

Chapter three – Developments in Research and Research Training

Before 1990, Australia's higher education research sector was dominated by the nineteen universities that existed prior to 1987. These universities performed almost all the research and trained almost all the research students. The former colleges of advanced education and institutes of technology had little role to play in research. Following the reforms of the late 1980s, all universities expanded their research and research training activities and research outputs, and the number of students completing research qualifications, publications, citations, patents and licences grew accordingly. By the late 1990s, research effort remained fairly concentrated within the universities with traditional strengths in research. However, all universities were actively engaged in research, virtually all could claim to be ranked among Australia's leaders in at least a few disciplines and Australian university researchers participated in many of the world's major research achievements.

As the research and research training functions of universities expanded, so the task of managing these activities increased in complexity. Institutions generally became more focussed on identifying their areas of research strength and strategic importance, and adopted internal funding mechanisms to ensure that these were adequately resourced. Planning and performance monitoring techniques became more sophisticated. In most institutions, linkages involving universities and researchers expanded as personal networks, and collaborative ventures and alliances grew. These trends were consistent with international developments in higher education research associated with increasing globalisation, developments in information and communications technologies, and an increasing interest in ensuring that the benefits of higher education research contributed to innovation.

Universities invested considerable resources to enhance the quality of their research training provision. The introduction of graduate schools provided a more systematic approach to the delivery of research training which became more widespread across the sector. All universities offered development opportunities, such as short training courses, to ensure that their students acquired a broad range of skills. Many institutions introduced mechanisms to ensure that the quality of supervision and access to equipment and facilities satisfied appropriate standards.

Australia's higher education research sector changed significantly over the decade. These changes occurred in a highly competitive environment in response to extrinsic pressures and opportunities, such as: international trends associated with globalisation; changes to the way knowledge is produced; the changing policy environment within Australia; and pressures to respond to community and business interests.

This chapter sets the scene by exploring the significant role that universities play in research. It then examines a number of the key developments that have shaped the research environment over the decade including: the changing forms of knowledge production; the changing policy environment; changing funding arrangements; a changing approach to managing research performance; developments in research training; and the growing emphasis on enhancing the contribution universities make to innovation. It discusses the challenges for universities in realising the benefits of research outcomes.

3.1 The role of universities in research

Research and experimental development may be defined as comprising:

creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society; and the use of this stock of knowledge to devise new applications.
(OECD, 1993, p 29)

The post-World War II period has seen Australia's universities place greater emphasis on a more strategic approach to research and research funding. They are important partners in the national innovation system. Their substantial research efforts are instrumental in:

- training the nation's research workforce and enriching undergraduate teaching;
- expanding the stock of world knowledge;
- promoting innovation and economic growth through the production and diffusion of knowledge and skills;
- providing access by Australian researchers to developments in the international research community; and
- contributing to public debate on important issues.

Training the nation's research workforce and enriching undergraduate teaching

Universities are the main sites for developing and training the nation's research workforce, and can be distinguished from other research enterprises by the presence of large numbers of students pursuing research qualifications and postdoctoral candidates embarking on research careers. While many research students undertake a significant portion of research degrees in a non-university setting – such as public research agencies, Cooperative Research Centres and industry – the ability of higher education institutions to accredit and award degrees ensures that they retain a leading role in research training.

The scale of Australia's research training effort means that much of the research performed in universities is undertaken by students. As student numbers grew more rapidly than those of staff, their relative contribution to research increased over the decade. By 2000, some 70 per cent of the higher education researcher effort⁴⁵ was performed by postgraduate researchers (Australian Bureau of Statistics 2002), up from 62 per cent in 1990 (Australian Bureau of Statistics 1995). (However, this does not imply that research students generate 70 per cent of higher education research outputs as their productivity is unlikely to match those of experienced researchers.)

In addition to the contribution of research to training the future research workforce, it is sometimes argued that the quality of the undergraduate experience is enriched by exposure to a culture of research. Strong proponents of this argument typically claim that there is a symbiotic relationship between research and teaching known as the 'teaching-research nexus', and that 'teaching informs research and research illuminates teaching'.

At some institutions, such as Swinburne University of Technology, this is developed further in a structured manner by providing a small number of select undergraduate students with the opportunity to be immersed in a high quality research environment as part of their formal studies.

Creating new knowledge

Around the world, business and, to a lesser extent, governments, have increased their investment in research and development with a view to achieving economic and social benefits. A good example of research that has the potential to achieve both types of benefits is the mapping of the human genome project (Box 3.1). Over the decade, new fields of research emerged such as

⁴⁵ Research effort as expressed in 'person years'.

proteomics and nanotechnology, and a number of nations around the world, including Australia are investing heavily in research in these areas.

Box 3.1 Mapping the Human Genome

In February 2001, the rival versions of the draft maps of the human genome produced by the international Human Genome Project and Celera Genomics were published in *Science* and *Nature*. The significance of the mapping of the human genome has been likened to the landing on the moon, the splitting of the atom and even the invention of the wheel. (*Nature* 2001) Taking 20 years to complete, the project involved thousands of scientists based in hundreds of laboratories around the globe, including a number of research groups in Australia. Participants were spurred on by a commitment to achieving a goal with far-reaching potential health and economic benefits, and a sense of collaboration and competition. It was underscored by a huge investment in financial and intellectual resources.

Australia is not a major nation in terms of its research outputs, but its contribution to the share of world knowledge exceeds its share of global gross domestic product, and its research is well regarded in international terms. During the 1990s, the most striking achievement of Australia's higher education research sector, was its strong growth, whether measured in terms of researcher effort, research output or expenditure. Between 1991 and 1999, for example, Australia's university researchers boosted their share of the world's scientific publications output⁴⁶ from 1.47 per cent to 2.06 per cent. Citations also showed a similar increase over the period (Butler, 2001b).

Australian universities have traditionally focussed on research at the more basic end of the research continuum, with a strong emphasis on the fields of health and medical science, the social sciences, the biological sciences and the humanities. Over time, the balance has shifted, with applied research accounting for an increased share of total higher education research expenditure. Nevertheless, Australia's universities perform more basic research than is typical among nations belonging to the Organisation of Economic Co-operation and Development (OECD). Australia ranks among the world leaders in terms of higher education expenditure on basic research expressed as a share of gross domestic product. Recent studies (Narin et al 2000, and the OECD 2001a) show a link between patenting activity and basic research. Narin's paper found that around 90 per cent of the scientific papers cited by patents issued in the United States to Australian firms were authored by researchers in publicly funded organisations – either in Australia or elsewhere. Furthermore, of the Australian papers that were cited by Australian-invented patents, approximately 64 per cent came from universities and their associated medical centres.

Contributions to innovation and economic growth

A series of recent studies have argued that knowledge, innovation and technology diffusion make an important contribution to economic growth at both the micro- and macro-economic levels (OECD 2000a, OECD 2001b). In certain fields, such as biotechnology and information and communications technology, the relation between scientific research and innovation may be relatively direct (OECD 2000b). Another study, however, has argued that economic growth is affected not only by the quantum of funding but by the way funds are allocated (for example, in terms of the institutions, fields and industries to which they are directed, and the mechanisms used to finance research) and by knowledge dissemination and research commercialisation practices that are adopted (OECD 2001b).

