment at the IAS in 1980-82 (Group 1 - Research/Postdoctoral Fellow; Group 2 - Higher than Research Fellow). The results are summarised below in Figure 3. In this figure, ‘study’ refers to higher degree training, and ‘job’ refers to postdoctoral position.

Figure 3



The main finding appears to be that overseas postdoctoral experience may be important in the ability to attract higher rates of citation. Those who had both studied and worked overseas did considerably better than those who only studied overseas, but, surprisingly, only as well as those who had no overseas experience at all. For academics whose higher degree qualifications were Australian, those that had overseas postdoctoral experience attracted citations at a greater rate than those who had not. It is a surprising finding that overseas study at the postgraduate level did not appear to be beneficial in respect of attracting citations.

Bourke and Butler (Appendix 2) tentatively conclude, considering the non-representativeness of the sample, that an increased visibility at the postdoctoral level in the international community can be the key to higher levels of citations, and that the ability of Australians to obtain overseas posts early in their careers is important. The researchers also stress the importance of testing this hypothesis on a larger and more representative sample.

2.3 Australian PhD graduates overseas

Reliable time-series data on the number of Australians undertaking postdoctoral study overseas were not available. The Graduate Careers Council of Australia does, however, survey all graduating students on 30 April each year, including graduating PhD students. Table 6 provides data on a sample of such students. While the data tell us nothing in terms of trends since the 1980s in Australian PhD graduates travelling overseas for study (postdoctoral work), the very low numbers under this category, compared to the total number of course completions, are revealing in themselves.

Table 6 The number and proportion of Australian PhD graduates by their location overseas (work/study/other) at the census datea and for selected years

Destination					**Years**					
	1982		**1985**		**1988**		**1991**		**1994**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
O/seas ft[1] work	64	(90)	55	(86)	58	(88)	49	(100)	57	(73)
O/seas ft study	2	(3)	2	(3)	0	(0)	0	(0)	2	(3)
O/seas other	5	(7)	7	(11)	8	(12)	0	(0)	19	(24)
Total O/seas	71	(100)	64	(100)	66	(100)	49	(100)	78	(100)
***Course completions*[2]**	**-**		***1122***		***2089***		***2558***		***3931***	

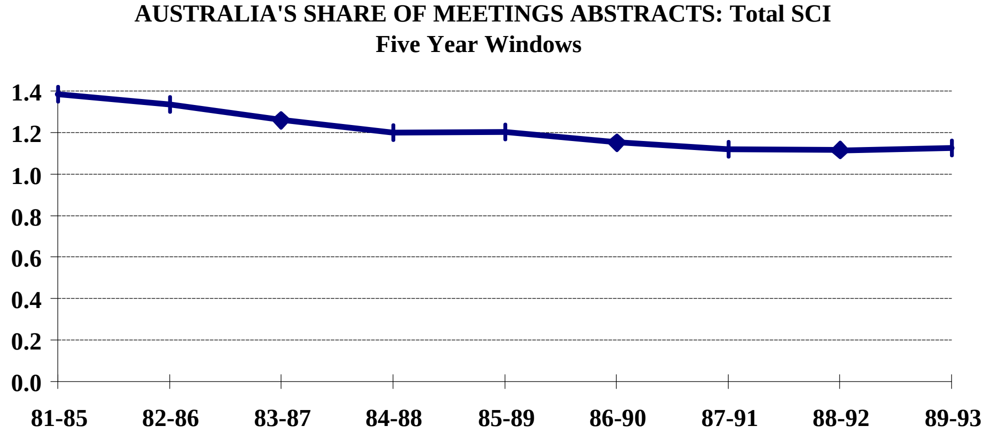
a 30 April each year; Source:Graduate Careers Council of Australia
[1] ft = full-time
[2]Source: Selected Higher Education Statistics - Commonwealth Teriary Education Commission and DEETYA.

The category ‘full-time work’, shows a decline between 1982 and 1985 of 14 percent. A problem in interpreting the data is that there is no indication of what type of work those in the ‘full-time work’ category are engaged, for example, are they engaged as postdoctoral fellows? The GCAA does try to ensure that respondents doing research and funded via scholarships are noted as being involved in ‘study’ as opposed to ‘employment’ (Bruce Guthrie, personal communication, July 1996). An additional problem arises with interpretation, as the response rate to the survey from which the data were extracted is unknown for PhD graduates as a separate group.

2.4 Attendance at international conferences

International conferences provide a valuable opportunity for Australian academics to establish and maintain contacts and networks with colleagues from overseas. Bourke and Butler (see Appendix 2 for full report) have analysed data related to publications classified as ‘meeting abstracts’, an indication of presentation at international conferences, and have examined Australia’s share of these compared to the rest of the world. Figure 4 contains the results, which indicate that Australia’s share of meeting abstracts is small and in decline.

Figure 4



2.5 International co-authorship

Internationally co-authored papers have been found to receive a larger share of citations in the international literature (NBEET, 1995). Recent data from a study of over 30 countries by Luukkonen, *et al.* (1992), indicates that the percentage of international collaborations as measured by joint publications has doubled over all fields in the ten-year period 1973-1983. The NBEET (1995) study of Australian publications found an increase in the percent change of the share of international collaborations by Australian researchers during the period 1981-1992 of 59 percent, with variations in increase between fields of 43 percent for Mathematical Sciences and 101 percent for Agricultural Sciences. There is no available Australian data for the period 1973-1983. However, no Australian field showed a doubling in the proportion of internationally co-authored papers over the time period 1981-1992 (unlike the 30 country study for the period 1973-83).

A recent *Science Watch* (1996) analysis notes that Australia, along with the People's Republic of China, vied for the lowest international collaboration of several nations (apart from the G7 nations) examined over the period 1981-1994, with approximately 22 percent of publications with international co-authorship by 1994.

In addition, the trend in the pattern of international collaboration by region has changed in the last decade, with a significant fall in the proportion of Australian collaborations with the United States of America and with the United Kingdom (NBEET, 1995). This is an important finding, and may have some influence on 'visibility' in the literature, as these countries dominate the international scholarly literature, and are the traditional collaborators for Australian scientists (NBEET, 1995). The NBEET report also contains relevant discussion of the policy implications for Australia for the future of the redirection of the major foci of the world's research towards the developing countries.

2.6 Discussion: Hypothesis 1

There appears to be mixed evidence for the hypothesis that there has been a decline in the tapping of international networks by Australian academics. On the one hand, studies reported in the literature suggest that Australian scientists do not publish in idiosyncratic local/regional journals thereby not receiving adequate representation in the journals of the ISI (Bourke, *et al., 1996)*; rather, Australian scientists report 75 percent of their research in international journals. Neither is our international collaboration in decline overall (NBEET, 1995), with evidence of a considerable increase in the share of internationally co-authored journal articles by Australians over the past decade. (NBEET, 1995).

From a more pessimistic angle, however, international co-authored publications with our traditional partners, the key players on the international research stage (USA, UK), has fallen off significantly (NBEET, 1995). In addition, Australia's presence at international conferences (measured by 'market' share of conference abstracts) is also shown to be low and in decline.

There is also strong evidence of a systematic 'Australianisation' of academia when viewed from a research training perspective. While the networks developed at the PhD training level are thought to only last around a decade, they are also viewed as critical for launching young academics into the international literature (NBEET, 1995).

As pointed out recently by Blume (1995), the internationalisation of research training has taken on new significance, with governments in most OECD countries treating the international aspect of the activity as an important and complex policy issue. Where most networks, structures and resources for international mobility used to be at the postdoctoral level, and driven largely by the scientific community, Blume points out that the impetus now is also coming from the centre, with governments becoming more directive with regard to international exchange and mobility, and research training programmes becoming the focus of serious interest and debate in this regard.

Australia has at least one program with a focus on developing international links through postgraduate research training. The Overseas Postgraduate Research Scholarships (OPRS) Scheme, administered by DEETYA, has as its purpose the attraction of top quality overseas students to areas of research strength in Australian universities. A recent review of this program (Grigg, in press) has provided evidence of the opportunities for the development of international partnerships that are generated through programs of this type. There are currently only limited programs and structures in place, however, that provide funding for top quality Australian students to receive their postgraduate research training at overseas universities.

There is also some indicative evidence that international postdoctoral experience may contribute in some way to larger citation rates for individuals. While systematic data on the volume of Australians travelling overseas for postdoctoral experience was not available, the GCAA data reported here, while scanty, indicates that there may not be large numbers of Australian PhD graduates doing so. This is in spite of considerable evidence of the importance of such experience for future successful international collaboration (NBEET, 1995), and the attraction of citations (IAS data, Appendix 2).

There is currently only one visible funding scheme available for the purpose of providing international postdoctoral opportunities to Australian scientists, the C.J. Martin Fellowships Scheme[3], and this scheme has been reported by medical researchers as being critical to their academic careers (NBEET, 1995).

The issue of international postdoctoral traning experience is of significant policy importance to warrant a detailed examination of the current situation within Australia at the institutional level. Apart from a fine-detail analysis of the origins of Australian scientists' postdoctoral training, the resources available for maintaining any networks established through this route should also be examined.

In addition, obstacles facing the recruitment of overseas scientists *to* Australian postdoctoral appointments, also a major linking mechanism, need highlighting. Australian labour market and immigration policies are not consistent with a view that research is an international activity, with heavy restrictions placed on university employers over appointments from overseas at this level. Other countries, such as Japan and the United States, have moved to overcome restrictive practices by setting up special categories of entry for postdoctoral fellows that do not conflict with their respective countries' immigration policies.

While there has perhaps been a change in the networks within Australian universities, it does not automatically follow that there has been a decline in the quality of Australian research. It cannot be left to chance, however, that Australia's research effort, both in terms of quantity and quality, will continue to be good.

The important point being made as far as international linking is concerned is that it is critical for Australia to be involved at an international level, not only with large scale projects such as the human genome project and the ocean drilling project, but also at the smaller-scale, individual level where information transfer is equally important (ASTEC, 1990). With regard to the former, ASTEC states that

> *Scientists, postgraduate students and technicians who undertake research at large (international) facilities not only acquire technical expertise by conducting experiments and keeping up-to-date with the relevant literature but they also talk to one another. Out of the conversations, new experiments are born. Technical specialisations, frequently reflecting know-how developed for local industrial reasons, are shared. Opportunities for future scientific and industrial collaboration are discovered. Membership of this informal*

[3] Administered by the National Health and Medical Research Council

> *information network is one of the important spin-offs from research at any major international facility. (p.6)*

It should be noted that Canada, a country whose publication and citation share were found to be rising in the Bourke and Butler study, is at the 'top end' in terms of its involvement in international projects. At the discipline level in Australia, Earth Sciences, also found to be faring well in terms of citation share, partakes in projects at the international level to a somewhat greater extent than other disciplines.

What may be required at the policy level is that apart from support to broad-based structures like centres of research excellence as a means of highlighting and internationalising Australian science, we need an increase in concentrated forms of assistance to *individuals* at all stages of their research careers, beginning at the postgraduate training level, focussing at the critical postdoctoral level, and continuing with Australia's top researchers having ample opportunities at all stages of their careers.

3. HYPOTHESIS 2: *There has been a 'greying' of Australian science*

The BIE Report (1996) discounts this hypothesis as an implausible one to explain the abrupt change in Australia's share of citations in the 1980s for several reasons. First, available evidence does not show that Australia's academic population is ageing more than other developed countries. Second, in countries where the age profiles are 'greying' (eg, Germany and Japan), the share of citations is increasing, while countries with a rapid growth in new and 'younger' scientists (eg, some Asian economies), the share of citations is falling (p.43).

A recent review of the literature on the subject of factors affecting performance (Linke, 1995) has also concluded that age alone is not a major determinant of research performance, and

> *...provides no basis for policy determination in relation to research productivity. While it is possible that increasing years may bring decline in certain aspects of intellectual capacity (in particular those normally associated with creativity in science) and that this might be associated with some qualitative change in research and publication output, there is no evidence of any uniform decline in total productivity... (p.19).*

Regardless of such evidence, the hypothesis is a popular one, and data are therefore presented here for particular fields of research and for the pre-1987 universities.

3.1 The age profile of Australian academics in selected fields of research

As mentioned in an earlier section, there are difficulties involved in obtaining time-series data of this kind, and the following are based on estimates derived from the DEET data base of selected higher education statistics.

Table 6 contains estimates of the total number of academic staff in each field (except Medicine) for selected years between 1974 and 1995 for the pre-1987 universities. All fields except Chemistry show an increase in the total number of academic staff, with the most notable increase in the field of Computer Science.

Table 6 The number of academic staff by field of research for the pre-1987 universities for selected years

Field	1974	1977	1980	1983	1986	1989	1992	1995
Elec Eng	212	225	220	230	245	282	338	371
Computing	67	84	121	178	233	294	444	475
Chemistry	574	552	521	472	480	403	534	494
Physics	439	401	369	354	363	370	491	491
Earth	249	236	228	233	199	181	240	294

Source: Estimates based on DEET data

A prediction regarding shifts in the age distribution of Australian academics has been made by Over (1985) that the median age of academics in the 1990s will be in the 50-55 year age group, in contrast to a median age of 40-45 years in 1985. The median age for the disciplines being considered for selected years is indicated in Table 7.

Table 7 Median age of academics in pre-1987 universities by field of research and for selected years

	Year		
Field	**1989**	**1992**	**1995**
Computer Science	42.0	41.9	41.6
Chemistry	43.4	42.6	41.7
Physics	43.4	44.7	43.1
Earth Sciences	43.5	43.8	42.6
Agricultural Science	43.8	43.2	44.0
Electrical Engineering	44.0	42.8	40.8

The predictions made by Over are clearly incorrect for these disciplines. The median age in all fields except Agricultural Science has decreased over the six year period. The greatest decrease has been in Electrical Engineering with a change of 3.2 years over the six year period.

Table 8 notes trends in the distribution of the number of academics within age groups for the years 1989, 1992, and 1995, while Figures 5 (a) to (f) show the proportion of staff in each age group for each field over the same time period.

Table 8 Age distributions of academic staff in selected disciplines in the pre-1987 universities for the years 1989, 1992, and 1995

	<25	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	>64	All
1995											
Computing	6	41	78	83	95	94	53	19	5	2	475
Chemistry	3	52	97	79	47	40	63	68	38	8	494
Physics	5	29	88	93	50	57	57	78	30	4	491
Earth	3	17	60	44	44	32	43	32	14	6	294
Agriculture*	2	15	37	52	54	61	39	26	12	2	298
Elec Eng	2	36	64	74	58	49	30	39	17	2	371
1992											
Computing	15	35	67	72	85	74	58	24	17	0	444
Chemistry	27	63	82	68	51	68	73	58	45	1	534
Physics	10	44	85	59	51	59	92	61	29	1	491
Earth	3	13	38	36	40	32	38	28	12	0	240
Agriculture*	3	16	27	32	30	32	29	19	8	1	194
Elec Eng	8	29	54	47	55	53	43	30	16	2	338
1989											
Computing	10	29	39	48	52	57	30	20	8	0	294
Chemistry	11	39	61	52	56	64	56	38	23	2	403
Physics	10	36	56	48	52	59	51	35	21	2	370
Earth	5	18	27	23	25	29	25	17	10	1	181
Agriculture*	1	15	33	33	29	33	30	18	15	1	208
Elec Eng	7	19	34	41	50	41	41	31	16	1	282