While the relationships between knowledge creation, innovation and economic growth are complex, there is widespread acceptance that the creation, distribution and exploitation of

⁴⁶ As measured by publications on the Science Citation Index indexed by the Institute for Scientific Information.

knowledge can lead to jobs growth and better standards of living. While Australian universities have been actively engaged in the creation of knowledge for around half a century, their roles in relation to the distribution and exploitation of knowledge have been less prominent until recently (Box 3.2).

Box 3.2 The Macquarie University Research Park

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Macquarie University is surrounded by the major Australian offices of many of the world's leading technology companies. This is the result of a far-sighted decision by Ryde City Council, at the time of the University's creation in the 1960s, to restrict the zoning of the North Ryde region to companies engaged in research and technology. The Macquarie University Research Park was conceived in the late 1980s and launched in 1996 as a means by which Macquarie could develop and utilise strong, enduring, links with industry which would:

- contribute to economic development in the region through research and consulting projects.
- enable the University to become more skilled at industry collaboration with Park tenants and thus to strengthen industry links in the Ryde precinct and beyond.
- provide opportunities to commercialise University research, including through incubation facilities for start-ups.
- earn income from ground rental in support of University research.

These broad objectives make large, trans-national companies highly suitable tenants, since those companies can work with the University in a number of areas. They also bring to the University vitally important international links in the global age. And, of course, large, successful companies are ideal tenants for a Park that is financed by private capital. The Park relies entirely on private investment. This exposes every development to the test of market relevance.

Despite the considerable potential benefits, world-wide experience shows that genuine collaboration between universities and industry within science parks has been difficult to achieve. Companies in science parks are commercially orientated and need to be persuaded that the University offers attractions. Macquarie's strategies for establishing relationships are designed to make staff of tenant companies feel part of the University community by:

- locating the Park close to the science departments;
- having Macquarie Research Ltd, the University's technology transfer company, as a Park tenant to manage commercial relationships;
- making the park manager responsible for facilitating interactions with the University. Some parks have neglected this key intermediary role;
- offering tenants privileged access to university facilities, such as the library, sporting and social clubs and staff seminars;
- holding regular seminars, social gathering and briefings, where university and tenant staff can mingle; and offering special scholarships for students to conduct their research projects through Park companies.

Four buildings have been completed, totalling some 35,000 square metres, with an investment by the private sector of over \$100 million. There are twelve tenants, ranging from large companies such as Siemens, EMC2, Goodman Fielder, Becton Dickinson (now BD) and Dow Corning, to smaller companies (in Australia though not globally) such as Covance and Eppendorf.

This has exceeded the University's expectations. Now that the infrastructure is in place and excellent tenants secured, the University has slowed the rate of development and is concentrating on filling gaps and targeting particular companies, especially in biotechnology.

Knowledge transfer and diffusion is facilitated by formal mechanisms, such as publication of research findings, patenting and licensing activities and by informal mechanisms, such as professional networks, and the movements of staff and former students between universities and other elements of the innovation system, both within Australia and internationally. Developments such as the emergence of cross-sectoral research centres, collaborative ventures and complex alliances, which draw together individuals from different backgrounds, have also encouraged the transfer and diffusion of knowledge between different elements of the innovation system. These trends have been supported by government incentives to promote university-industry collaboration.

Provision of access to global knowledge

Australia produces around two per cent of the world's knowledge and in terms of research output 'punches above its weight' relative to economic indicators and population. However, in order to access the other 98 per cent of knowledge produced elsewhere in the world, Australian researchers must remain actively and successfully engaged with the global research community. In effect, Australia's investment in research, including higher education research, is buying access to global knowledge, and to the influential bodies and individuals with which it is associated. This concept was articulated in a submission by the Walter and Eliza Hall Institute of Medical Research to the Industry Commission's report on research and development (1994).

Being professionally and successfully engaged in research buys one a seat at the international table and in particular in the power elites or 'invisible colleges' which surround every major discovery area. Reading scientific papers and textbooks, or attending large international conferences as an 'outsider' are relatively ineffective ways of judging competing new ideas and technologies, not only because of significant delays (9-18 months) between discovery and promulgation in these forms; but also because a deep involvement in the research field of interest lends a perspective and a balance that can be obtained no other way.

(Industry Commission 1994, p. c33)

Professional networks established and maintained on the basis of the reputation and contribution to the discipline of individuals and of teams, facilitate access to research developments around the globe. They are vitally important to knowledge diffusion particularly for researchers working at a distance from the key areas of activity in their field.

Contributions to public discourse

The final contribution made by some academics – who are usually active researchers – is by promoting informed, open debate on matters of public interest. Scientists engaged in research with a strong public interest dimension, for example, may be well placed to help explain the nature and potential applications of their endeavours. In the last decade, advances in science and medicine, in particular, have raised important questions of equity, ethics, the law, privacy and public safety. Examples of issues where research has generated strong community interest and debate include:

- equity issues associated with the fact that some research breakthroughs may be accessible only to the most affluent members of society;
- ethical concerns associated with the use of human embryonic stem cells to grow tissues to replace those lost to disease, injury or ageing;
- privacy concerns associated with the collection and use of vast quantities of personal information in sophisticated data bases;
- concerns over the extent to which business should be permitted to acquire and exert rights over genetic material; and
- concerns with the production and use of genetically modified organisms, including in food.

3.2 The changing forms of knowledge production

Academic research is traditionally structured in terms of a discipline-based framework, and conducted in accordance with a research agenda determined by the academic interests of the research community (Gibbons et al. 1994). Research findings are formally communicated through publications in professional journals and through conferences. This model tended to reinforce an essentially linear view of the relationship between research and its application, with the university researcher being perceived to function at the high theory end of the chain, far removed from the application and commercial exploitation of knowledge.

While research conducted in this manner will continue to be important, it was suggested early in the decade (Gibbons et al. 1994) that a new form of knowledge production and dissemination – ‘Mode 2’ knowledge – was emerging. This new form of knowledge production occurs in a wide range of settings and commonly spans discipline, sectoral and geographic boundaries and is often based on the efforts of teams and networks of researchers, rather than individuals. In some cases, the teams are transient in nature, brought together to perform particular tasks, and dissolved once their objectives have been met. By the middle of the decade, basic research, and academic research generally, was coming into closer interaction with technology development (National Board of Employment, Education and Training 1995), and industrial application interests and parameters were helping to guide problems in basic research (National Board of Employment, Education and Training 1996).

Trends in the public funding of higher education, pressures for commercialisation of university generated intellectual property, new approaches to research management within corporations, a changing culture of learning, and growth in small companies in high technology industries led to the emergence of new forms of research that required close working relationships between people from different disciplines and professions (Australian Research Council 2001). These trends were noticeable in the United States where there were:

formally designated interactions of university-based researchers with business people, venture capitalists, patent lawyers, production engineers, as well as research engineers located outside the university. This has invariably shared use of academic and industrial facilities. Under these conditions, technology is more likely to be trans-disciplinary, and to be carried out by people who are able to rise above disciplinary and institutional loyalties. These and similar changes and transformations are advancing so rapidly that their impact on traditional institutions and attitudes has just begun to be understood.
(Ganguly 1999, quoted in Australian Research Council 2001 p. 21)

In the Australian higher education sector too, at the end of the past decade much research was being conducted in ways that were radically different from the conventional academic model. However, while the pace of change may have escalated in the late 1990s, it is also important to recognise that these trends have been underway in the Australian context for more than two decades:

- since the mid-1970s there has been a subtle but steady increase in the share of research performed in higher education institutions at the more applied end of the research continuum;
- collaboration in research publications has grown steadily since the early 1980s;
- research centres, which provide a platform to tackle research problems on a cross-disciplinary, and sometimes, cross sectoral basis, have been an important feature of the Australian higher education research landscape since the mid-1980s;
- distinctions between basic and applied research were recognised by the Commonwealth as largely artificial and meaningless in some situations (Dawkins 1989); and

- universities have developed a complex array of alliances and collaborative ventures with other institutions, research organisations, governments and industry, both domestically and internationally to take advantage of potential opportunities.

During the late 1980s and the 1990s the pace of change quickened as higher education institutions attempted to respond to the massive increase in demand for specialised knowledge associated with the emergence of the 'knowledge-based economy'. Collaboration has become the norm for publishing academic research, with single author papers accounting for only around ten per cent of Australia's scientific publications by 1999 (Butler 2001b). Networks and alliances, based on cooperation and collaboration, are becoming increasingly important. Universities have become more closely linked with other institutions, public research agencies and industry through complex collaborative arrangements and alliances than was previously the case, and are attempting to leverage entrepreneurial advantage from these arrangements. Multi-disciplinary research centres began to emerge as leading performers of research in Australia and they may have already accounted for half of Australia's higher education research effort by 1995 (National Board of Employment, Education and Training 1995).

University-industry partnerships received further impetus by the spread of venture capitalism, and Australian venture capitalists were becoming much more involved in university-business-finance partnerships in technology areas (Australian Research Council 2001). A recent example of such a partnership is the Australian Photonics Cooperative Research Centre (Box 3.3).

Box 3.3 The Australian Photonics CRC Story

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The Australian Photonics Cooperative Research Centre was originally established in 1992, bringing together the Optical Fibre Technology Centre, the Photonics Research Laboratory, the Optical Communications Group and the Optical Sciences Centre. The Centre was initially supported by Telstra, Siemens, Fibernet, TransGrid and NEC and later joined by eight additional industry participants. Its brief was renewed in 1999 for another seven years. It now has 29 participants. Five universities, DSTO, TAFE NSW, two venture capital companies, as well as five Cooperative Research Centre start-ups and other industry participants. The mission of the Centre is to conduct high quality research which can be taken up by industry, the outcome of which provides social and economic benefit to Australia.

The Centre has a distinctive approach to managing research and research training which lies in its 'laissez faire' approach, based on trust, to maximise innovation from researchers, underpinned by a strong intellectual property regime. In the early years, attempts were made to establish research project management systems but the Cooperative Research Centre management team quickly found that they were drowning in reports. In establishing research priorities within a limited budget, there has been continuing tension between seeding research over a wide spread of projects and technologies, and focusing more substantial resources on a few projects.

Research projects fall into four different categories:

- Centre projects funded by the CRC grant (for which the intellectual property is owned by the participants as tenants in common and is available to all participants);
- Collaborative projects, with intellectual property rights determined by contract between the research institution(s) and industry participant(s) and intellectual property owned by the contracting parties and made available to all participants as background intellectual property;
- Applications projects undertaken under contract but with background intellectual property only available to contracting parties; and
- Associated projects which use Cooperative Research Centre facilities.

Centre projects tend to involve longer-term strategic research and often arise from serendipitous discoveries made by researchers or research students. It is our experience that some of our most significant patents have their basis in student research. Projects conducted under contract are much more tightly managed with researchers being required to meet milestones and provide regular reports. Incentives for researchers and other staff to participate in the outcomes of successfully commercialised research have been developed through a number of unit trusts that have access to shares in spin-off companies.

From our experience over the past nine years of research collaboration in an industrial context, we can conclude that research innovation can be stifled by too much management; that there is a need to keep a balance between focused research and projects which provide the freedom to go beyond the square; that research staff should share in the benefits of commercialisation, and that there is never enough funding to support all the work that needs to be done to underpin the growth of new industries in Australia.

Advances in information and communications technologies are also driving changes in the way knowledge is being produced and disseminated. The changes can be profound as illustrated by recent developments in biology where research to model the behaviour and functions of genes and proteins is likely to be transformed from a bench science, dominated by competing research groups, into a collaborative enterprise organised around huge databases and their associated computational tools (Butler 2001b). Already a number of research groups are developing global databases to assist researchers around the world. Online publishing of research findings in these fields could eventually replace the conventional scientific paper as the dominant form of communication. These trends are still in their infancy, and can be expected to develop further during coming years.

3.3 The Commonwealth policy framework for higher education research

The late 1980s were a watershed period for higher education, coinciding with changing community expectations for education, a deteriorating economic climate, and growth in the scale of teaching and research functions of higher education institutions. Previously, higher education research and research training had been dominated by the nineteen existing universities. These institutions were funded at a higher rate than the colleges of advanced education as they were considered to have a specific responsibility to perform research that was not expected of other higher education institutions.

In 1988, the pre-1987 universities accounted for 95 per cent of total higher education research. However, while the colleges and institutes were ineligible for Commonwealth research grants, they did perform some research and expended some of their Commonwealth funding on research activities. In addition, some of the institutes attracted industry funding to perform industry-related research. Interestingly, 30 per cent of all higher education research revenue from industry in 1988 was associated with these activities (Department of Employment, Education and Training 1993 p. 267).

However, the overall contribution of the former colleges and institutes was small, and even among the pre-1987 universities, resources and activity tended to be concentrated in a smaller grouping. Karmel (1992, p. 144) noted that just nine universities enrolled two thirds of research students, seven universities conducted two thirds of all research activity and only nine or ten universities had significant research libraries. Despite its relatively small size, the Australian National University had established an enviable reputation for research due in large part to the standing of its Institute of Advanced Studies, which was specifically funded by the Commonwealth to perform research.

Reviews and Commonwealth policy statements in the late 1980s

During the late 1980s, the Commonwealth commissioned several inquiries which reported on the position of higher education research and research training and which recommended substantial reforms. These included the Australian Science and Technology Council's (ASTEC) report *Improving Research Performance of Australia's Universities and Other Higher Education Institutions* (1987) and the Report of the Committee to Review Higher Education Research Policy (the 'Smith Review Committee') *Higher Education Research Policy* (1989). The Government responded first in the White Paper, *Higher Education, A Policy Statement* (Dawkins 1988), which announced a new framework for the higher education sector, and in more detail in the Ministerial statement on research titled *Research for Australia: Higher Education's Contribution* (Dawkins 1989).

The impacts of these reforms were substantial and far-reaching and established the policy framework that endured for most of the 1990s. The most significant outcome was the virtual doubling of the number of public universities, all of which were expected to perform research. To support the expanded teaching and research functions associated with the reforms, the Commonwealth increased funding for operating grants over the 1989-91 triennium. It also introduced a controversial 'clawback' which redirected a portion of the operating grants provided to the pre-1987 universities (\$65 million annually in 1987 dollars) (Department of Employment, Education and Training 1993, p. 256) to the competitive grants programmes administered by the newly established Australian Research Council, and the National Health and Medical Research Council. From 1990, additional funds were also provided for research infrastructure and research training.