* Selected fields
Source: DEET

Figure 5(a) Staff age distribution - Computing

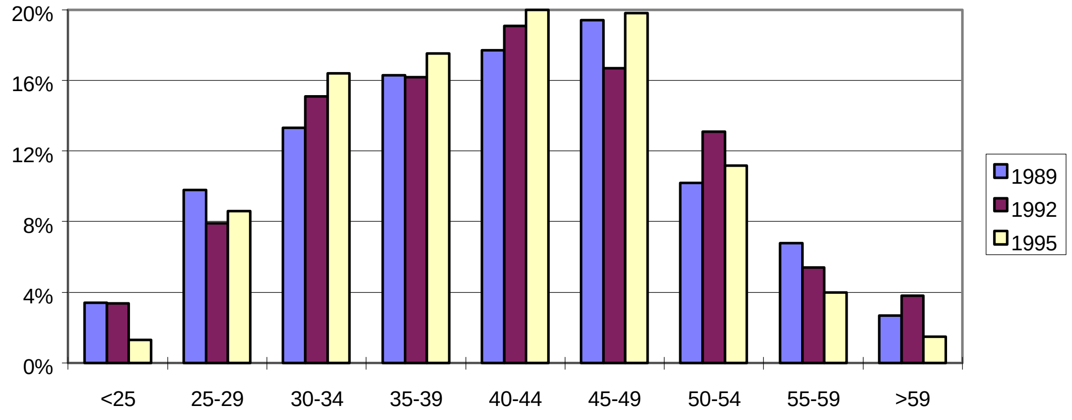


Figure 5(b) Staff age distribution - Chemistry

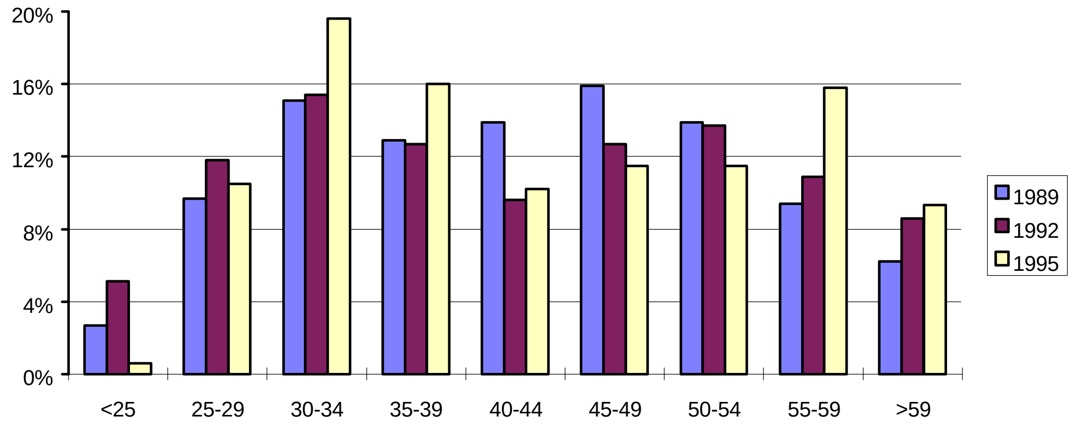


Figure 5(c) Staff age distribution - Physics

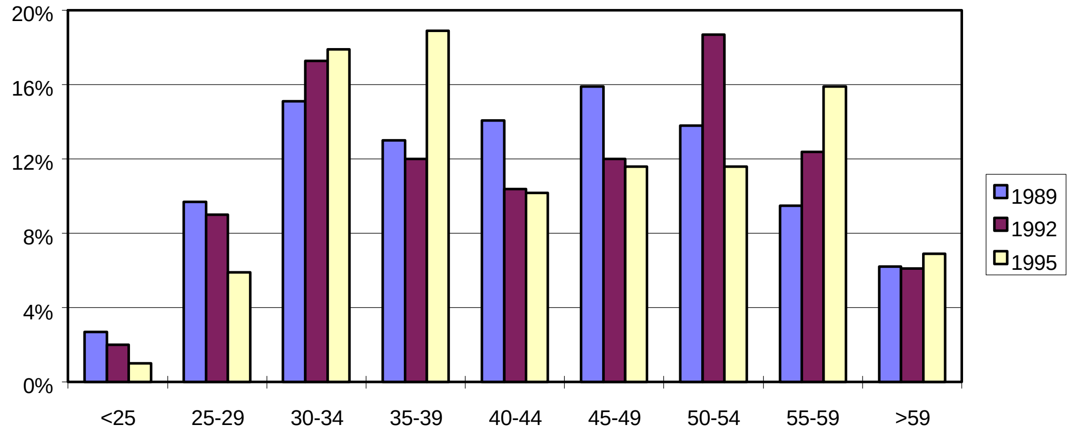


Figure 5(d) Staff age distribution - Earth

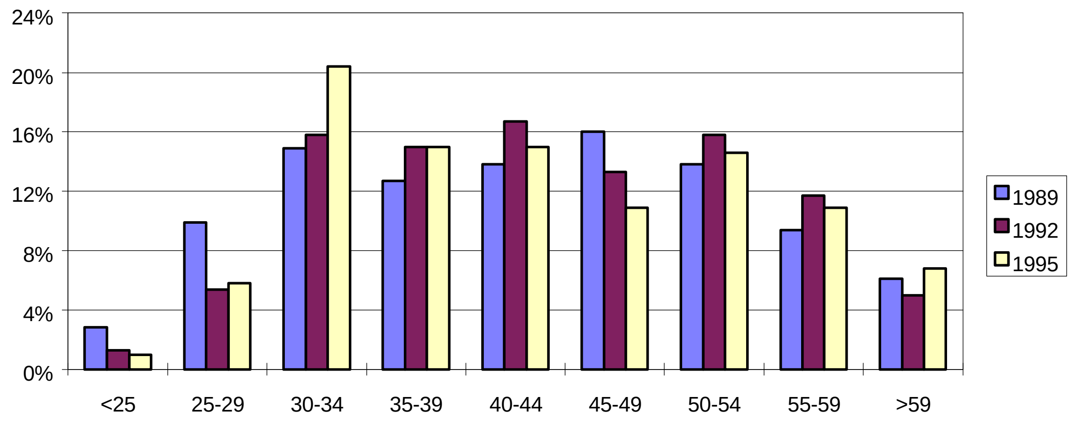
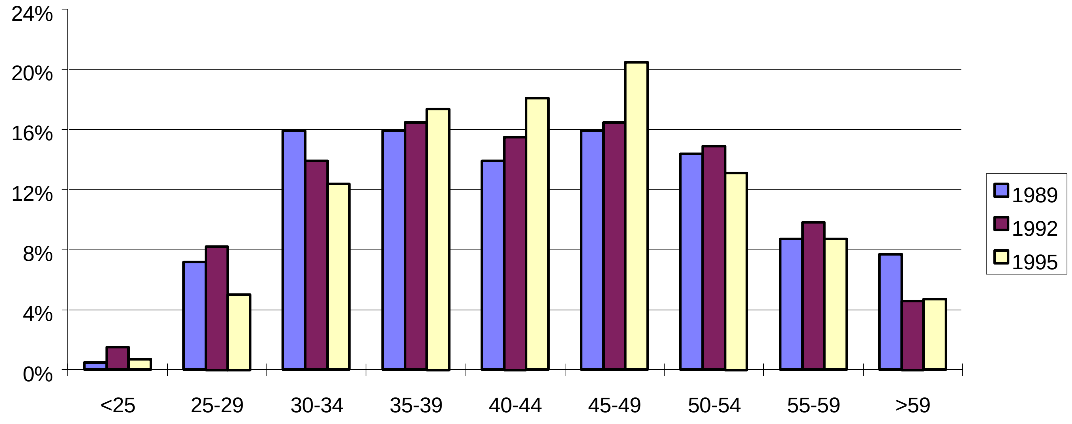
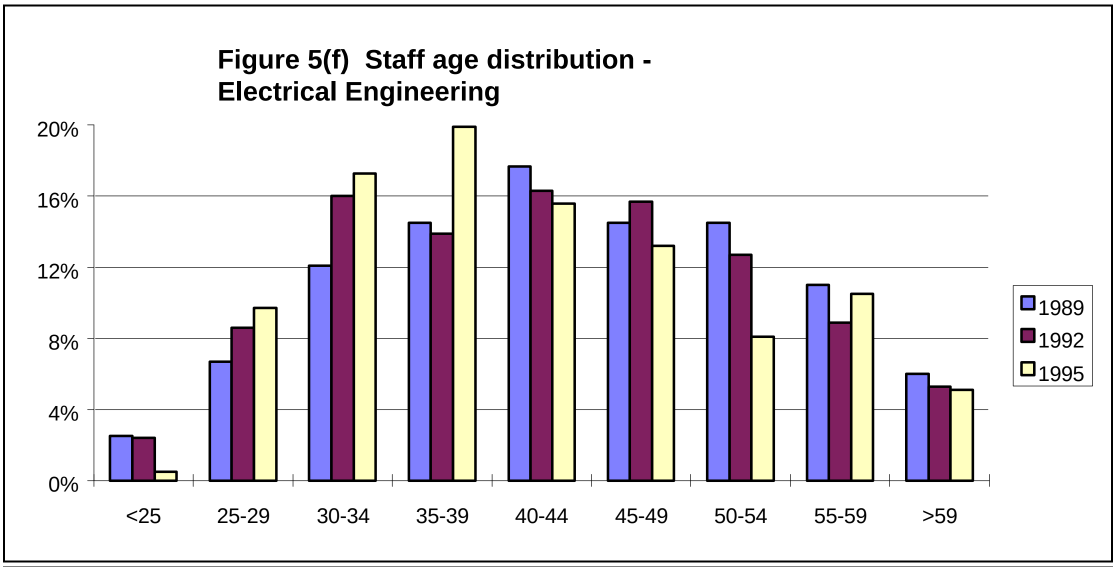


Figure 5(e) Staff age distribution - Agriculture





While the median ages are very similar for each discipline area, there is evidence of a bimodal distribution in some areas, for example, Physics and Chemistry. The bimodality appears to have intensified over time, and the concern in the discipline is that the distributions reflect the pattern of tenured and untenured staff.

Table 9 includes gender data for 1995 staff. In all fields, the proportion of female academics is higher in the lower age cohorts - a well known fact - and is included for completeness.

Table 9. Age and gender distributions for 1995 staff for selected departments within pre-1987 universities

	<25	25-29	30-34	35-39	40-44	45-49	50-54	55-59	>59	>64	All
Computing	6	41	78	83	95	94	53	19	5	2	475
% Female	28.6	28.4	15.2	15.8	21.6	20.5	9.9	3.7	10.8	0.0	16.6
% Male	71.4	71.6	84.8	84.2	78.4	79.5	90.1	96.3	89.2	100.0	83.4
Chemistry	3	52	97	79	47	40	63	68	38	8	494
% Female	0.0	24.5	18.2	12.5	8.3	11.9	1.5	5.7	10.3	0.0	11.6
% Male	100.0	75.5	81.8	87.5	91.7	88.1	98.5	94.3	89.7	100.0	88.4
Physics	5	29	88	93	50	57	57	78	30	4	491
% Female	20.0	13.3	7.8	7.3	9.6	15.5	0.0	5.0	3.2	0.0	7.8
% Male	80.0	86.7	92.2	92.7	90.4	84.5	100.0	95.0	96.8	100.0	92.2
Earth	3	17	60	44	44	32	43	32	14	6	294
% Female	33.3	27.8	14.8	15.6	8.9	6.1	6.8	9.1	0.0	0.0	11.0
% Male	66.7	72.2	85.2	84.4	91.1	93.9	93.2	90.9	100.0	100.0	89.0

Source: DEET

3.2 Discussion: Hypothesis 2

This does not appear to be a useful hypothesis to pursue. There is no revealing evidence to suggest a link between the age profile of Australian academics and a decline in the visibility/impact of Australian science as measured by citation share of the international literature.

While age *per se* may be discounted as a critical factor influencing research performance, opportunities at age are another matter. Recent ARC initiated strategic reviews of various disciplines have been vocal in reporting the perception that 'younger' academics are experiencing great difficulty in obtaining funding for research projects. A forthcoming ARC investigation of early career researchers in Australia (Bazeley, Kemp, Stevens, Asmar, Gbrich, Narsh, & Bhathal, in press) has, among other things, looked at the issue of age and ARC Large Grants for the 1995 and 1996 rounds, and the following findings are of interest here:

- the median age range for both all applicants and successful applicants in both years was 40-49 years;
- differences in success rates for those under or over 50 were significant for 1996, but not 1995, with those over 50 having higher than mean rates;
- successful applicants in Physics were significantly younger (43 years) than those from other disciplines;
- age is not a factor in success when all investigators, as opposed to first-named, are considered.

The study concludes that for younger applicants to be successful in obtaining funding from agencies such as the ARC, they need to apply with a more experienced researcher. The responsibility of nurturing and providing opportunities for new researchers in this way is essentially that of the universities, and is reasonably widely practised. However, it is also the responsibility of those charged with maintaining the health of the disciplines in this country to ensure that where the evidence suggest future needs in some fields, opportunities exist to ensure that talented researchers remain and flourish in the research world.

4. HYPOTHESIS 3: *There has been a shift from 'basic' to 'applied' research activity*

As 'basic' research is the most common research activity reported in the journals of the ISI, and because of recent government policy imperatives, this is an interesting and popular hypothesis. Bourke and Butler (1993) report the prevalence of a *perception* in the academic community of a pressure to move away from the basic end of the research spectrum towards a more applied/industry/socio-economic focussed research activity, largely as a result of the restructuring of the CSIRO, but also because of perceived changes in reward systems within the research sector in general. However, as pointed out by the BIE Report (1996b) which discounts this hypothesis, CSIRO's citation rate has actually increased in the past decade (conclusion based on Bourke & Butler, 1993, data).

Bourke and Butler have also conducted an analysis of CSIRO publications per 'professional' staff member (PSM), with a finding of a low number of publications per PSM and a downward trend in volume of publications per PSM. This analysis with caveats concerning interpretation, is included in Appendix 2.

4.1 Trends in the type of research activity

Notwithstanding arguments regarding the folly of drawing distinctions between 'types' of research activity, research expenditure data are collected by the Australian Bureau of Statistics and DEETYA and organised by type of research activity - 'pure' basic research, strategic basic research, applied research, and experimental development.

Figures 6(a) to (f) depict the proportion of each type of activity for each broad field over the years 1984, 1988 and 1992. Table 10 presents the total expenditure and the proportion of expenditure for basic ('pure' plus strategic) research versus applied (applied plus experimental development) research for each field for the same years.

Worthy of note is the increase in the relative amount of basic research conducted over this time period in the field of Computing Science. Of relevance to the time period of decline in citation share however, is the reduction in relative emphasis on 'pure' basic research in the fields of Physics, Chemistry and Earth Sciences between 1984 and 1988.

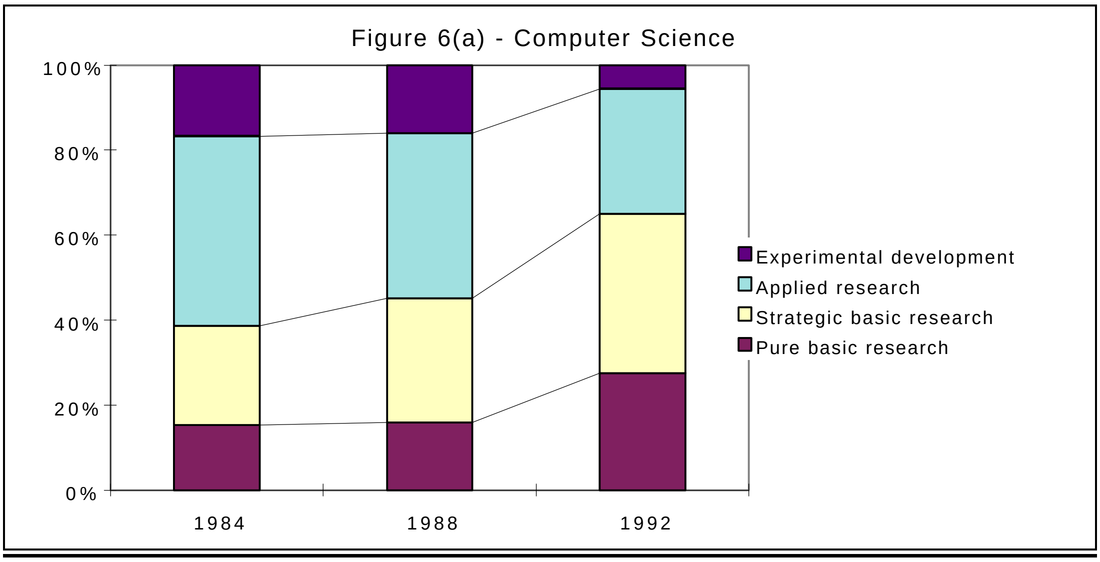


Figure 6(a) - Computer Science
100%
80%
60%
40%
20%
0%
1984
1988
1992
Experimental development
Applied research
Strategic basic research
Pure basic research