Building on the former Australian Research Grants Committee, the Australian Research Council was responsible for supporting research in all disciplines except clinical medicine and dentistry, which would continue to be supported by the National Health and Medical Research Council. To this end, the Council was required to make recommendations to the Minister on the distribution of resources administered under its programmes, including the new funding provided through the 'clawback' and for research infrastructure. Its funds grew rapidly – for example, research grant funding alone increased from \$59.8 million in 1989 to \$104.6 million in 1993 (1991 dollars) (Department of Employment, Education and Training 1993, p. 286). The Australian Research Council was also responsible for advising the National Board of Employment, Education and Training on research policy issues, including matters such as national research priorities, the coordination of research policy, the development and funding requirements of research support programs, research training and measures to improve interaction in research between the public and private sectors.

One of the outcomes of the reforms was the suggestion that funds should be allocated to researchers of outstanding ability on a competitive basis:

research funds should be allocated competitively, and should go to those institutions, research groups, and individuals best able to make effective use of them.
(Dawkins, 1989, p. 2)

This approach had been widely used by government research agencies and industry, but less used within Australia's higher education sector to that time. A greater proportion of competitive funding to support research in universities was introduced in order to respond to international trends associated with the increasing scale and complexity of research, rising equipment costs, the emergence of interdisciplinary research and commercialisation interests. The Commonwealth considered that the competitive peer review processes of the Australian Research Council and the National Health and Medical Research Council and institutional research management processes would be the vehicles for achieving the selectivity and concentration necessary to achieve a

critical mass of research effort, to provide a stimulating environment for research training, and to respond to escalating costs associated with research equipment and resources (Dawkins 1989, pp. 14, 18).

To encourage institutions to allocate their research funds in a manner 'under which priority is given to the best researchers,' the Commonwealth (Dawkins 1989, p. 2) announced that universities would be required to develop research management plans to guide their funding decisions. The research management plans formed part of the documentation to be submitted to the Commonwealth for profiles negotiations and described the range and scale of institutions' research activities, areas of specialisation, and their research objectives.

Another issue addressed by the Australian Science and Technology Council and Smith Committee Reports was an attempt to define the roles of higher education research in the national research system. This issue had been the subject of debate during the preceding decades over the relative importance of higher education in advancing knowledge, almost as a national cultural responsibility on the one hand, and in contributing to national, social or economic objectives on the other (Department of Employment, Education and Training 1993, p. 248). The Australian Science and Technology Council report recommended that the Commonwealth should endorse the following statement on the major roles of higher education institutions in the national research system:

- To undertake basic research for scientific and cultural reasons;
- To undertake research of value to the Australian economy and society;
- To provide research training at postgraduate and postdoctoral levels;
- To assemble, analyse and disseminate new knowledge across a wide range of disciplines; and
- To examine problems of national and regional importance, including issues related to Australia's geographic size and location.

(Australian Science and Technology Council 1987, p. 18).

This definition was supported by the Smith Committee, with the additional proviso that 'high quality should be the hallmark of all research whether basic, strategic or applied, conducted in higher education institutions' (Committee to Review Higher Education Research Policy p. 19, cited in Department of Employment, Education and Training 1993 p. 248). The Commonwealth did not explicitly endorse the statement, although it acknowledged in *Research for Australia* (Dawkins 1989) that it expected that most research done in the higher education sector would continue to be basic in orientation.

The new policy framework provided a challenging environment in which to perform research and research training. Some critics alleged that the new framework shifted the balance for decision making responsibilities from institutions to a centralised body, namely the Australian Research Council. Others, such as Meek and O'Neill (1996) claimed that the policy framework could actually work against diversification by encouraging some universities to imitate the research profiles of other universities. A further widely held concern was that the available resources were inadequate to sustain a strong research and research infrastructure capability across the sector and that well intentioned but misguided attempts to spread research resources too thinly could put at risk the overall quality of institutions' research and teaching functions (Senate Standing Committee on Employment, Education and Training 1994a).

However, despite its critics, the new research framework stimulated a surge of activity across the sector which continues to this day. Universities with an established research tradition sought to strengthen their research profiles. The post-1987 universities, and those parts of older universities that were not traditionally oriented towards research, attempted to define their research mission and establish a research culture consistent with this vision. Substantial resources were devoted to

supporting staff to acquire the skills and qualifications necessary to enable them to fulfil their research functions. The Commonwealth supported the newer universities in this process through the Staff Development Fund.

Underpinning this activity were the motivating factors of prestige and financial rewards. In an academic context, prestige is strongly linked to perceived research performance. Ramsden (1999, p. 342) has suggested that 'somewhat paradoxically, in an age of mass higher education, research performance is possibly the most important factor for assessing the standing of the modern university'. Slaughter and Leslie (1997) argued that universities and individual academics are 'prestige maximisers' and that success in attracting external research funds, whether from government or industry, is a crucial factor in enabling institutions and individuals to acquire prestige and differentiate themselves from others. Research performance is acknowledged through success in winning externally derived research income and also provides one of the few opportunities for universities to grow their revenue stream.

The framework announced in *Research for Australia* rewarded institutions for their research performance by awarding competitive grants on the basis of research excellence and by allocating funding under the 'Research Quantum' and other research infrastructure schemes on the basis of research performance. The Research Quantum was born out of the White Paper reforms and was intended to recognise the non-salary components of research within the operating grants. It was initially set at around 6 per cent of operating grants and was allocated to institutions on the basis of their success in attracting Commonwealth competitive grants.

It was soon recognised, however, that income from competitive grants reflected only one dimension of universities' overall research performance. The mechanism was expanded to take account of research income from other sources, including industry, and incorporated output measures, such as publications and research degree completions. However, while the Research Quantum remained merely a component of operating grants and barely moved in value over the decade, the performance measures with which it was associated were highly influential in driving institutional behaviour.

Research for Australia announced that a small number of postgraduate awards would be established for students undertaking research projects in association with industry. Shortly afterwards, the Government also announced the first collaborative grants to 'support research with the potential to achieve social or economic benefits to Australia'. While higher education research funding would continue to be allocated primarily on the basis of research excellence, it would also take account of the requirements of research users and the potential for innovation. From these modest beginnings, support for the Australian Research Council's industry collaboration programmes grew strongly over the decade, reflecting government commitment to strengthen cross-sectoral linkages, and to enhance the contribution of universities to innovation.

The West Review and the Policy Statement *Knowledge and Innovation*

In the 1996 Budget, the then Employment, Education, Training and Youth Affairs Minister, Senator Amanda Vanstone, announced a broad ranging review of higher education financing and policy, to include research and research training. The review committee, under the chairmanship of Mr Roderick West, identified weaknesses with respect to both research and research training and made recommendations to the Commonwealth on a range of issues including alternative funding arrangements for research students, the provision of increased funding for research infrastructure, and changes to structure of the Australian Research Council and its programmes (West, 1998).

The Government did not provide a detailed formal response to the West Review, but it recognised that there were several areas of emerging concern with the provision of higher education research and research training, particularly with respect to the quality of research training provision. Drop out rates and completions times were excessive (Karmel et al, 2001), with a consequential loss of

time, talent, enthusiasm and resources. Research students were distributed more widely across the sector than research income (a crude proxy for research performance), suggesting a degree of misalignment between the location of research students and high quality research environments. Bourke and Butler (1998) observed that the distribution of Australian Postgraduate Awards with stipends was less concentrated in the research intensive universities than other measures of research performance, such as research expenditure and publications and citations in journals indexed by the Institute for Scientific Information. A report on research training requirements (Department of Education, Training and Youth Affairs 1998) identified a number of issues to be addressed to maintain and enhance the quality of the postgraduate research training environment. While acknowledging that there were pockets of excellence in research training, the Government considered that the overall standard left room for improvement. It also observed that the Commonwealth's policy framework provided few incentives to encourage institutions to improve their research training performance.

Other areas of concern included the need to strengthen the Australian Research Council, and to streamline and increase the flexibility of its programmes; stronger incentives for universities to strengthen their links with other institutions, government and industry; and improved accountability by higher education institutions for the expenditure of public funds on research and research training. The Minister for Education, Training and Youth Affairs, Dr David Kemp issued the discussion paper *New Knowledge, New Opportunities* in mid 1999, and a policy statement on research and research training titled *Knowledge and Innovation* in December 1999 which addressed these areas of concern. *Knowledge and Innovation* revisited a number of the issues identified in *Research for Australia* a decade earlier, including competitive funding arrangements, research selectivity and concentration, and the quality of research training.

The statement was intended to respond to concerns that Australia's research effort needed to be further concentrated in areas of strength in order to build on areas of performance in research and keep pace with international competitors. It acknowledged that improved linkages with industry and other users of research, and increased responsiveness to potential commercial opportunities could promote innovation, economic growth and social wellbeing. It also sought to encourage universities to adopt diverse approaches to global market opportunities and to set strategic research priorities tailored to institutional requirements.

Knowledge and Innovation announced changes in five key areas. Firstly it sought to address concerns identified in respect of research training by introducing performance-based funding for research training places. Funding for places would take account of institutions' success in attracting research income, in achieving research degree completions and in publications output. The introduction of a limit to Commonwealth support for higher degree students, amounting to four years equivalent full-time for PhD students and two years for Masters students, was intended to improve the rate and duration of student completions and encourage universities to look to their internal arrangements for selecting students, structuring research programmes and providing supervision and support. Further information concerning this initiative is provided in the section on developments in research training.

The second major change was to further encourage universities to diversify their funding sources and enhance their links with industry and government by increasing the rewards for attracting research income from these sources. Until this time, the peer review assessment processes and the highly competitive nature of competitive grants were used to justify greater recognition for research income from competitive grants. The new framework changed this arrangement so that industry-sourced income would be valued as highly as income from competitive grants for the first time. This change recognised that industry and other 'purchasers' of research have strong incentives to invest in research in a discriminating manner and that direct peer review is not the only process that is able to discern high quality research. It is also consistent with the findings of Harman (1999, p. 100) who undertook a study on university-industry links in the science and

technology disciplines and found that researchers who are supported by industry are commonly senior academics with highly regarded research reputations.

Knowledge and Innovation announced that the Australian Research Council would be established as an independent body under its own Act, with strengthened powers and responsibilities, and a new structure comprising a Board, with a Chair and a Chief Executive Officer. The Australian Research Council's programmes would be rationalised into a single, flexible national competitive grants programme, comprising a 'discovery' element focusing on support for basic research, and a 'linkage' element to underpin collaborative research. The new *Australian Research Council Act 2001* came into effect from July 2001.

The fourth change announced in *Knowledge and Innovation* was the introduction of Research and Research Training Management Reports as an accountability mechanism and pre-condition to receive block grant funding for research and research training. The final initiative announced in *Knowledge and Innovation* was the introduction of targeted funding to support research of benefit to regional communities and additional funding to ensure that regional universities would not be disadvantaged by the introduction of the new policy framework.

3.4 Changing finances

The growing importance of research and research training activities in the higher education sector has been underpinned by a steady increase in expenditure on research and research training. Australia's higher education research expenditure grew strongly during the 1980s, but by the end of the decade still remained in the mid-range among countries belonging to the OECD. In 1990, Australia's expenditure on higher education research represented 0.34 per cent of gross domestic product compared with an OECD mean of 0.36 per cent (OECD 2001c, p. 161). However, by the late 1990s, Australia's investment in higher education research expenditure had reached 0.43 per cent of gross domestic product, compared with an OECD average of 0.38 per cent (ABS 2002, p. 4; OECD 2001c, p. 161). In 2000, the percentage fell slightly to 0.41 per cent (ABS 2002, p. 4), due largely to the strong growth in Australia's gross domestic product.

In Australia, research is concentrated to a greater extent in universities than is typical for OECD nations. In 1998-99, some 29.4 per cent of Australia's research expenditure occurred in the higher education sector, up from 25.5 per cent in 1990 (see Table 3.1) (OECD 2001c, p. 151). By comparison, universities in the European Union performed 20.4 per cent of their nations' research effort by the late 1990s, and universities in the United States accounted for only 14.1 per cent (OECD 2001c, p. 151). The share of research performed by business in Australia, while growing over the decade remained relatively low by international standards, accounting for only 46 per cent of the total research effort, compared with around 70 per cent across the Organisation of Economic Cooperation and Development (OECD 2001c, p. 151). As a result of the relatively modest contribution by the business sector, Australia's total expenditure on research and development in 1998 accounted for 1.49 per cent of the nation's gross domestic product compared with 2.18 per cent for the OECD as a whole (OECD 2001c, p. 147).

Table 3.1 Expenditure on research and development in Australia, by sector

	1990-91	1992-93	1994-95	1995-96	1997-98	1998-99	1999-00
Higher education	\$1,332.80 (26%)	\$1,695.2 (26%)	\$1,829.6 (25%)	\$2,029.1	\$2,307.6 (26%)	\$2,602.7 (29%)	Na
Business	\$2,099.8 (40%)	\$2,861.9 (44%)	\$3,498.7 (47%)	\$4,356.8	\$4,246.9 (48%)	\$3,991.7 (45%)	\$4,045.3
Public research agencies	\$1,704.0 (33%)	\$1,823.9 (28%)	\$1,982.6 (27%)	Na	\$2,076.9 (24%)	\$2,071.6 (23%)	Na
Total	\$5,222.0	\$6,482.9	\$7,466.6	Na	\$8,804.8	\$8,849.9	NA

Source: Australian Bureau of Statistics (1998b, 2000b)⁴⁷

Traditionally, Australian universities have focussed on research at the more basic end of the research continuum. Over time, the balance has shifted so that applied research has become more significant. In 1978, applied research and experimental development accounted for some 31 per cent of total higher education research expenditure. This share had grown to 37 per cent by 1990, and almost 46 per cent by 2000 (ABS 1995b and ABS 2000b). Between 1990 and 2000, expenditure on applied research increased from \$403 million to \$1.26 billion. However, this does not mean that basic research was in decline. Despite losing overall share, expenditure on basic research increased from \$669 million in 1988 to \$1.513 billion by 2000, (ABS 1995b and ABS 2000b) and it continued to remain at the heart of Australia's university research enterprise.

Commonwealth funding for higher education research and research training

While State and Territory governments, industry and international sources each make a significant and growing contribution to funding research, the principle source of funding has traditionally been the Commonwealth Government. The Commonwealth's substantial contribution is justified in economic terms on the basis that research and research training provide a public benefit. In 1986, it is estimated that 93 per cent of higher education research expenditure was sourced from the Commonwealth. This declined to 88 per cent by 1990 (Industry Commission, 1994) and was estimated at around 70 per cent⁴⁸ in 2000 as other sources of revenue, including industry and related sources, increased in relative importance.