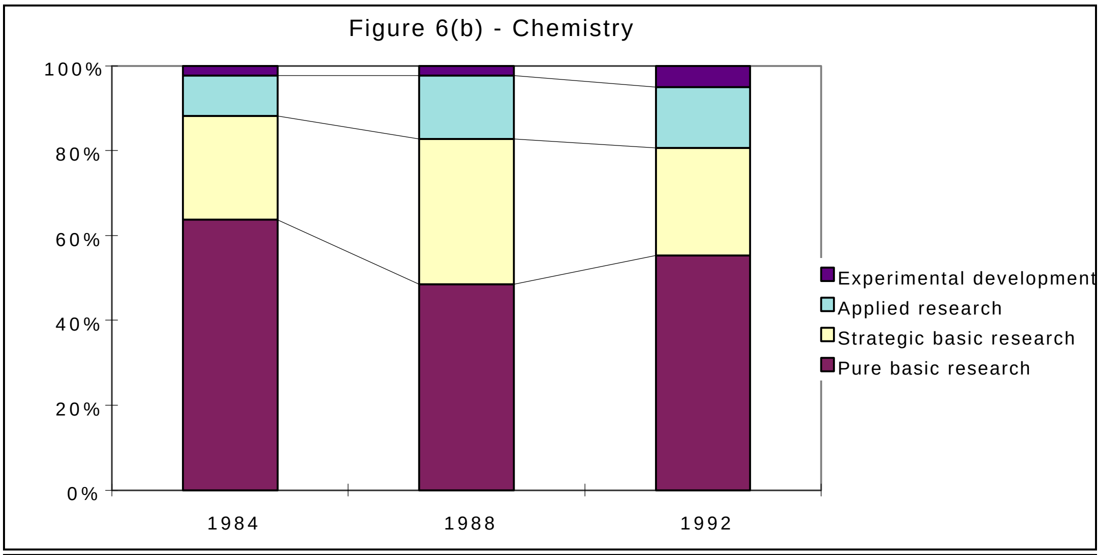


Figure 6(b) - Chemistry
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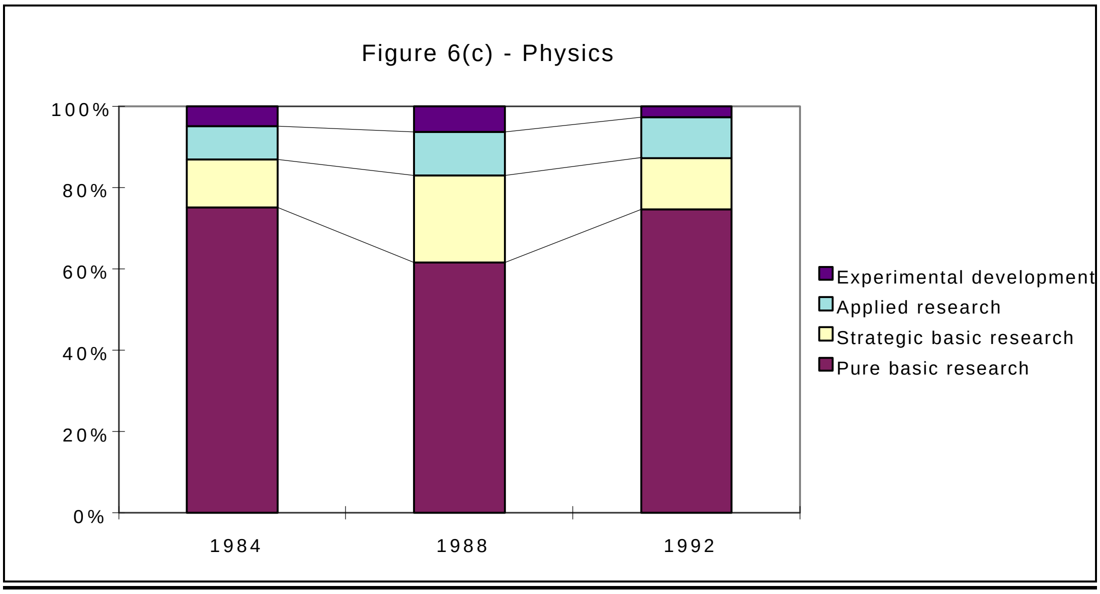

Figure 6(c) - Physics
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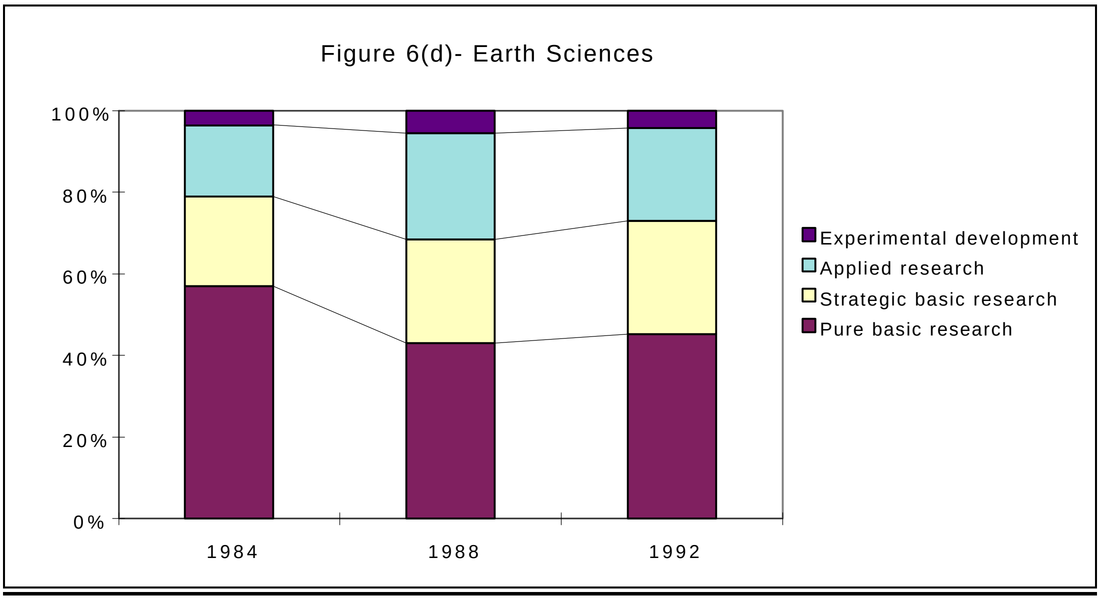
Figure 6(d)- Earth Sciences
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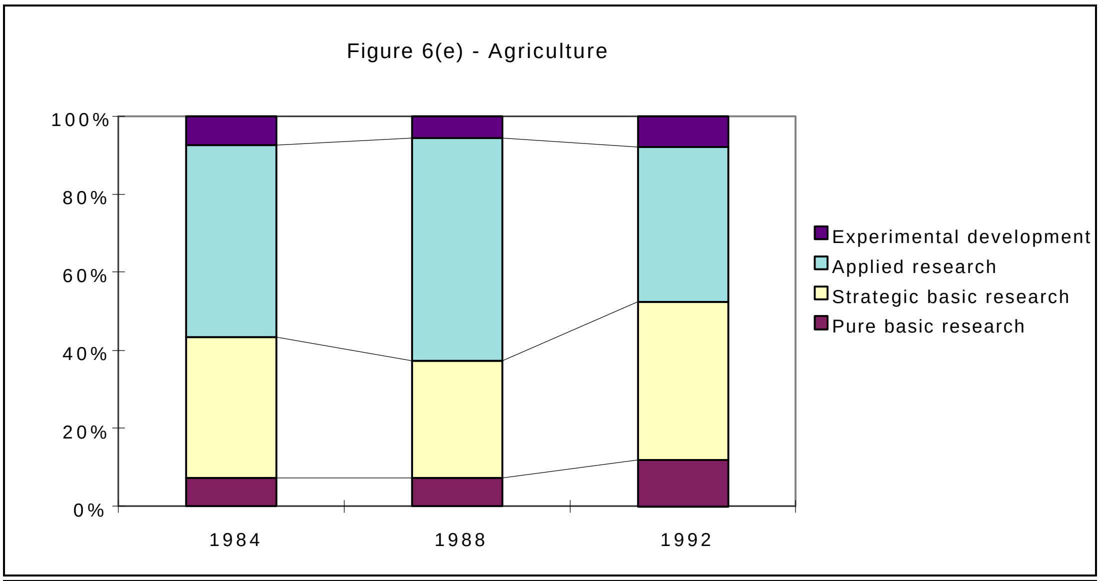
Figure 6(e) - Agriculture
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Experimental development
Applied research
Strategic basic research
Pure basic research

Table 10 The proportion of research activity by type of activity and broad field of research for the pre-1987 universities (1984, 1988, 1992)

	1984			1988			1992		
Field of research	**Total expenditure* $000**	**Basic research**	**Applied & experimental eevelopment**	**Total expenditure* $000**	**Basic research**	**Applied & experimental development**	**Total expenditure* $000**	**Basic research**	**Applied & experimental development**
		%	**%**		**%**	**%**		**%**	**%**
Elec Eng							19586	57.8	42.2
Computing**	15826	38.7	61.3	26482	45.1	54.9	43023	65.1	34.9
Chemistry	56694	88.2	11.8	65584	82.7	17.3	80769	80.6	19.4
Physics	62290	86.9	13.1	65719	82.9	17.	73129	87.3	12.7
Composite Earth	44584	79.0	21.0	55448	68.5	31.5	69235	73.0	27.0
Agriculture**	37244	43.4	56.6	42056	37.2	62.8	53136	52.4	47.6
Medical Science**	49176	70.2	29.8	59913	64.3	35.7	88449	74.1	25.9
All Engineering	72582	34.7	65.3	101443	34.7	65.3	158535	50.1	49.9
All Agriculture	54890	44.4	55.6	67956	37.8	62.2	89060	46.6	53.4
All Medical Science	136683	56.8	43.2	186612	49.4	50.6	286933	53.2	46.8

** Sub-fields as listed in Appendix 1; Source:ABS Statistics. Numbers include imputed amount for academic salaries.

Data at the sub-field level for the fields of Agricultural and Medical Sciences are reported in Tables 11(a) and 11(b) for the broad categories of 'basic' and 'applied' research.

Table 11(a) The proportion of research activity by type of activity (basic/applied) and year for sub-fields of Agricultural Science

	1984			1988			1992		
Field of research	**Total $**	**Basic[1] %**	**Applied & exp devel %**	**Total $**	**Basic %**	**Applied & exp devel %**	**Total $**	**Basic %**	**Applied & exp devel %**
Soil&Water	7032	41.6	58.4	9557	33.7	66.3	9412	43.5	56.5
Crops, Pasture & Horticulture	19477	41.9	58.1	20697	39.0	61.0	26047	53.9	46.1
Animal Production	10734	47.5	52.5	11802	37.0	63.0	17677	55.0	45.0
Selected Areas in Agriculture	37244	43.4	56.6	42056	37.2	62.8	53136	52.4	47.6

[1] Includes Basic and Strategic Basic Research
Note: Pre-1987 universities only

Table 11(b) The proportion of research activity by type of activity (basic/applied) and year for sub-fields of Medical Science

	1984			1988			1992		
Field of research	**Total $**	**Basic[1] %**	**Applied & exp eevel %**	**Total $**	**Basic %**	**Applied & exp devel %**	**Total $**	**Basic %**	**Applied & exp devel %**
Physiology & Neurosciences	19818	73.1	26.9	28969	70.8	29.2	49088	81.6	18.4
Immunology	13327	65.2	34.8	14526	61.4	38.6	21017	69.6	30.4
Pharmacology	16031	70.8	29.2	16419	55.4	44.6	18345	59.1	40.9
Selected Areas in Medicine	49176	70.2	29.8	59913	64.3	35.7	88449	74.1	25.9

[1] Includes Basic and Strategic Basic Research
Note: Pre-1987 Universities only

There has been a noticeable reduction in the proportion of activity reported in basic research across all sub-fields of Agricultural Science and Medical Science, with the most noticeable reduction in the sub-field of Pharmacology between 1984 and 1988. The amount of actual dollars applied to basic research activity in the same period was relatively constant, except for Animal Production and Pharmacology. A noticeable increase in basic research funding against the trend was noted for the sub-field of Physiology and Neurosciences.

4.2 Discussion: Hypothesis 3

The shift in *emphasis* from basic research to applied research activity was noticeable in the period 1984 to 1988 for Chemistry, Physics, Earth Sciences, Medical Sciences, and Agricultural Sciences. However, from 1988 to 1992, there has been a return to basic research activity for all fields with the exception of Chemistry. The data appear to indicate that for the period 1984 to 1988, the hypothesis is supported for all fields apart from Computer Science. It should be noted, however, that in terms of the total expenditure on basic research activity, this increased across all fields from 1984-1988.

It is very difficult to devise an appropriate data form to test this hypothesis. Apart from the difficulty of comparing data across years, the classification of research activity into the various categories of research is a self-classification system by respondents, with all the attendant problems of such data. In addition, the collection methodology has varied from year to year, and between institutions. Suffice it to say that

> *...several recent policy changes have had the effect of shifting the centre of gravity of university research further towards the applied end. (Industry Commission Report, 1995, p.C.5)*

5. HYPOTHESIS 4 *There has been an inadequate funding of research so that researchers do not have adequate resources to undertake high quality science*

The vast majority of those involved in research in the higher education sector believe this hypothesis to be the case. Comprehensive studies of higher education research infrastructure have been conducted (NBEET, 1993) indicating a funding shortfall of over $120 million. However, as far as convincing government is concerned this appears to be a no-win argument. The most recent denial that substantial cuts in funding had been experienced by the higher education sector in the last thirteen years comes from the new Minister in a discussion of a report prepared by the Higher Education Council (*The Australian*, 19 June, 1996) on total higher education funding.

What appears to be a large part of the problem in accepting the hypothesis of inadequate funding is the lack of detailed, reliable data on research funding and research infrastructure spending. The BIE Report (1996) found that there was a high positive correlation between citation rates and R&D spending per head of population, which of course has risen in recent years.

This section looks at data at the *field* level for the pre-1987 universities derived from Australian data bases, and also examines some ABS-derived OECD data on the trends in the amount of funding per Australian research scientist and engineer (RSE) over certain fields.

5.1 Trends in research expenditure

All of the data reported in this section required special data runs either by the ABS or DEETYA, and then further manipulation in order to present it in a form suitable for the purposes of this study. Caveats surrounding the accuracy and reliability of the data have already been mentioned, and extreme caution is required in interpretation. For example, trends in research expenditure may simply reflect trends in staff numbers, simply because of the way the data was collected and recorded originally.

Table 12(a) contains trends in the total amount of research expenditure from all sources from 1978 to 1992 for the selected fields of research for the pre-1987 universities. Figure 7 depicts the same data as a proportion of total research expenditure.

In actual dollar terms, Table 12(a) depicts evidence of increases in all fields with the exception of Physics. Table 12 (b), on the other hand, indicates that all fields except Medicine (and to a lesser extent, Earth Sciences) have experienced a decline in their *share* of available research funds across all disciplines in pre-1987 universities. This is particularly noticeable in the field of Physics where between 1981 and 1986, this field's share of total research expenditure went from 10.9 percent in 1981 to 6.1 percent in 1986, with no recovery since then (4.6 percent share in 1992). Applied

Science and Engineering also experienced a sharp decline between 1981 and 1984 (from 11.0 percent to 8.1 percent), although it appears recovery is taking place.

Table 12(a) Trends in expenditure in selected fields of research for pre-1987 universities

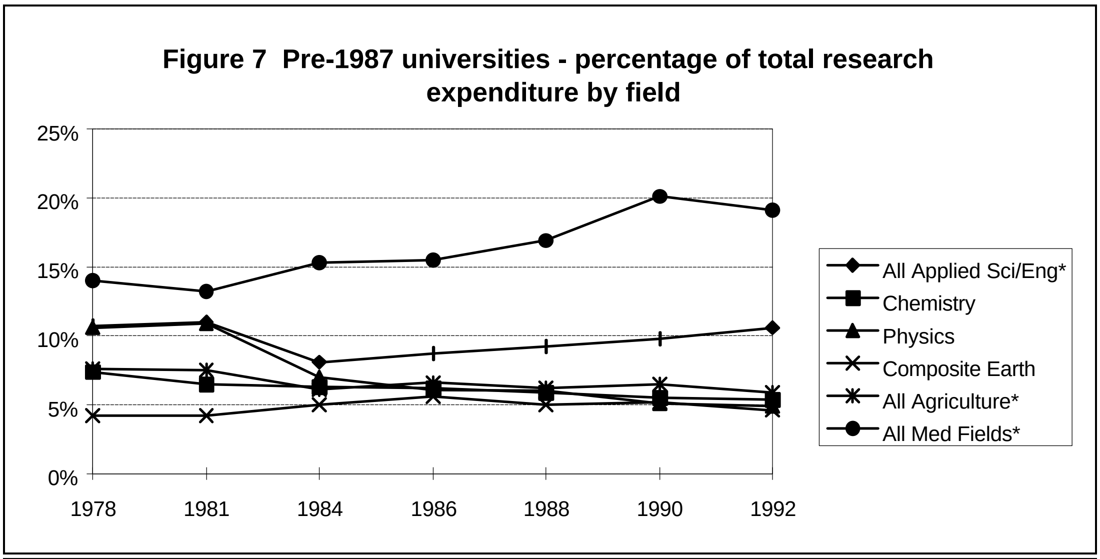
Field of research	1978	1981	1984	1986	1988	1990	1992
Elec Eng						15525	19586
All Applied Sci/ Eng	81343	89436	72582	86931	101443	118045	158535
Computing			15826	19443	26482	30203	43023
Chemistry	56613	52797	56694	61760	65584	66374	80769
Physics	80642	89225	62290	61215	65719	61262	73129
Composite Earth Sciences	32346	34293	44584	56311	55448	62440	69235
Selected Ag Fields			37244	44020	42056	48630	53136
All Agriculture	58142	61009	54890	66495	67956	78884	89060
Selected Medical Fields			49176	51424	59913	77166	88449
All Med Fields*	106467	107373	136683	155394	186612	241921	286933
Total**	762899	815515	894740	1000197	1102459	1206494	1501802

$(000) at Constant 1989-1990 Prices; includes salary component
Note: ** Total is for all fields of research represented in the system, not just those indicated in the Table.
Selected fields are those of interest to this study as indicated in Appendix 1 (disaggregation was not always possible)

Table 12(b) Pre-1987 universities - trends in expenditure in selected fields of research (as a percentage of total research expenditure)

	1978	1981	1984	1986	1988	1990	1992
All Applied Sci/ Eng*	10.7	11.0	8.1	8.7	9.2	9.8	10.6
Chemistry	7.4	6.5	6.3	6.2	5.9	5.5	5.4
Physics	10.6	10.9	7.0	6.1	6.0	5.1	4.9
Composite earth	4.2	4.2	5.0	5.6	5.0	5.2	4.6
All Agriculture*	7.6	7.5	6.1	6.6	6.2	6.5	5.9
All Med Fields	14.0	13.2	15.3	15.5	16.9	20.1	19.1

Notes:
* Aggregate data has been included because data for selected fields is not available for earlier years due to classification changes.
** Total research expenditure of pre 1987 universities for all fields of research, including humanities and social sciences.
Source: Australian Bureau of Statistics, unpublished statistics for the Research and Experimental Development Collection.