Most of the Commonwealth funding expended on research was allocated through universities' recurrent grants rather than targeted specifically for research. Until 1986, targeted funding for research represented only about 17 per cent of Commonwealth higher education research funding. This situation contrasted with most other member nations of the OECD which provided a greater share of their support for university research through targeted programmes. During the latter part of the 1980s, targeted research funding became more significant in the Australian context, so that by 1991 it comprised around 29 per cent of Commonwealth higher education research funding (Department of Employment, Education and Training 1993). This trend was associated with the emergence of research centres – which concentrate research effort into designated areas – as an important feature of the higher education research landscape.

The Commonwealth provides support for higher education research and research training through complex funding arrangements involving a range of portfolios and programmes. In particular, these include grants to support higher education research and research training specifically, grants to support the full range of university functions, including research, and grants to support

⁴⁷ Figures in this chart do not equal the total provided because the small "Private non-profit" sector has been excluded.

⁴⁸ Derived using Australian Bureau of Statistics data. In addition to including all funds that are fully sourced from the Commonwealth, the figure includes an estimate of the Commonwealth's contribution to 'General University Funds'.

specific objectives (such as health and medical research) available on a contestable basis, including to university researchers.

For universities, the balance of funding provided through these mechanisms is an important consideration. Operating grants, including the Research Quantum, and some of the targeted programmes may be expended as universities determine, providing the capacity to nurture areas of strategic importance, particularly where these are not sufficiently mature to attract substantial grants in their own right, and to support valued fields which may not align with external funding priorities. This was particularly important during the 1990s as many institutions were developing their research profiles. Competitive grants, on the other hand, provide tied funds. Over the course of the decade, an increasing share of research funding was allocated for specific projects through competitive grants.

Commonwealth support provided through the education portfolio

It is apparent that most of the Commonwealth’s support for research and research training is provided through the education portfolio. Expenditure on research and research training from funding provided by the education portfolio, including notionally derived elements, is estimated to have grown from \$941 million in 1990-91 to around \$1.8 billion by 2000-01. A significant share of this funding is expended on research training. Estimated expenditure on research training places increased from \$229 million in 1991, to \$285 million in 1993, \$420 million in 1995 and \$487 million in 1999.⁴⁹ Due to strong growth in research students over the decade, it is estimated that funding for research training places increased from an estimated 7.6 per cent of operating grants in 1990, to 11.5 per cent by 1999.

However, while these figures are helpful in shedding light on the overall scale of support for higher education research through the education portfolio, it is important to recognise that derived components can only be estimated. On the other hand, targeted funding or ‘special research assistance’ is provided specifically for research purposes, and has been collected in a consistent and soundly based manner since the early 1980s. Table 3.2 demonstrates that targeted funding⁵⁰ has increased from \$209 million to \$462 million between 1990 and 2000 (expressed in 2002 constant dollars). Over this time, periods of growth occurred in the years 1988-1994 and 1996-1998.

Table 3.2 Targeted assistance for research provided through the education portfolio

1990	1992	1994	1996	1998	2000
\$m	\$m	\$m	\$m	\$m	\$m
209	304	354	424	475	462

Source: Department of Education, Science and Training

⁴⁹ The relative funding model established cost relativities for places occupied by undergraduate and postgraduate students in different courses. The model enables the Commonwealth’s support for research training at each institution to be determined on a notional basis. Figures are extracted from the Science and Technology Budget Statements for 1991-92, 1993-94, 1995-96 and 1999-00. Comparisons of the estimated share of operating grant expended on research training exclude funding provided through the capital roll in. Expenditure on research training as a share of operating grant is extracted from the 1999-00-2000 Science and Technology Budget Statement.

⁵⁰ ‘Targeted research funding’, or ‘special research assistance’ here includes Australian Research Council competitive grants, funding for research infrastructure, research scholarships and awards and fellowships. It excludes funding for research training places and the Research Quantum. This arrangement enables funding to be compared on a consistent basis over an extended period. Funding is expressed in 2002 dollars.

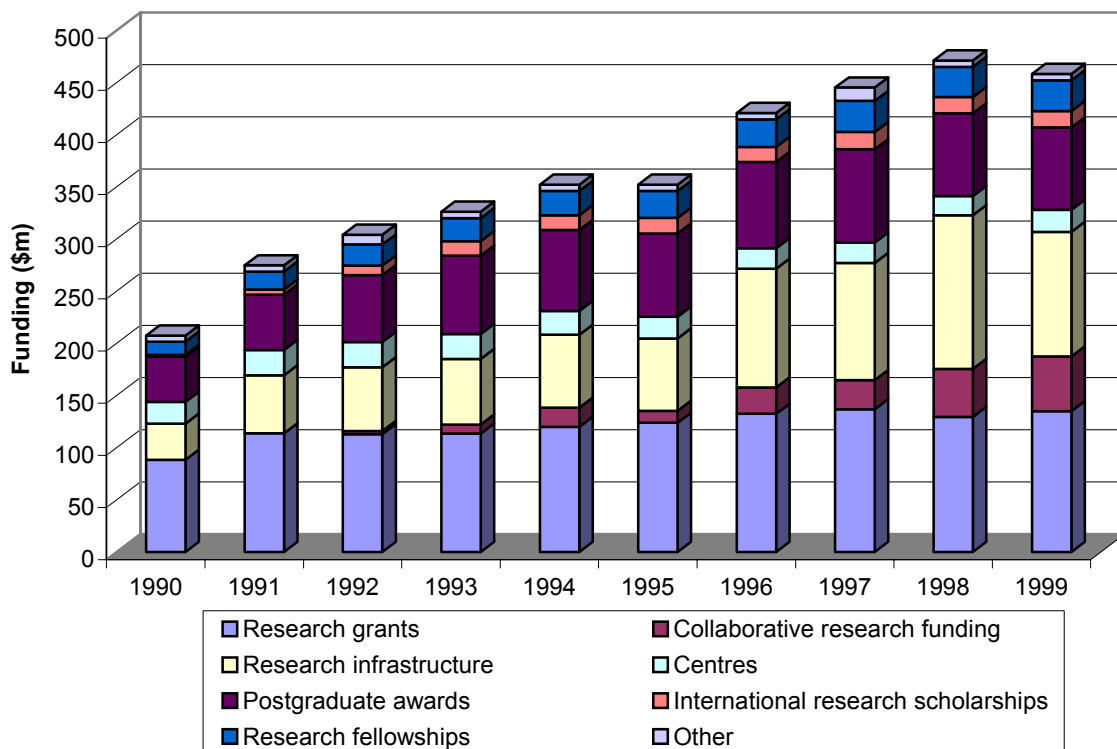
Increased funding for research provided through the education portfolio was generally directed to support areas of specific Commonwealth priority, particularly after 1996, rather than to facilitate a general increase in the research capacity of the sector.

Early in the past decade, following the abolition of the binary divide, the Commonwealth supported an overall improvement in the research capacity of the sector by providing targeted support for research infrastructure, research centres, postgraduate awards to meet the anticipated demands of a growing research labour market, research fellowships, and general research grants. Funds were allocated to establish AARNet, the computer-based communications network for the research and academic communities, and to support collaboration between universities and industry. In the mid to late 1990s, the Commonwealth announced several funding increases to improve the quality of research infrastructure and to encourage collaboration between universities and industry.

Following the conclusion of the decade, the Commonwealth announced substantial additional funding for higher education research under the innovation statement *Backing Australia's Ability*. This initiative is designed to enhance the nation's capabilities in basic and applied research, support research infrastructure, and improve opportunities for early career and for outstanding, established researchers, to build careers in Australia.

The figure 3.1 illustrates how funding provided through the education portfolio over the 1990s reflected the Commonwealth's changing priorities, particularly with respect to increasing support for research infrastructure and encouraging collaboration with industry. The various priority areas are then examined in turn.

Figure 3.1 Targeted funding for research provided through the education portfolio, by area of support (2001 dollars⁵¹)



Source: Department of Education, Science and Training

⁵¹ Funding is expressed in 2001 dollars.

Funding for research infrastructure

Research infrastructure encompasses the range of physical, human and technological services and facilities which provide general support to the research activity of a university. Definitions of research infrastructure and funding mechanisms to support research infrastructure vary considerably around the world. In Australia, research infrastructure generally includes laboratories, equipment, computing and telecommunications support, library facilities, and technical and maintenance personnel but does not cover the salaries of academics or the direct costs of particular research projects.

Until the beginning of the 1990s, almost all funding for research infrastructure was provided indirectly through operating grants. Successive reports had identified that the poor quality of Australia's higher education research infrastructure was a serious impediment to the nation's capacity to perform research. *Research for Australia* instituted targeted programmes to support research infrastructure and announced that \$230 million would be made available for research infrastructure over the period 1990-1994. The programme arrangements were quite complex and established separate funding streams for pre- and post-1987 universities, and for the acquisition of costly large-scale equipment for use by institutions on a collaborative basis. These arrangements were rationalised from the mid-1990s.

It soon became apparent however that the funds provided by *Research for Australia* were inadequate to meet the additional demands for infrastructure arising from rapid growth in the number of research students and the scale of competitive grants programmes, most of which provided only marginal support for infrastructure. It was estimated that there were about 78 national competitive grants programmes by 1994, so success in winning grants could prove a costly imposition on university resources (Senate Standing Committee on Employment, Education and Training, 1994b). Various reviews, reports and committee deliberations (such as the review of research infrastructure by the Boston Consulting Group for the National Board of Employment, Education and Training (1993) and the West Review (1998) confirmed that infrastructure funding remained a serious problem, particularly by comparison with leading Organisation of Economic Cooperation and Development nations. As a result, the Commonwealth boosted funding for research infrastructure in successive budgets during the middle and the second half of the decade. However, some of these increases lasted only several years, so they did not provide a long-term solution for the sector's infrastructure requirements.

Support to encourage collaboration between university researchers and industry

Another major priority area for the Commonwealth was encouraging industry-research collaboration in order to promote knowledge diffusion and innovation and to enhance the nation's return on its investment in research (Box 3.4). Quite clearly, it was also intended to foster the development of a more diverse funding framework for research. Several significant developments occurred in this area during the 1980s, including the introduction of the 150 per cent research and development tax concession, the establishment of the Cooperative Research Centres Scheme in 1990 and the establishment of the Grants for Industry Research and Development Scheme. As noted previously, a number of the former institutes of technology had established linkages with industry, which formed the foundation upon which they developed their early research efforts. In 1990, the Business-Higher Education Roundtable was established, comprising the chief executive officers of prominent businesses and the Vice-Chancellors of a number of universities.

Box 3.4 ARC Special Research Centre for Quantum Computer Technology: The Universities of New South Wales, Queensland and Melbourne

Robert Clark, University of New South Wales

The ARC Special Research Centre for Quantum Computer Technology is a multi-university collaboration undertaking research on the fundamental physics and technology of building, at the atomic level, a solid state quantum computer in silicon together with other high potential implementations.

The Centre was established in January 2000 through funds from the Australian Research Council and participating institutions. The Centre has nodes at the Universities of New South Wales, Queensland and Melbourne. It also maintains an important collaboration with Los Alamos National Laboratory in the USA. 80 people work on the project: 50 faculty, research, technical and administrative staff and 30 postgraduate and honours students.

The Centre is currently exploring two contrasting approaches to the task of constructing a silicon-based solid state quantum computer. The first involves a bottom-up approach, which utilizes scanning probe technology to construct a device atom-by-atom. The second is an top-down approach, in which phosphorus ions are implanted into a device at precise locations using a more conventional semiconductor processing route but with significant innovations.

The combination of experimental and theoretical research within the Centre requires extensive collaboration, both amongst the three nodes and with other research groups nationally and internationally. Coordination requires a high degree of organisation and planning to cultivate the science focus and to obtain objectives within the team. To achieve this, the project has been divided into ten programs, each with an experienced program manager. A high level of interaction amongst the parallel research programs has been achieved through very effective communication that includes quarterly meetings of the key research management staff, internal research workshops, a vigorous research seminar program and the active participation of staff in national and international conferences and visits including the hosting of two international conferences.

An important challenge for the Centre is the management of intellectual property that arises from the Centre's research. Due to the dynamic nature of research into quantum computing, intellectual property of scientific and potentially commercial importance is being generated across all three nodes of the Centre. This intellectual property is central to the value of the outcomes generated by the Centre for the benefit of Australia and it is important that a complete and well-managed intellectual property policy be adopted. Unisearch Limited, the University of New South Wales' commercial arm, is responsible for assisting in the commercialisation and transfer of research and technology developed by the Centre.

The initial year of operation has produced a number of major research outcomes spanning the entire range of programs and encompassing all three nodes of the Centre. The Centre is also making its own contribution to reversing the so-called brain drain with staff joining the Centre from University of Cambridge, Oxford Instruments, National Physical Laboratory and University of Leeds in the United Kingdom, and Los Alamos National Laboratory, Caltech, University of North Texas and University of Maryland in the United States of America.

However, at the beginning of the 1990s, university-industry collaboration was still in its infancy — the focus of many words but comparatively little action — and had little bearing upon the lives of most academics. This started to change as the Commonwealth Government introduced the 'industry' postgraduate awards and a new programme of collaborative research grants. In their first year, the Commonwealth's contribution to the collaborative grants was \$2.7 million, which was matched by industry contributions. Following several funding increases, the Commonwealth's contribution to collaborative grants awarded in 2001 had grown to \$57.9 million, which were