Data on funding by source and field for the years 1984, 1988, and 1992 for pre-1987 universities are contained in Tables 13(a) and 13(b). Figure 6 depicts the percent of Commonwealth funding by field for the same three years. Clearly, research in these fields relies heavily on Commonwealth funding compared to other sources with proportions of Commonwealth expenditure in these fields ranging from 87.9 percent for Medicine to 97.7 percent for Chemistry. This is not new or surprising information. Once again, in absolute dollars (corrected for inflation), Commonwealth expenditure in each field has increased. However, in percentage share terms (see Figure 8), there is evidence of a declining trend in Commonwealth expenditure across most fields with the notable exception of Agricultural Sciences between 1988 and 1992.

A slight and probably not significant increase in expenditure is noted in the fields of Physics and Chemistry between 1988 and 1992. The share of funds from other sources such as Business is still exceptionally small, and it would seem pre-emptive that the Commonwealth's share is reducing when expenditure from other sources is almost insignificant by comparison.

Table 13(a) Funding by source for selected fields of research and years, for the pre-1987 universities

	1984						1988						1992					
Field of research	Total*	C'wealth govt	State & local govt	Bus. enter-prise	Private non-profit and other Aust.	Overseas	Total	C'wealth govt	State & local govt	Bus. enter-prise	Private non-profit and other Aust.	Overseas	Total	C'wealth govt	State & local govt	Bus. enter-prise	Private non-profit and other Aust.	Overseas
Elec Eng													19586	17358	783	703	294	447
Computing	15826	15392	60	82	204	89	26482	25366	210	318	419	169	43023	39653	512	2280	402	176
Chemistry	56694	55416	272	535	391	80	65584	61988	177	1793	1447	180	80769	77093	562	1352	1136	626
Physics	62290	59506	51	129	1163	1442	65719	62335	266	948	867	1304	73129	70342	206	1430	862	290
Earth	44584	42198	479	1172	445	290	55448	51768	487	1285	1538	370	69235	64024	967	2200	1479	565
Agriculture	37244	33454	2112	635	927	116	42056	36338	2391	1663	1354	311	53136	48453	2017	891	1462	312
Selected Medical	49176	44789	148	435	3411	393	59913	52634	916	1495	4301	568	88449	79076	521	1647	6399	806
Total	894740	843399	8788	11030	24660	6863	######	1017677	12835	20218	44342	7387	######	1376576	27169	31783	57012	9262

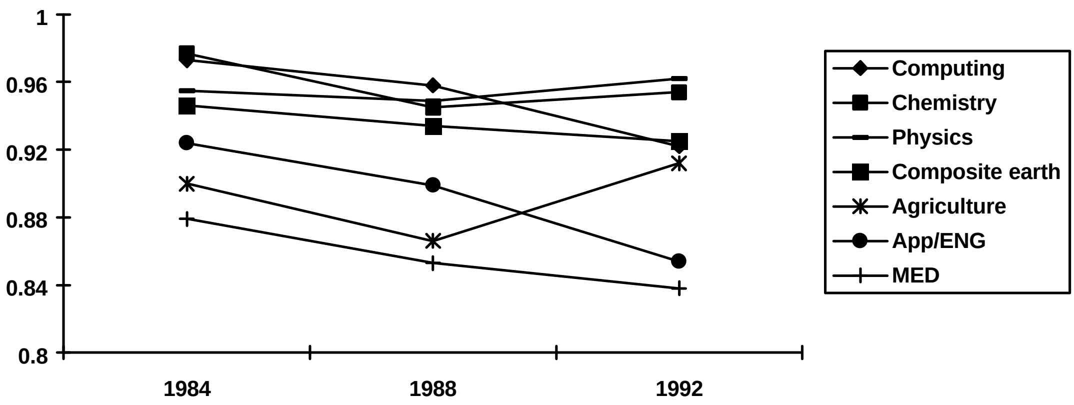
Source: Australian Bureau of Statistics, unpublished statistics from the Research and Experimental Devellopment Collection.
Total = Total for allfields represented in the R&D system
Note: In constant 1989-90 dollars

Table 13(b) Proportion of funding by source for selected fields and years, for the pre-1987 universities

	1984						1988						1992					
Field of research	Total*	C'wealth govt	State & local govt	Bus. enter-prise	Private non-profit and other Aust.	Overseas	Total	C'wealth govt	State & local govt	Bus. enter-prise	Private non-profit and other Aust.	Overseas	Total	C'wealth govt	State & local govt	Bus. enter-prise	Private non-profit and other Aust.	Overseas
Elec Eng													19586	88.6%	4.0%	3.6%	1.5%	2.3%
Computing	15826	97.3%	0.4%	0.5%	1.3%	0.6%	26482	95.8%	0.8%	1.2%	1.6%	0.6%	43023	92.2%	1.2%	5.3%	0.9%	0.4%
Chemistry	56694	97.7%	0.5%	0.9%	0.7%	0.1%	65584	94.5%	0.3%	2.7%	2.2%	0.3%	80769	95.4%	0.7%	1.7%	1.4%	0.8%
Physics	62290	95.5%	0.1%	0.2%	1.9%	2.4%	65719	94.9%	0.4%	1.4%	1.3%	2.0%	73129	96.2%	0.3%	2.0%	1.2%	0.4%
Earth	44584	94.6%	1.1%	2.6%	1.0%	0.7%	55448	93.4%	0.9%	2.3%	2.8%	0.7%	69235	92.5%	1.4%	3.2%	2.1%	0.8%
Agriculture	37244	89.8%	5.7%	1.7%	2.5%	0.3%	42056	86.4%	5.7%	4.0%	3.2%	0.7%	53136	91.2%	3.8%	1.7%	2.8%	0.6%
Selected Med & hlth	49176	91.1%	0.3%	0.9%	6.9%	0.8%	59913	87.8%	1.5%	2.5%	7.2%	0.9%	88449	89.4%	0.6%	1.9%	7.2%	0.9%
Total	894740	94.3%	1.0%	1.2%	2.8%	0.8%	######	92.3%	1.2%	1.8%	4.0%	0.7%	######	91.7%	1.8%	2.1%	3.8%	0.6%

Source: Australian Bureau of Statistics, unpublished statistics from the Research and Experimental Development Collection
*Total = Total for all fields represented in the R&D system

Figure 8 Percentage of Commonwealth funding by field and year



The Bureau of Economics Report (1996b) used expenditure on fixed assets in public sector research to conclude that ‘there has been strong growth in expenditure per researcher from 1978-79 to 1990-91 followed by a fall in 1992-93’ (1996b, p.44). The ARC (1996) believes that ‘expenditure on fixed assets’ is a very narrow definition of research infrastructure and that findings based on such a definition are misleading. It ignores, for example, growth in postgraduate student numbers and the consequential increase in demand on space and equipment, as well as the increased requirement for technical support and research space that has not kept pace with the increase in overall research activity (ARC, 1996).

The BIE (1996a) also used ABS-derived OECD data to take a snapshot (one year, 1993) of OECD countries’ gross expenditure on R&D per R&D worker.
Tables 14 and 15 also depict ABS-derived OECD data, and provide *trend* information on the expenditure on R&D in the Australian higher education sector by broad field of research, and on the R&D expenditure per research scientist and engineer (RSE) respectively. Figure 9 graphically depicts the information contained in Table 15.

Table 14 Gross expenditure on R&D in the Australian higher education sector by field of research

Million A$ (1990 prices)

Field of research	1981	1984	1986	1987	1988	1990
Natural sciences	227.0	265.2	286.2	-	286.8	171.7
Engineering	67.6	83.5	104.4	-	115.8	240.0
Medical sciences	78.0	109.7	125.6	-	141.2	184.4
Agricultural sciences	44.4	44.4	53.0	-	52.3	61.8
Sub-total NSE	417.0	502.8	569.2	612.9	596.1	657.8
Social sciences	-	145.5	154.1	-	153.5	215.0
Humanities	-	80.3	95.1	-	95.2	88.2
Sub-total SSH	182.6	225.8	249.2	229.7	248.7	303.2
Total NSE + SSH	599.6	728.6	818.4	842.8	844.8	960.9

Source: OECD; Basic Science and Technology Statistics; Australian data derived from the ABS
Figures for 1988,1989 include all universities in the current Unified National System.

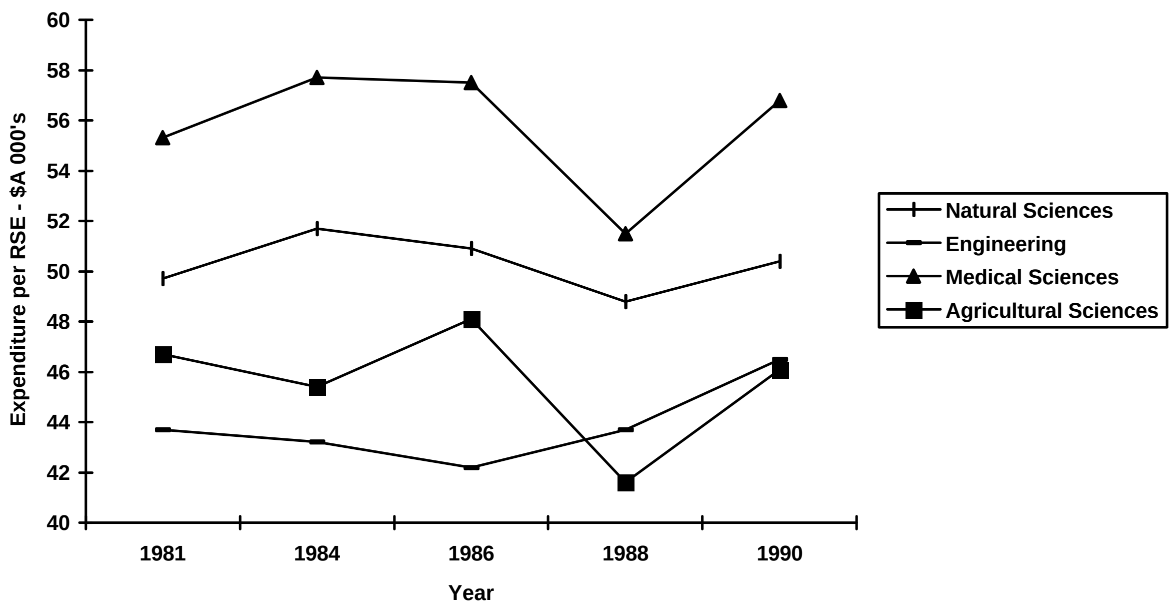
Table 15 Gross expenditure on R&D per research scientist and engineer (RSE) in the Australian higher education sector by field of research and year

A$ (1990 prices)

Field of research	1981	1984	1986	1987	1988	1990
Natural sciences	49 726	51 666	50 907	-	48 800	50 426
Engineering	43 669	43 242	42 182	-	43 682	46 503
Medical sciences	55 319	57 706	57 509	-	51 533	56 773
Agricultural sciences	46 688	45 445	48 094	-	41 640	46 119
Sub-total NSE	49 209	50 573	50 000	-	47 597	50 011
Social sciences	-	45 158	42 853	-	39 059	43 788
Humanities	-	35 993	36 105	-	33 240	33 897
Sub-total SSH	35 553	41 408	40 000	-	36 606	40 357
Total NSE + SSH	44 056	46 520	46 489	45 628	43 731	46 497

Figures for 1988, 1989 include all universities in the current Unified National System

Figure 9 Gross expenditure (in 1990 $'s) on R&D per research scientist and engineer (RSE) in the Australian higher education sector by field of research and year



All fields experienced substantial increases in gross expenditure on R&D during the period of interest - 1981-88 (Table 14). However, when the data are examined per RSE, the opposite effect is witnessed with the majority of fields experiencing a decline in funding per RSE between 1981 and 1988, and one field remaining constant (Electrical Engineering). This is in spite of escalating costs in many areas of science during the same time period (ASTEC, 1989; Palca, 1990).

An analysis of price movements for chemicals, periodicals, equipment and salaries serves to confirm the latter point for the field of Chemistry (Larkins, 1988, 1991). The major findings are listed below for a ten-year time period (1977-1987):

- the cost of periodicals in Chemistry increased over the ten-year period by 2.13 times;
- the cost of a parcel of eight chemicals increased by 1.54 times in real terms;
- average equipment costs rose in real terms by 1.35 times over the period;
- the salary of a university professor decreased by 12 percent over the ten-year period; and
- the cost of the *Journal of Chemical Physics* increased in real terms by 188 percent in the time period 1980-1990.

As Larkins (1990) notes

> *Lack of infrastructure resources results in a decrease in the quality of our postgraduate education and the quality of our chemical research. Ultimately our international economic competitiveness suffers.*

5.2 Discussion: Hypothesis 4

The total level of funding of research has increased across all fields over the time period 1984-1992. From 1978 to 1984, however, expenditure decreased for Applied Science/Engineering, Physics, and Agricultural Sciences. Across the period 1981 to 1990, there has been little change in the total research expenditure per research scientist and engineer, indicating no change in the intensity of the funding in spite of the obvious escalation of the real (inflation corrected) costs of research. The hypothesis receives partial support from this point of view.

The increasing ‘sophistication factor’ at the top-end of the scale of research equipment cannot be underestimated when examining this data. ASTEC (1989) made the point that restricted access to expensive facilities was a factor making it difficult for Australia to maintain a place in or near the leading edge of science. This is particularly the case in those disciplines such as Physics, Chemistry, Materials Science and Biotechnology, which are dependent on the use of specialised techniques (ASTEC, 1990). It is believed by many that Physics in Australia is being priced out of the market, with scientists forced into less expensive research activity, and away from the leading (and expensive) edge. Fields such as Optical Astronomy are at the point of dropping from the leading edge.

The sophistication factor, coupled with the devaluation of the Australian dollar, make the flat growth witnessed in Table 15 considerably worse than it may appear. However, apart from the increasing sophistication and cost of research equipment, the problem of lack of technical support in the major universities for such equipment is also concerning. Future large national research facilities should also take into account the provision of modest technical support as well as the provision of equipment in their requests for funds.

Before definitive conclusions can be made concerning the erosion of infrastructure and its extent, an examination of the adequacy and significance of research infrastructure at the field level is required. Detailed figures on infrastructure spending by field are not available (BIE, 1996b). In addition, a major attempt by policy advising bodies such as the ARC to obtain comparable data from overseas countries is urgently required.

6. HYPOTHESIS 5 *Foreign libraries have policies and practices related to the management of international journals that may impact on the visibility of Australian science*

There is a real and growing potential for library acquisition and collection management policies to affect citation behaviours. While no data exist to add weight to this statement, the following very brief review of the literature on the subject indicates that some general trends in serials collection management in libraries throughout the world warrant consideration in any discussion regarding citations.

6.1 Citation analysis as a tool for collection management in libraries

Many libraries have been using citation analyses and the ISI's journal impact factors for more than a decade to evaluate the journals which they acquire and retain in their collections (Budd, 1986; Haas & Lee, 1991; McCain, 1981; McReynolds, 1984). Databases have been developed using *Journal Citation Reports* to guide libraries' periodical collections (Calhoun, 1995), or to measure the strength of holdings in research libraries (Heidenwolf, 1994).

Knowledge of citation habits in particular disciplines have also been used to adjust libraries' periodical and monograph collection policies (Bowman, 1991; Burdick, Butler & Sullivan, 1993; Mack, 1991; Swigger & Wilkes, 1991).

The effects of such practices are very difficult to determine. Clearly, the most frequently cited journals are being identified and targeted for acquisition regardless of cost, and this has been the practice in many libraries for the last decade. If Australian fields of science are not publishing to any great extent in the 'top' journals in their fields, one could hypothesise a flow-on effect in terms of reduced share of citations from such library acquisition policies. The issue of publications in 'top' journals is addressed further in Section 7.

6.2 Cost as a factor in periodical subscription and cancellation

Libraries around the world are cutting back on library acquisitions because of the escalating costs of periodicals (Spang, 1995). The BIE Report (1996b) notes evidence that in the United Kingdom the costs of medical journals have risen by 82 percent, and of science and technology journals by 88 percent during the period 1989-1994. The result appears to be reluctance to subscribe to journals which are outside the mainstream or core journals in a field. Journals on the periphery of a field, highly specialised journals in new fields, and journals from smaller scientific nations have been found to be neglected by some United States and Canadian libraries resulting in underrepresentation in research collections (Walden, Fineman, Monroe & Parrine, 1994). Academic library collections are reported to be looking more and more similar, with a focus on core areas only (Perrault, 1995, cited in BIE, 1996b). The BIE Report makes the point that if Australians are overrepresented in 'peripheral' journals on the ISI list, then, given global library practices, there could be a problem with visibility.

6.3 Discussion: Hypothesis 5

As no data exists on the matters raised on this issue it is impossible to reach a firm conclusion regarding this hypothesis. Section 1 of this discussion paper referred to results of a study by Bourke, *et al.*,(1996*)*, which indicates that Australian scientists are not in the peripheral journals when these are defined as those journals *not* in the ISI indices. However, no data has been gathered regarding representation in low-impact journals *within* the ISI compared to other countries, and this may be an avenue worth pursuing.

7. VARIOUS BIBLIOMETRIC HYPOTHESES:

- ***There has been a decline in the proportion of Australia's publications that are very highly cited ('big bangs'), leading to a decline in citation shares;***
- ***Australians are finding it harder to publish in the 'top' journals and this is a major contributing factor to the decline in Australia's citation shares; and,***
- ***Australians may be publishing fewer review articles, leading to a reduction in citation shares.***

Appendix 2 contains a full report of the analyses conducted to investigate the above hypotheses. A summary of the findings and general conclusions is reported below.

7.1 A decline in highly cited articles?

The hypothesis regarding a decline in the proportion of very highly cited Australian publications was not supported. In data based on a two-year citation period, Australia actually exhibited an increase in the proportion in all but one band (1980-1989) in this top bracket between the beginning and end of the period. A similar trend was exhibited when the citation period was increased to four years.

7.2 A decline in publishing in 'top' journals?

One explanation for the decline in share of citations for Australian science shown in Bourke and Butler (1993) is that there has been a declining presence in the high impact journals. The analyses reported in Appendix 2 does appear to provide a partial explanation. Of six case studies of declining fields that were studied in detail, three suggested the hypothesis could be part of the answer - Chemical Sciences, Physical Sciences and Immunology. For the other three fields - Physiology, Neurosciences and Pharmacology - no decline in high impact journals was noted. Of the two fields that had remained strong in terms of citation shares in Bourke and Butler (1993) - Earth Sciences and Agricultural Sciences - both showed an increasing presence in the high impact journals for their fields.

While the hypothesis regarding high impact journals does appear to provide part of the explanation for Australia's decline in citation shares, the question of cause remains: is there a decline in the quality of Australian science, or are there displacement effects, with more and more researchers competing for an outlet in the 'top' journals?

7.3 A decline in review articles?

Review articles are the most highly cited type of journal publication in the Science Citation Index. Australia's share of this type of publication has increased significantly over the time period 1981-1993, and is at a higher level than that for the average of all publication types. This hypothesis is therefore not supported by the evidence.

8. CONCLUDING COMMENTS

The purpose of this discussion paper is to provide a starting point for a dialogue on those policy issues that may be critical for the future conduct and support of research within Australian universities. The examination of reasons for the decline in Australia's 'visibility' in international science, first indicated in *A Crisis for Australian Science?* (Bourke & Butler, 1993), has probably raised more questions than it has provided answers. Nevertheless, indirect evidence on phenomena currently present within the research system is indicated, and some of these phenomena are discussed briefly below.

A change in the international networks

International networks are critical for a country of the size and location of Australia in order to benefit from advances of knowledge from around the world and to promote and stimulate excellence in Australian science. Apart from ensuring the exchange of leading-edge knowledge, international links enhance a country's ability to attract to its laboratories and universities the world's top scientists and scholars. Through excellent international science, we are able to 'contribute to, and benefit from, international deliberations on complex social, legal and ethical questions' and to 'discriminate between first rate and third rate science' (Science and Technology Review, Canada, 1994). To manage and fund a presence on the international research stage requires a long term perspective, and deliberate strategies.

The major findings regarding international networks in this study include:

- strong evidence of a systematic 'Australianisation' of academia, with a large increase (142%) since the 1970s, in the number of Australian academics with both undergraduate and postgraduate qualifications from Australia;
- evidence that overseas postdoctoral experience may be important in maintaining visibility in the international literature;
- evidence to suggest that Australia's share of international conference abstracts is small and in decline;
- evidence that while Australia's international collaboration (measured by co-authorship of publications) is increasing, it is low in world terms, and in line with the performance of China; and,
- indications that there has been a fall in the proportion of collaborations with the United States and the United Kingdom, the key players in the international research arena.

While the appearance of a change (and decrease) in the international 'networks' over time does not imply a decline in the quality of Australian academics or their research, it does raise several fundamental questions. Does Australia need to build better linkages to international science and technology? What are the appropriate roles of the universities, the funding agencies, and the Government in this regard? What weaknesses in the current system present obstacles to the free flow of people and ideas between countries? In terms of developing and sustaining international networks, what is the appropriate balance between (a) funding individuals (and at what stage of their careers)? (b) funding projects and teams? and (c) funding participation in international large-scale research facilities?

Steady-state research funding

In spite of escalating costs in most fields of science and technology over the last decade, the level of funding in Australian higher education per research scientist and engineer has remained constant (in real terms) in the majority of disciplines. The increasing 'sophistication factor' at the top-end of the scale of research equipment, together with the devaluation of the Australian dollar, make such flat 'growth' a matter of considerable concern.

While the issue of the erosion of research infrastructure has been canvassed more than any other in recent times, important management questions remain.
What *is* the state of Australia's science infrastructure? Can it be enhanced or improved through existing budgets, and if so, how? Are cost-savings achieved through collaborations? Are some fields of endeavour in danger of dropping from the leading edge because of inadequate levels of research infrastructure, and does this matter?

Before definitive conclusions can be made concerning the erosion of infrastructure and its extent, an examination of the adequacy and significance of research infrastructure at the field level is required. Detailed figures on infrastructure spending by field are currently not available (BIE, 1996b). In addition, a major attempt by policy advising bodies such as the ARC to obtain comparable data from overseas countries is urgently required.

In the meantime,

> *'While money is not an unambiguous determinant of quality in research', it is well understood and accepted in advanced European nations that 'investment in research is taken as a guarantor of competitiveness' (Maddox, 1995).*

A shift to applied research

The shift in *emphasis* from basic research to applied research activity was noted in this study for Chemistry, Physics, Earth Sciences, Medical Sciences, and Agricultural Sciences for the period 1984-1988. However, from 1988 to 1992, there has been a return to basic research activity for all fields with the exception of Chemistry.

It is very difficult to devise an appropriate test for the hypothesis of a shift from basic to applied research. Apart from the difficulty of comparing data across years, the classification of research activity into the various categories of research is a self-classification system by respondents, with all the attendant problems of such data. In addition, the collection methodology has varied from year to year, and between institutions. Suffice it to say that it may be the case that

> *...several recent policy changes have had the effect of shifting the centre of gravity of university research further towards the applied end. (Industry Commission Report, 1995, p.C.5)*

The question is raised of the role of government and funding agencies in facilitating such shifts, and are they necessary anyway? If one answers 'yes' to the latter, the question of the appropriate balance between 'basic' and 'applied' research needs to be addressed.

While the contribution of basic research to industry in particular, and society in general, is incredibly hard to measure, Pavitt (1996) has recently reported on two separate studies both of which found that most of the 'useful' basic research (that is, cited by 66 American companies as research that generated 'know-how', and also, research that was cited in American patents in 1993 and 1994) came from university departments that were highly rated by the US National Academy of Sciences, proving, according to Pavitt, that 'useful' science is good science. Moreover, the federal government was found to be overwhelmingly the source of funding for this research, largely through the National Science Foundation, and the National Institutes of Health. Collaboration between academic researchers and industry was also found to emerge as a matter of course from this academic research. There are numerous other well known instances of how the discoveries of basic science have changed the way we view the world.

The point being made is that if governments, or funding agencies for that matter, wish to be catalysts in generating a shift to more applied areas of science, by investing, for example, in collaborative research between universities and industry, how should we select and evaluate such research investments? What unique approaches are required to best respond to the needs and opportunities of the different sectors? What is the appropriate balance between investments of this nature and investments in basic research, and do we have it right?

Australians are not publishing in 'top' journals

Many fields of Australian research were shown in the Bourke and Butler study to be in decline in terms of shares of citations in the international literature. Because of the very skewed nature of citation practice, and the influence in overall ratios of a very small number of highly cited journals, it was hypothesised that the decline in citation share may be a result of Australians finding it harder to publish in these high impact journals. Of the six case studies of 'declining' fields which were studied in detail for this project, three - Chemical Sciences, Physical Sciences, and Immunology - had declined in their presence in top journals over the last decade. Such a result, however, does not define the cause. For example, is this a decline in the quality of Australian research in these fields? or, is it a displacement effect, with more and more researchers competing for an outlet in the 'top' journals? We should look urgently for the answers to these questions.

In conclusion, if Australia is to sustain its more than creditable contribution to international science, and to strengthen its collaboration in world-class scientific endeavours, it is time to develop deliberate and long-term successful strategies in important areas of contemporary research. Many countries, including those in the developing nations, now possess world-class research capabilities. It is only sensible that we restate our commitment to investment in scientific research, and that we quickly come to grips with the movement towards a knowledge-based economy in a *global* environment.

> *...there must be no gaps in the ability to either make the fundamental discovery, to bring the idea from elsewhere, or in the ability to apply the discovery or to translate the discovery into jobs, products, improved government services etc....As with any process which requires a chain of events, our national system of innovation is as weak as the weakest link. It is therefore absolutely critical that we identify and address any weak links and that we put in place a strategy that will correct any deficiencies. (Gerrard, 1994, cited in Science and Technology Review, 1994)*

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APPENDIX 1

(a) Fields of research investigated

(b) Departments in pre-1987 universities examined for academic qualifications

(c) Selected higher education statistics - caveats

Appendix 1 (a)

FIELDS OF RESEARCH (numbering refers to the Australian Bureau of Statistics field of research (FOR) classification

020000	Physics;
030000	Chemistry;
040000	Earth Sciences;
050000	Information, Computer and Communication Technologies (Information Systems and Technologies (050100), Computer Software (050300));
070000	General Engineering (Electrical and Electronic Engineering (070500));
090000	Agricultural Sciences (Soil and Water Sciences (090100), Crop and Pasture Production (090200), Horticulture (090300), Animal Production (090400);
100000	Medical and Health Sciences (Immunology(100100), Neurosciences (100600), Physiology (100500), Pharmacology (100400)).

APPENDIX 1(b)

Departments in pre-1987 universities examined for academic qualifications profile:

Physics
Chemistry
Electronic Engineering
Electronics
Computer Science
Information Sciences
Computer Sstudies
Communications
Systems and Control
Soil Science
Agriculture
Agricultural Science
Animal Husbandry
Plant Breeding
Horticulture
Livestock Husbandry
Animal Production
Croop Production
Physiology
Pharmacology
Developmenetal Neueroscience
Neuroscience
Geology
Earth Sciences
Mining - Applied Geology

Note: Data from these departments was aggregated under the following groupings:

- Physics
- Chemistry
- Electrical Engineering
- Computer Science
- Agricultural Sciences
- Medicine
- Earth Sciences

APPENDIX 1(c)

SELECTED HIGHER EDUCATION STATISTICS (comments on sources of data, reliability etc)

Staff data

Data on staff of pre-1987 universities were obtained from two sources: as a custom extract from the DEET Higher Education Staff Collection (1995, 1992, and 1989); and from the reports of the former Commonwealth Tertiary Education Commission (1986, 1983, 1980, 1977, 1974). The data was not classified by field of research but field academic organisational unit or by departmental group. These classifications were used to allocate staff as accurately as possible to field of research.

The classification system changed several times between 1974 and 1995. In some years, for example 1989, data has only been classified at the broadest level (Engineering, Science) while for 1992 and 1995 and some earlier years a finer level of classification (biological, chemical, earth) is available. So for some fields reasonable allocations for the selected fields were able to be made. For Medical Science this proved more difficult.

There are two other difficulties that reflect on the accuracy of these data. First, some of the detailed DEET data file is missing for 1992, which meant that the data had to be scaled up to known aggregates. Second, in order to make the pre- and post-1987 data comparable, some allowance for amalgamations needed to be made. The addition of Chisholm into Monash, for example, affected staff numbers in fields such as computing and engineering. Staff data for years just prior to amalgamation were used to make appropriate adjustments.

A final source of inaccuracy is the classification of staff by level and their inclusion as academic staff - research officers for example would be included in some cases but not others. This tends to vary by institution and year and it is not practical to attempt to revise the data.

Funding and type of research activity data

These data were purchased from the Australian Bureau of Statistics (ABS) as custom extracts from the ABS Higher Education R&D Statistics. Field of research data by funding source and activity data for pre-1987 universities was obtained for the years 1992, 1990, 1988, 1986, and 1984. Field of *science* data is available for 1978 and 1981.

The field of research classification was changed in 1990. This means that trend data is not available for some of the selected fields (eg, Medical Sciences 100100, 100400, 100500 and 100600 and Electrical Engineering), and for others, such as Computing and Agriculture, the data are indicative only.

All funding data has been expressed as constant 1989-1990 dollars. Deflators were supplied by the ABS.

APPENDIX 2

Bibliometric analyses undertaken for the Academy of Science by:

Professor Paul Bourke and Linda Butler
Research Evaluation and Policy Project
Australian National University

BIBLIOMETRIC ANALYSIS UNDERTAKEN FOR:

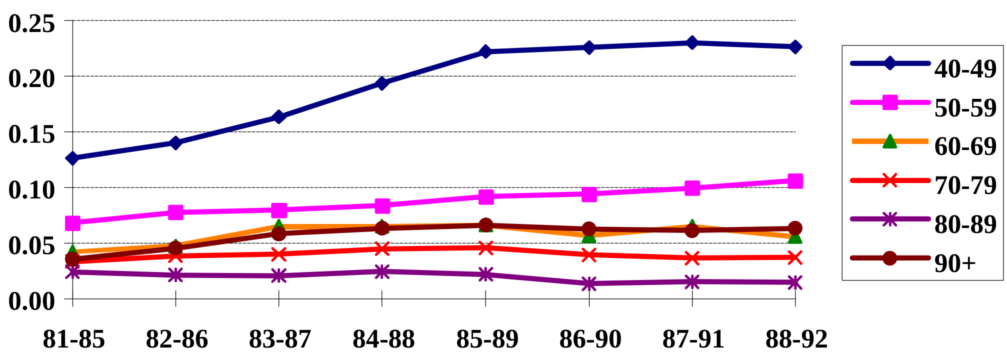
THE IMPACT OF AUSTRALIAN SCIENCE: A STOCKTAKING

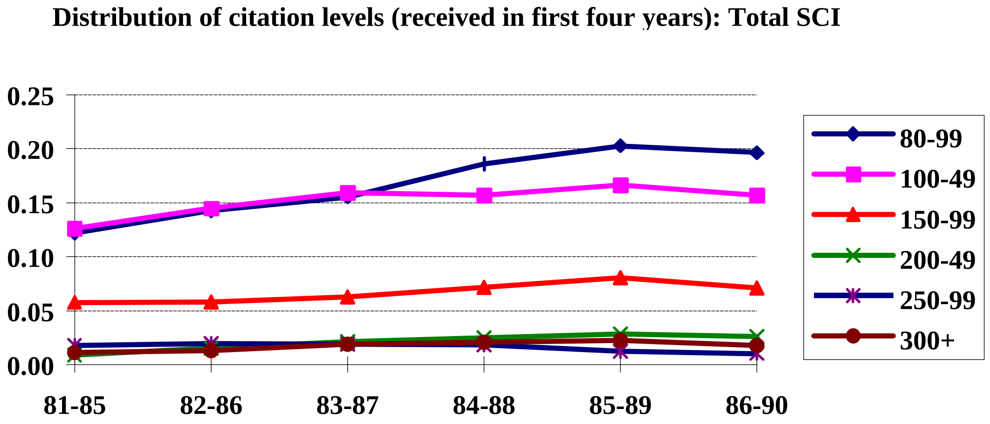
1. *Hypothesis: There has been a decline in the proportion of Australia's publications that are very highly cited ('big bangs'), leading to a decline in citation shares*

This hypothesis was proposed because of the very skewed nature of citation practice and the influence in overall ratios of a small number of very highly cited items, particularly at lower levels of aggregation. We completed two runs on the total Australian data to analyse the distribution of very highly cited items. In the first run, we limited citations to the year of publication and the subsequent two years. In the second run, we expanded citations to the year of publication and the subsequent four years. The strategy was aimed at trying to find out if there had been a decline in the number of 'big bang' publications from Australia, ie, that small number of publications achieving exceptionally high citation rates. The citation window was limited to enable a sufficient run of years to be analysed. We focussed on citation counts above 40 for data on citations in the first two years, and on counts above 80 for data on citations in the first four years.

We had expected that if the declining 'big bang' theory held any currency, then we would see a decline in the proportion of Australian publications in the top bracket.

Distribution of citation levels (received in first two years): Total SCI

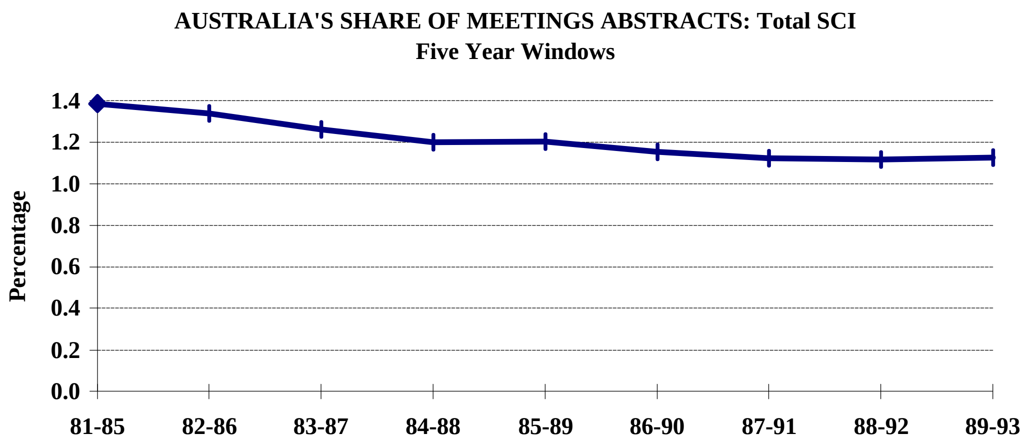




The hypothesis did not hold true. In data based on a two-year citation period, Australia actually exhibited an increase in the proportion in all but one band (80-89) in this top bracket between the beginning and end of the period. A similar trend was exhibited when the citation period was increased to four years.

2. *Hypothesis: Australia's share of SCI 'meetings abstracts' has declined indicating reduced contact with international experts*

In the Journal Citation Reports volume of the SCI, the number of items classified as 'meetings abstract' are noted. From our database we can count the number of Australian publications classified to the same publication type and calculate the proportion these represent of the total. The information for the 'world' is published only for the total SCI, with data not being available at field or sub-field level. There is a break in the time series at 1989. Prior to this, meetings abstracts in all SCI source journals were indexed; from 1989 onwards, only those in the 'top 500' journals were indexed.



The data show that Australia's representation is low and declining (from 1.4% in 1981-85 to 1.1% in 1989-93) which supports the proposed hypothesis.

3. *Hypothesis: Australians are finding it harder to publish in the 'top' journals and this is a major contributing factor to the decline in Australia's citation shares*

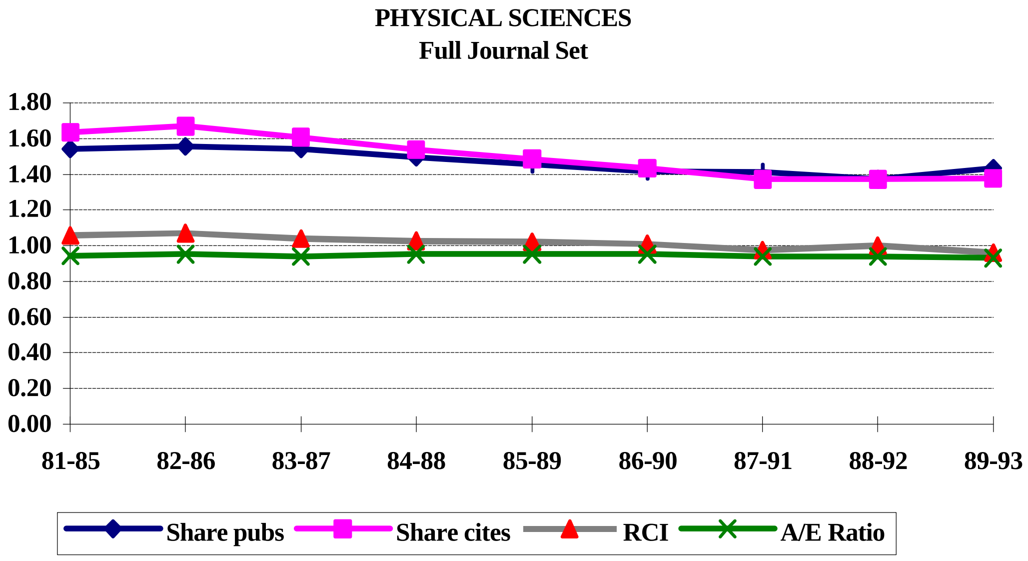
The hypothesis we wished to test was that Australians were finding it harder to get their research published in the high impact journals leading to a decline in its share of citations. This hypothesis was proposed because of the very skewed nature of citation practice and the influence in overall ratios of a small number of very highly cited items/journals. The signs that this might be the case for a given discipline would be a declining relative citation impact (RCI) due to a declining citation share with a constant ratio of 'Actual' to 'Expected'(A/E) citations for the full journal set, coupled with a declining share of publications in the high impact journals.

The results for a selection of fields and sub-fields is set out in the following pages.

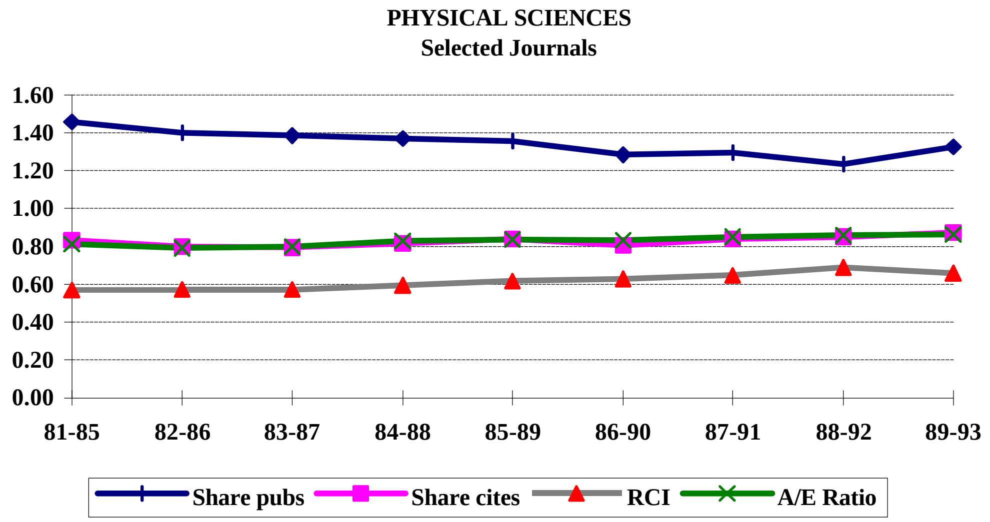
(a) Physical Sciences

The selected journals:

Annual Review of Nuclear and Particle Science
Journal of Physics A-Mathematical and General
Journal of Physics B-Atomic Molecular and Optical Physics
Journal of Physics C-Solid State Physics
Journal of Physics D-Applied Physics
Journal of Physics E-Scientific Instruments
Journal of Physics F-Metal Physics
Journal of Physics G-Nuclear Physics
Physical Review A
Physical Review B-Condensed Matter
Physical Review C-Nuclear Physics
Physical Review D
Physical Review E
Physical Review Letters
Physics Letters A
Physics Letters B
Reports on Progress in Physics
Reviews of Modern Physics
Rivista Del Nuovo Cimento
Zeitschrift Fur Physik A-Hadrons and Nuclei
Zeitschrift Fur Physik B-Condensed Matter
Zeitschrift Fur Physik C-Particles and Fields



The full Physics journal set used in *Crisis* showed a declining RCI, particularly since 1986. Both the share of publications and citations fell over the period, but the share of citations fell at a greater rate. The A/E ratio shows a much steadier course over time. This suggested that in more recent years Australia's publications might be appearing more in journals at the lower impact end of the scale.



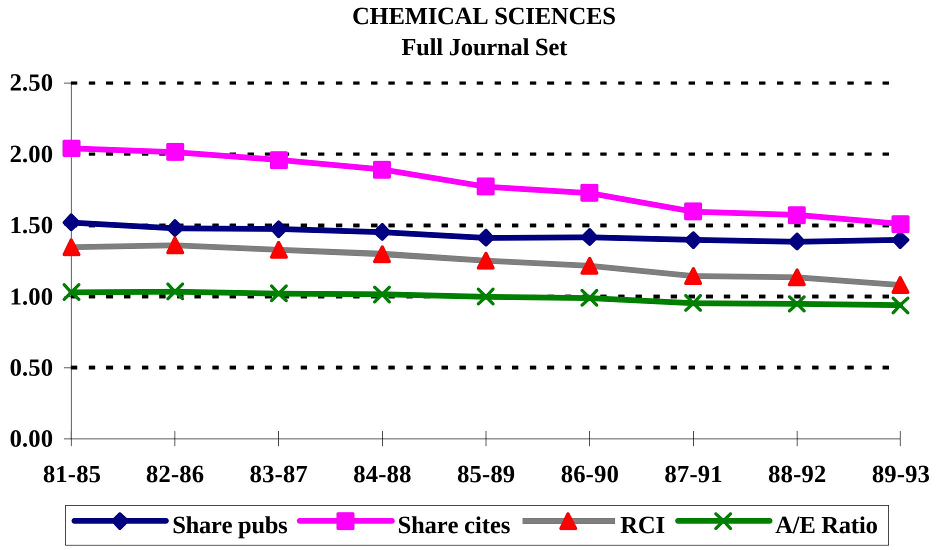
Australia's share of publications in the selected 'high impact' journal set declined from a peak of 1.6% in 1981 to a low of 1.1% in 1990, though there has been an upturn in the 1990s.. This data suggests there may be some validity in the hypothesis for Physical Sciences.

It is interesting to note that in the 1990s the relative impact of articles in these journals has improved — there may be fewer of them, but their share of citations has increased. This improvement was too recent to have affected the trends shown in *Crisis*, but does give hope that they are now being reversed.

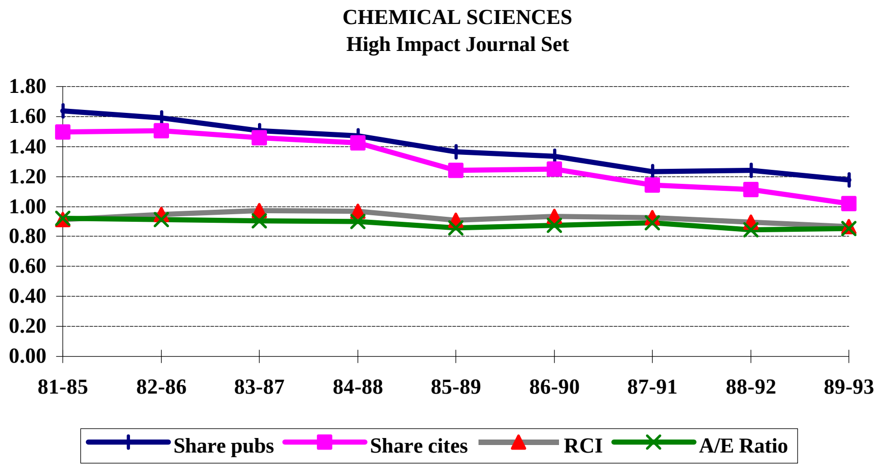
(b) Chemical Sciences

The selected journals:

Accounts of Chemical Research
Advances in Carbohydrate Chemistry and Biochemistry
Advances in Catalysis
Advances in Colloid and Interface Science
Advances in Heterocyclic Chemistry
Advances in Inorganic Chemistry and Radiochemistry
Advances in Organometallic Chemistry
Advances in Physical Organic Chemistry
Advances in Polymer Science
Annual Review of Physical Chemistry
Catalysis Reviews-Science and Engineering
Chemical Reviews
Chemical Society Reviews
Coordination Chemistry Reviews
Journal of the American Chemical Society
Journal of Computational Chemistry
Macromolecular Review
Metal Ions in Biological Systems
Progress in Energy and Combustion Science
Progress in Nuclear Magnetic Resonance Spectroscopy
Progress in Solid State Chemistry
Structure and Bonding
Surface Science



The full Chemical Sciences journal showed a declining share of citations and a stable share of publications. The resulting decline in the RCI over time is mirrored in part by a declining A/E Ratio, though the extent of the decline for the A/E Ratio is far smaller (under 10% compared to 25%). The pre-conditions for our hypothesis have been met.

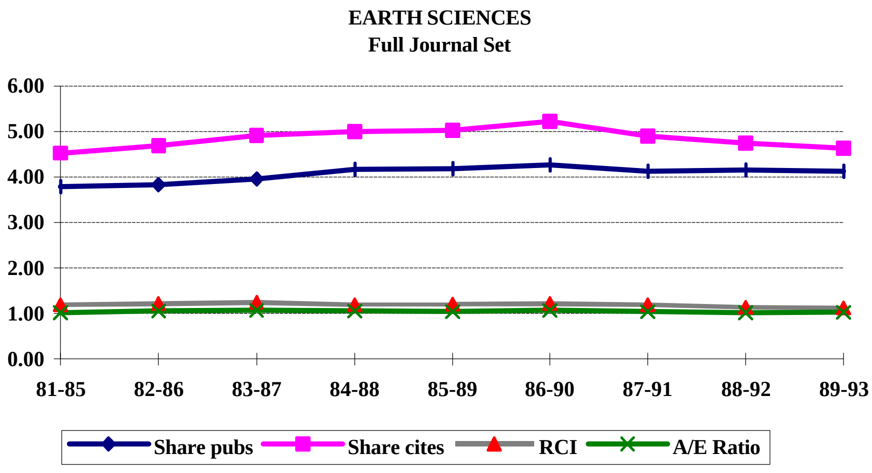


Australia's share of publications for the selected journals has declined to a much greater extent (by 28%) than has the total journal set (by 8%). The fall in the share of citations mirrors the fall in publications share. This data for Chemical Sciences lends credence to the hypothesis.

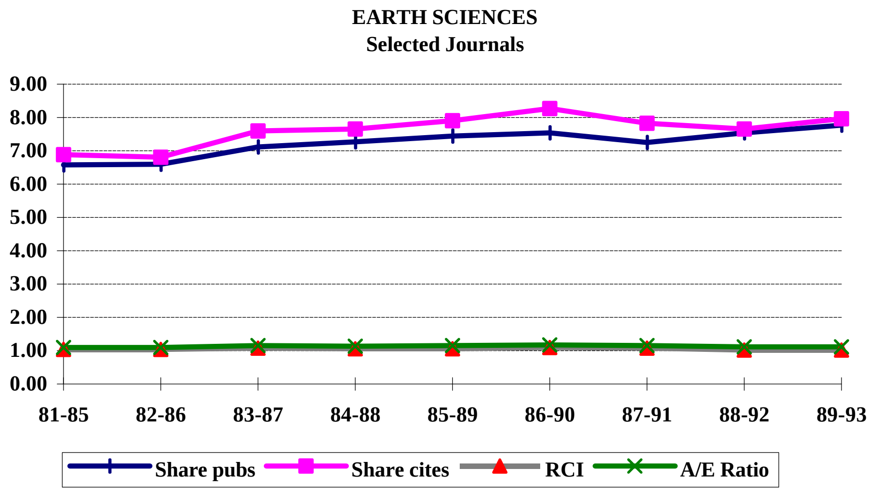
(c) Earth Sciences

The selected journals:

Australian Journal of Earth Sciences
Contributions to Mineralogy and Petrology
Earth and Planetary Science Letters
Economic Geology
Economic Geology and the Bulletin of the Society of Economic Geologists
Geochimica et Cosmochimica Acta
Geology
Geophysics
Journal of the Atmospheric Sciences
Journal of Geophysical Research-Planets
Journal of Geophysical Research-Space Physics
Journal of Geophysical Research-Solid Earth
Journal of Geophysical Research-Atmospheres
Journal of Geophysical Research-Oceans
Journal of Hydrology
Journal of Paleontology
Journal of Physical Oceanography
Journal of Sedimentary Petrology
Journal of Structural Geology
Mineralium Deposita
Palaeontology
Sedimentology
Tectonophysics



This was a discipline that had exhibited a strong performance in the period covered by *Crisis*. The share of publications in the full journal set has risen and the increase in the share of citations has almost kept pace. The general stability of its RCI across time was mirrored by the A/E Ratio. The A/E ratio was however consistently lower than the RCI which suggested that Australia's presence in the high impact journals might be greater than its presence in the full journal set. This was confirmed by the data extracted for the high impact journal set.



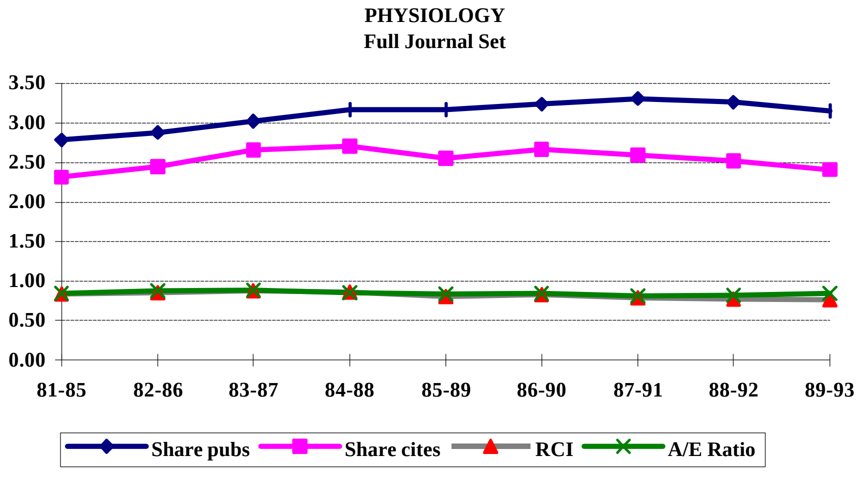
Whilst Australia's share of the full journal set was around the 4% level, its share of the high impact has been increasing across the period to nearly 8%. The share of cites in this select journal set is increasing at the same rate as that for publications and has remained above the publications share. The RCI and A/E Ratio for this set were very similar across time, remaining above 1.00 for the whole period.

Earth Sciences is a field that was counter-trend in Crisis and is a useful comparison for those fields that were in 'decline'. It does not exhibit any declining presence in the higher impact journals - in fact, quite the opposite.

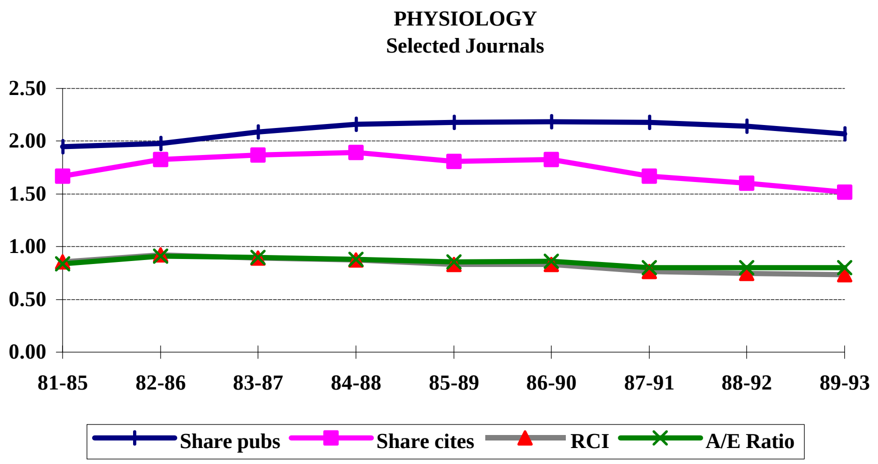
(d) Physiology

The selected journals:

American Journal of Physiology
Annual Review of Physiology
Biophysical Journal
Brain Research
Circulation Research
Developmental Biology
European Journal of Neuroscience
Experimental Brain Research
Journal of Applied Physiology
Journal of Clinical Investigation
Journal of General Physiology
Journal of Neurophysiology
Journal of Neuroscience
Journal of Physiology-London
Kidney International
Neuron
Neuroscience
Pflugers Archiv-European Journal of Physiology
Physiological Reviews



In *Crisis*, the sub-field of Physiology had shown an increasing share of publications, to a level well above the average for Australian science. The increase in the share of citations had not kept pace with that for publications, and had remained at a significantly lower level. The A/E ratio has not declined to quite the same extent as the RCI, but there is not a great deal of difference and both are significantly below 1.00. The hypothesis is unlikely to hold the explanation for the poor performance in this sub-field.

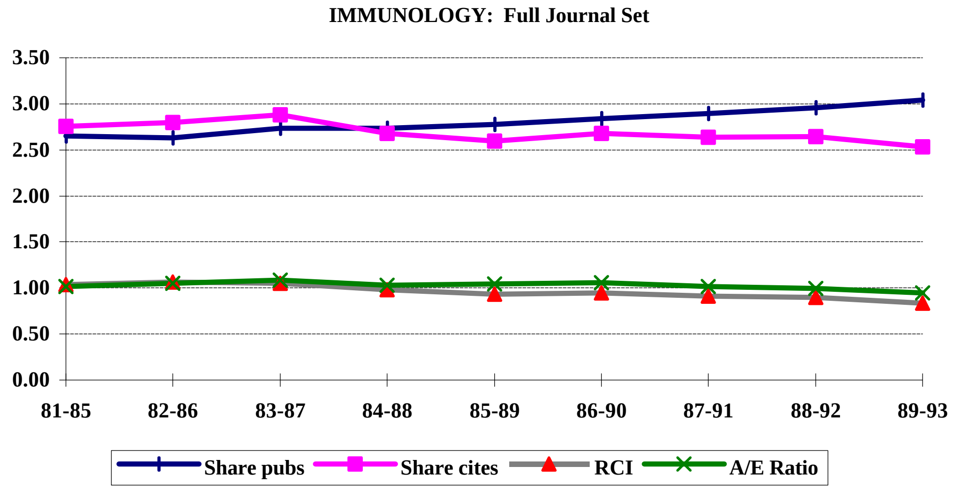


Australia has a smaller presence in the selected journals than the full journal set. Otherwise the trends for both are similar. The explanation underlying Australia's performance in this sub-field lies elsewhere than in the hypothesis.

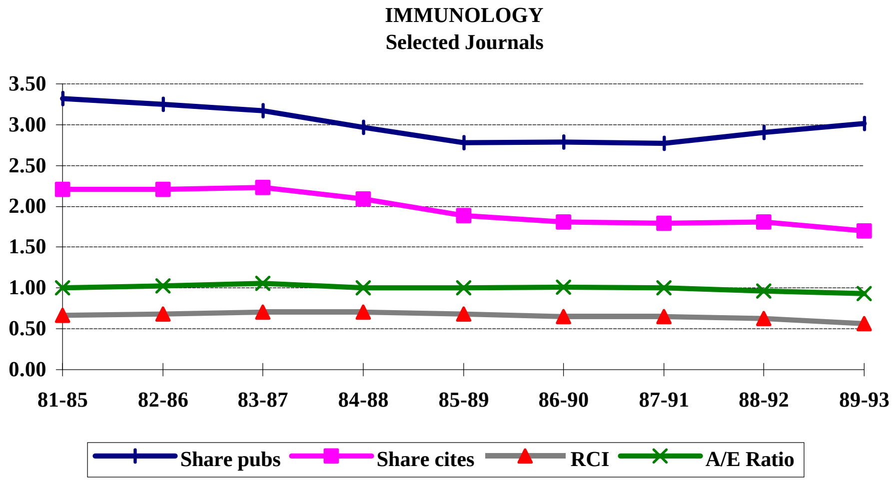
(e) Immunology

The selected journals:

Advances in Immunology
Annual Review of Immunology
Cell
Current Opinion in Immunology
European Journal of Immunology
Immunity
Immunogenetics
Immunological Reviews
Immunology
Immunology Letters
Immunology Today
International Immunology
Journal of Experimental Medicine
Journal of Immunological Methods
Journal of Immunology
Molecular Immunology
Transplantation



In *Crisis* we show a declining RCI for the full Immunology journal set due to an increasing share of publications but a declining share of citations. This decline is particularly evident for the period 1983-87 to 1987-91. However, for this same period Australia's A/E remained fairly constant at around 1.00 (the decline in recent years is post-*Crisis*). This suggests an investigation of the hypothesis may prove fruitful.



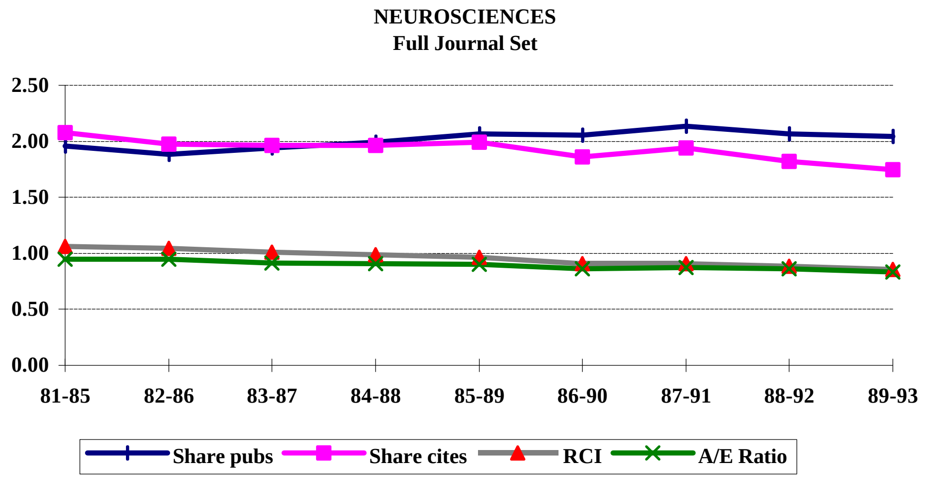
For the period in which we are directly interested: there has been a reduction in Australia's share of publications in these high impact journals; its share of citations is considerably less that its share of publications; the RCI remained relatively steady but at a very low level; the A/E ratio was also steady, but at a much higher level of around 1.00.. The above scenario suggests that Australia's presence is in the lower impact journals of this group and is declining. Whilst Australia's presence in the full set of journals has increased by 10% in the period being studied, its presence in the selected journals has decreased by 16%. The data here supports the hypothesis.

The addition of data for two additional years does not improve the position of this sub-field. While the decline in Australia's share of publications in the selected journals appears to have reversed, its share of citations continues to decline. For the full journal set Australia's A/E has fallen below 1.00 for the first time and the RCI continues to decline.

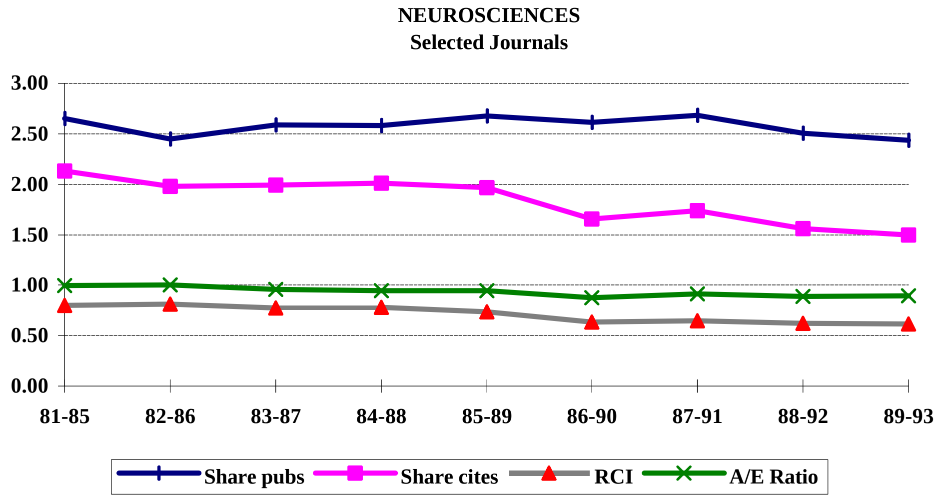
(f) Neurosciences

The selected journals:

Behavioural and Brain Sciences
Brain
Brain Research
Cell
Cell and Tissue Research
Developmental Brain Research
European Journal of Neuroscience
Experimental Brain Research
Journal of Comparative Neurology
Journal of Neurocytology
Journal of Neuroscience
Journal of Neurobiology
Journal of Neurology
Journal of Neurophysiology
Journal of Neuroscience Methods
Neuron
Neuropeptides
Neuroscience
Neuroscience Letters
Neuroscience Research



The full journal set exhibited a marked decline in RCI over the period covered by *Crisis*, due to the share of citations falling at the same time as the share of publications was rising. The RCI and A/E Ratios exhibited almost identical trends over time so we would not expect the decline in RCI to be due to the effect of a decreasing presence in high impact journals.



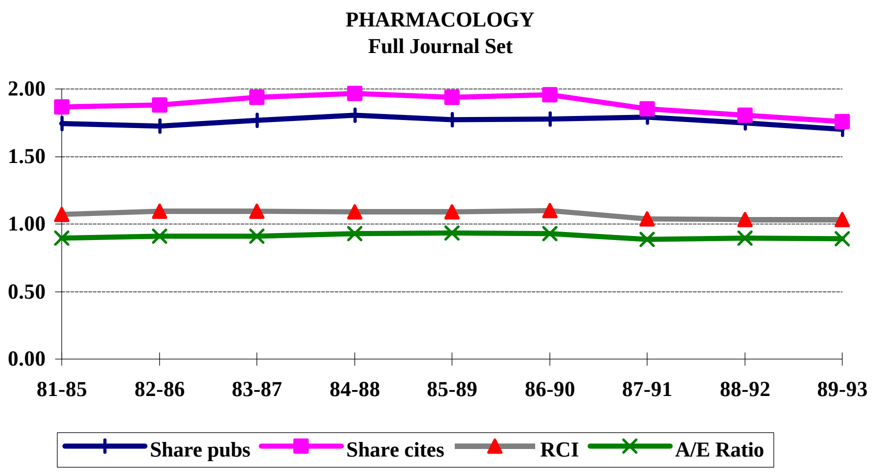
For the period covered by *Crisis*, Australia's share of citations declined whilst the share of publications appearing in the selected journals remained constant leading to a declining RCI similar to that for the full journal set. A comparison of RCI and A/E rates over time showed matching trends. It is interesting to note that Australia's share of publications in the selected journal set is higher than for the full journal set (2.5% level compared to 2% level) but it has a lower share of citations. The fact that the A/E, though exhibiting the same trend as the RCI, is much higher suggests that Australia's publications are appearing in journals at the lower-impact end of this set.

Recent data suggest the performance in this sub-field continues to worsen - there is no sign of a reversal occurring.

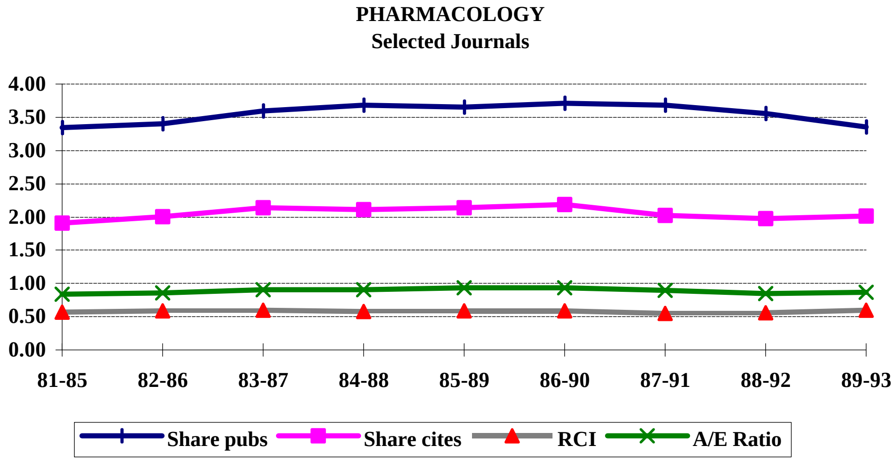
(g) Pharmacology

The selected journals:

Annual Review of Pharmacology and Toxicology
Biochemical Pharmacology
British Journal of Pharmacology
Cardiovascular Research
Circulation Research
Clinical and Experimental Pharmacology and Physiology
European Journal of Pharmacology
Journal of Autonomic Pharmacology
Journal of Cardiovascular Pharmacology
Journal of Neurochemistry
Journal of Neuroscience
Journal of Pharmacology and Experimental Therapeutics
Molecular Pharmacology
Naunyn-Schmiedebergs Archives of Pharmacology
Neuropharmacology
Pharmacological Reviews
Trends in Pharmacological Sciences



The trends for citation and publication shares in this sub-field are similar across the period of *Crisis*, though it can be seen that the decline shown for citation shares in 1987-91 anticipated a decline that would also occur in publication shares (this becomes apparent with the addition of data for an extra two years). It was interesting to note that while the RCIs trend over time was mirrored by the A/E Ratio, the A/E Ratio was lower. This led us to expect that Australia's share of the high impact journals would be higher than for the full journal set, but that it would not be achieving the commensurate number of citations.

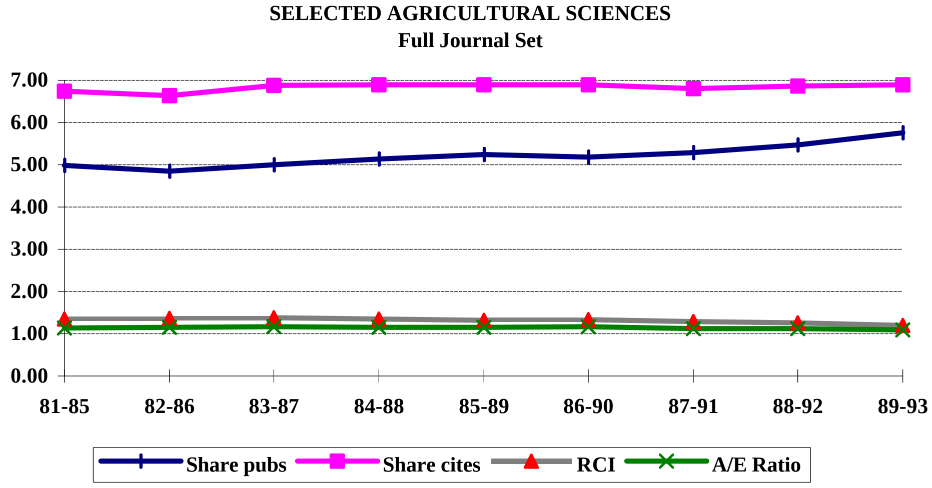


Australia’s share of the selected journal set was very high at around 3.5%, compared to 1.8% for the full journal set, but its share of citations was only at the 2% level. The A/E rate for Australia’s publications in these journals whilst not quite at the 1.00 level was much higher that the RCI, suggesting that it is appearing in journals at the low-impact end of the spectrum. However, there was little change over the period covered by *Crisis*.

(h) Agricultural Sciences[1]

The selected journals:

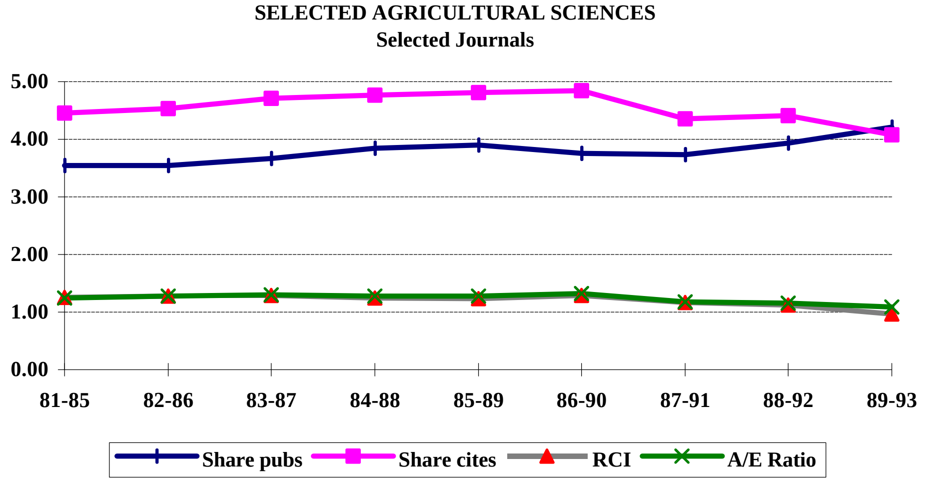
Advances in Agronomy
Agronomy Journal
Environmental Entomology
Journal of Agriculture and Food Chemistry
Journal of Environmental Science and Health (Part B: Pesticides, Food Contaminants and Agricultural Wastes)
Pesticide Science
Plant and Soil
Plant Pathology
Weed Research
Animal Production
Journal of Animal Science
Journal of Dairy Science
Livestock Production Science
Journal of the American Society for Horticultural Science
Journal of Horticultural Science
Biology and Fertility of Soils
Journal of Soil Science
Soil Biology and Biochemistry
Soil Science
Soil Science Society of America Journal



In *Crisis*, Agricultural Sciences was one of Australia's strongest fields. The four selected sub-fields of agricultural science exhibited similar trends: increasing publication shares coupled with constant citation shares (or citation shares not rising as rapidly as publication shares). All showed a decrease in RCI though still

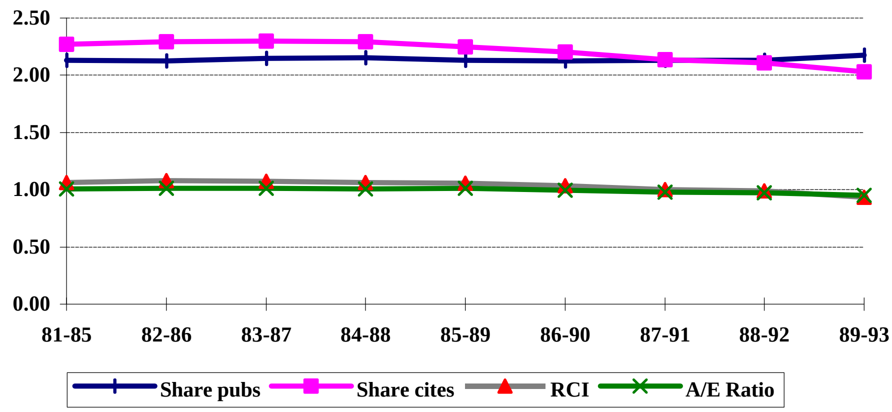
[1] Only selected sub-fields of Agricultural Sciences were covered, namely Soil & Water Sciences, Crop & Pasture Production, Horticulture and Animal Production.

at a level well above 1.00. These trends are shown in the above graph for the four sub-fields combined. The RCI and A/E have followed similar trends across the period, hence we did not expect the hypothesis to hold true in this case.



Australia increased its share of the selected journal set, though this share remains below the level for the whole journal set. There is some cause for concern with the addition of the two additional years data. Whilst the share of pubs has increased, the share of citations has decreased significantly. The A/E ratio has remained above 1.00 but the RCI has fallen below, suggesting that Australia's presence in this set has in recent years moved to the lower impact end of this group of journals.

TOTAL SCI



In *Crisis*, the picture for Australia's science output in total showed a steady share of publications and a sharply declining share of citations, resulting in a declining RCI. However, at the same time the A/E rate declined to a much lesser extent. The preconditions have been set for the hypothesis to be an answer **in part** to Australia's declining citation share.

General Conclusion: We set out to test whether the decline in RCI shown in *Crisis* for Australian science could be explained by a declining presence in the high impact journals. This hypothesis does appear to provide a clue to part of the explanation. Of six case studies of declining fields that were studied in detail, three suggested the hypothesis could be part of the answer - Chemical Sciences, Physical Sciences and Immunology. For the other three - Physiology, Neurosciences and Pharmacology - the answer has to be looked for elsewhere. Both the two case-studies of fields that had remained strong - Earth Sciences and Agricultural Sciences - showed an increasing presence in their high impact journals.

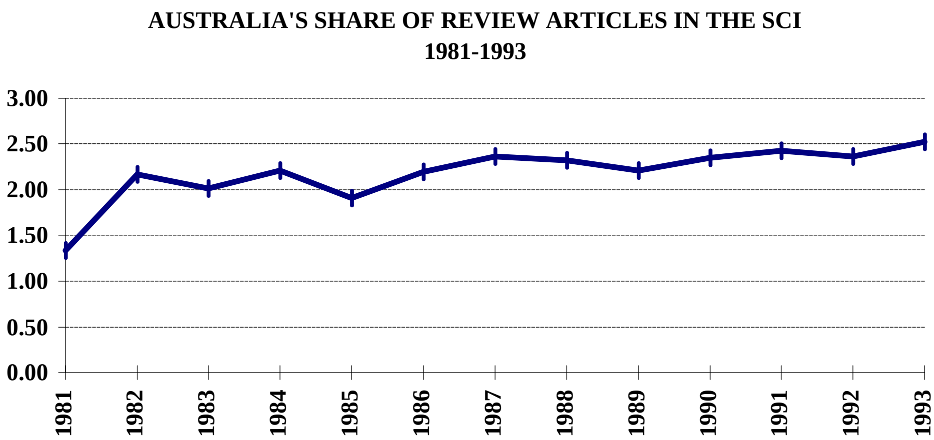
Even though the hypothesis does appear to provide part of the explanation for Australia's decline in citation shares, there remains the question of cause: is it a decline in quality? or is it a displacement effect, with more and more researchers competing for an outlet in the 'top' journals?

4. *Hypothesis: Australians may be publishing fewer review articles, leading to a reduction in citation shares*

Review articles are the most highly cited type of SCI publication. The table below shows the distribution of Australian publications in the SCI by type of publication. It also details the citations per publication rates for each type of publication.

Type of Publication	No.	cpp	*% Dist*
Articles (incl Proceedings Papers)	86798	8.08	*71.1*
Meeting Abstracts	13049	0.29	*10.7*
Notes	8416	5.25	*6.9*
Letters	8356	1.74	*6.8*
Editorials	2017	2.33	*1.7*
Reviews, Bibliographies	**2480**	**17.97**	***2.0***
Discussions	397	1.04	*0.3*
Book Reviews	506	0.12	*0.4*
Biographical Items	59	0.19	*0.0*
Software Reviews	11	2.60	*0.0*

Australia's share of review articles in the SCI over the period 1981-1993 is shown in the graph below.

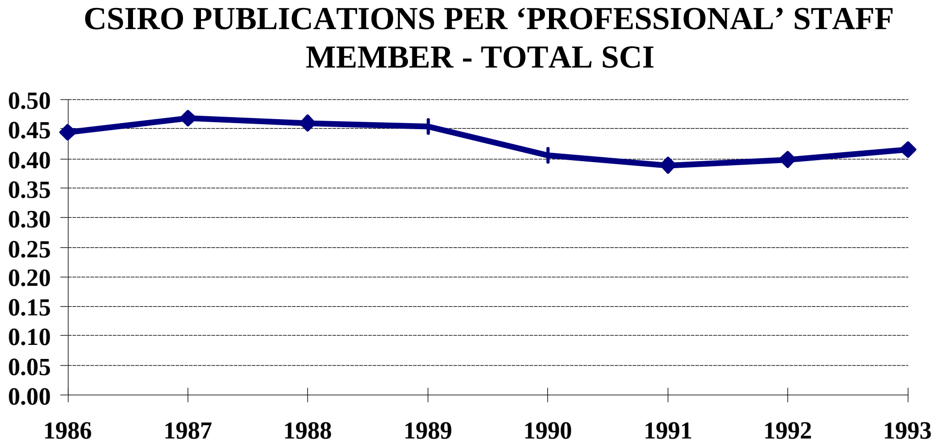


Rather than a declining share of review articles, Australia's share has increased significantly across the period and is at a higher level than that for the average of all publication types. This hypothesis is not supported by the evidence.

5. Hypothesis: CSIRO has moved away from basic research and this has affected Australia's share of citations

CSIRO has historically been a strong performer in basic science as measured in the SCI. A move to more applied research will have a two-fold effect in the current context. Firstly, journals at the applied end of the spectrum attract citations at a lower rate than those that have a more basic focus; secondly, less of CSIRO's output may be appearing in journals captured by SCI - more may be in the form of government reports, consultancies, etc.

It is not possible at this stage to test the first of these aspects, though it may be so in the future. Dr Francis Narin of Computer Horizons Inc produces lists of publications assigned to four levels of research from basic through to strategic which he has available for purchase. An analysis of the pattern of CSIRO's recent publications using this information could prove instructive. In relation to the second aspect, we have undertaken a very crude analysis based on the number of CSIRO publications in the SCI and the number of 'professional' staff of the organisation to see if there has been a reduction in the number of publications per person appearing in the SCI across time. Unfortunately, at this stage we only have staff numbers going back to 1986, and are unsure if the category 'professional' is a true reflection of the number of staff undertaking research.



The result of this analysis does heighten concern over the staff numbers used in the calculations as a level of 0.40-0.45 publications per staff seems low - the term 'professional' may be too broad in its catchment. However the downward trend in the figures does suggest that this avenue is worth pursuing if more reliable staff figures can be obtained.

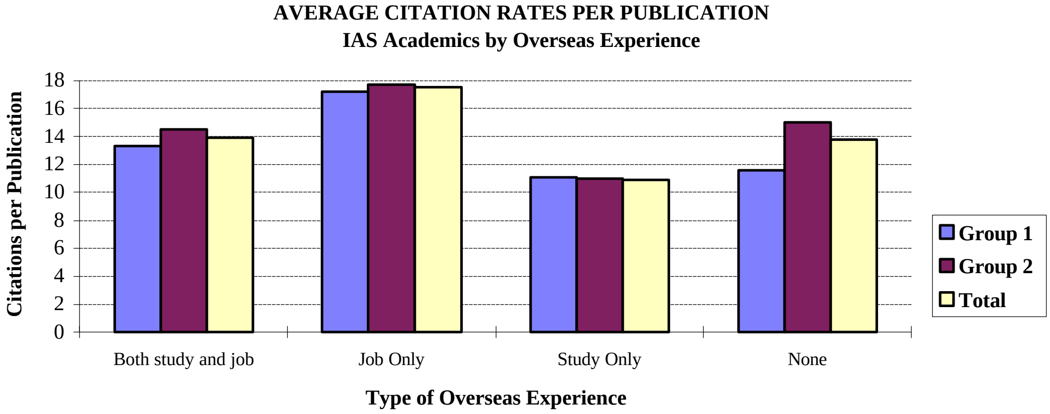
6. Background Information on 'tapping international networks'

Data obtained by Dr Grigg show that the proportion of Australian academics who obtained their higher degrees overseas has significantly declined in recent years. The inference that could be drawn from this is that the extent of their international networks has also declined, leading to the reduction of citation rates. There is no system-wide database that allows us to test the theory that academics who obtained their degree and/or did post-doctoral work overseas attract citations at a greater rate than those who did not. However, the database we constructed for the 1990 review of the Institute of Advanced Studies does allow us to examine this question in relation to the staff of the IAS.

From this database we were able to study the citation rates of 343 academics who we classified according to where they obtained their higher degree and whether or not they had worked overseas prior to taking up a position in IAS. These academics were further divided into two groups:

Group 1: Academics appointed at the level of research fellow or post-doctoral fellow in the period 1980-1982
Group 2: Academics who, in the period 1980-82, were at a level higher than research fellow

We limited the analysis to academics from the IAS's five science schools, and the spread across the different disciplines was fairly even for the number of academics covered. The table below shows the breakdown of citation per publication rates for each of the categories listed above.



The main finding to come out of this analysis was the seeming importance of overseas work in the ability to attract higher rates of citation - those who had both studied and worked overseas did considerably better than those who only studied. For academics whose higher degree qualifications were Australian, those that had worked overseas attracted citations at a greater rate than those who had not. The location of the higher degree appeared to have less importance. While we are reluctant to draw any conclusions from analysis based only on academics from the IAS, it is supported by anecdotal evidence we collected and reported in *International Links in Higher Education Research (ILHER)*. In the *ILHER* study we were told by a number of researchers that their strongest international links were forged during post-doctoral postings overseas, and that links formed during PhD studies were far less important. An increased visibility in the international community can be the key to high levels of citations. The above analysis would suggest that the ability of Australians to obtain overseas posts early in their careers is important, though we would like to test this on a larger sample. We do not, however, have any data to show whether the number of Australians obtaining overseas posts has declined in the period of this study, so we cannot test whether this could play a part in Australia's declining citation shares.