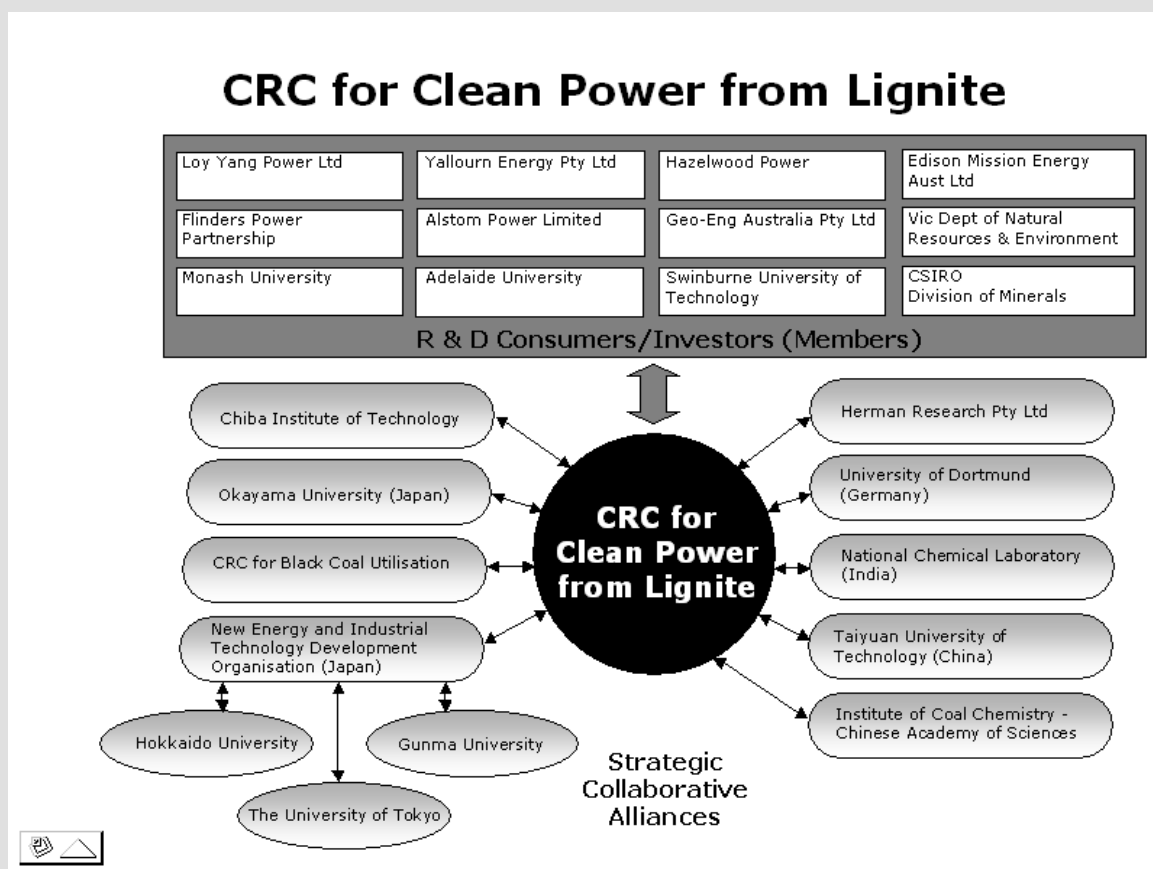
matched by estimated cash and in kind contributions from partners totalling some \$79.8 million (DETYA 2001, p. 197).

The impact of this was significant. Payments made by Australian business for research undertaken by universities more than doubled between 1994 and 2000. In addition, the proportion of higher education research and development funded by business has risen from 3.5 per cent to 4.9 per cent between 1994 and 2000.

Other programmes also encouraged greater collaboration between universities and other participants in the innovation system. These included programmes to encourage the joint acquisition and use of major research facilities and the Cooperative Research Centres Scheme programme. The programme brings together researchers from universities, public research agencies and private industry in long term, large scale projects of commercial and social significance. The centres also offer research training in a multi-disciplinary and commercially oriented research environment. Support for the centres is provided by the Commonwealth, by the research partners, including universities, and by industry partners. At July 2001 there were 64 centres working in the areas of manufacturing technology, information and communications technology, mining and energy, agriculture and rural based manufacturing, environment, and medical science and technology (www.crc.gov.au).

The Cooperative Research Centres Scheme demonstrates extensive and complex patterns of collaboration between research providers, governments and industry partners, both domestic and international. Box 3.5 illustrates the many opportunities for knowledge transfer through formal and informal networks.

Box 3.5 Collaboration through a Cooperative Research Centre



Partly in response to these programmes and other incentives to diversify their revenue, universities have substantially boosted their funding from industry and other sources⁵². Between 1993 and 2000, external research income from these sources grew from \$126.3 million to \$330.4 million.

In addition to Cooperative Research Centres, universities participated in many other collaborative arrangements. The Australian Partnership for Advanced Computing is an example, and received substantial Commonwealth support (Box 3.6).

Box 3.6 A National Approach to Developing Australia's Advanced Computing Infrastructure

John O'Callaghan, Executive Director Australian Partnership for Advanced Computing

In 1998, the Federal Government announced its intention to form the Australian Partnership for Advanced Computing (APAC) to provide the leadership and focus needed to position Australia amongst the top ten countries in terms of research, expertise and industrial use of advanced computing systems. The Partnership was initiated by an agreement between Department of Education, Training and Youth Affairs and the Australian National University (ANU) under which the ANU has the role of host institution of APAC.

The model for the APAC partnership was developed from the responses to an expression of interest issued in 1999 inviting organisations to become APAC partners. In June 2000, the partnership was established by agreement between six organisations. Another organisation joined in December 2000. When the organisation in South Australia joins in mid-2001, the APAC partners will consist of an organisation in each State as well as the ANU and CSIRO. The investment being made by APAC and its partners in the advanced computing infrastructure in Australia is more than \$80m over the three years to June 2003.

APAC's National Facility provides substantially more computing resources than is available at the facilities of APAC partners. It has one of the most powerful computing systems in the world (in the top 60 on the TOP500 list (www.top500.org)). The Facility operates on a resource share model whereby partners and other organisations have committed cash and in-kind contributions to buy a share of the resources of the National Facility. Access is awarded under a merit allocation scheme to staff in higher education institutions and their collaborators in other research organisations, government and industry.

AARNet provides the main communications infrastructure for users to access the National Facility and Partner Facilities. A major upgrade to this infrastructure has been planned. This will connect the AARNet Points-of-Presence and the advanced computing systems at the APAC National Facility and the Partner sites in Melbourne, Sydney and Brisbane.

The Expertise Program aims to drive the development and use of the National Facility for the benefit of users and potential users through Partners providing high-level user support services and conducting research and development projects in nominated areas of expertise. The Education Program strengthens the expertise required to develop and use advanced computing systems and environments, through education and training programs leading to awards and degrees. The focus for the activities is on advanced computing and its applications within the areas of computational science and engineering, computing science and engineering and computational mathematics.

⁵² 'Other' sources of research income includes income from contracts, grants, donations, bequests and foundations, syndicated research and development and international income. Income for 1993 is published in the Industry Commission's report on Research and Development using data obtained from the AVCC, while income for 2000 is based on the Higher Education Research Data Collection.

In order to provide more substantial support for industry, APAC is developing a cooperative organisational network in the area of computational engineering that covers the integration of such technologies as finite element analysis, computational fluid dynamics and computer-aided design with product development and process improvement.

Even at this early stage APAC and its partners have strengthened the advanced computing infrastructure in Australia. They are making substantial investments in skills development, education and industrial outreach and are fostering cooperation with similar organisations in other countries.

Support for research through measures announced in 'Backing Australia's Ability'

Towards the end of the decade, the governments of many nations, including Canada, Finland, France, Germany, Japan, Singapore, the United Kingdom and the United States announced substantial increases in funding for research. In the United States, for example, funding for the National Science Foundation and for the National Institute of Health was increased by 7.1 per cent and 15 per cent respectively in 1999. In Australia, the Commonwealth announced in the 1999 Budget that funding for health and health research would be increased by \$614 million over a six year period. Against this background, two complementary reviews were commissioned by the Commonwealth Government. The Chief Scientist, Dr Robin Batterham, reviewed Australia's science capabilities, while Mr David Miles chaired a committee tasked to make recommendations to the Commonwealth on the outcomes of an Innovation Summit held in early 2000 in conjunction with the Business Council of Australia. The recommendations arising from these processes were similar and both urged the Government to substantially increase funding for Australian Research Council competitive grants and university research infrastructure.

While outside the decade under review it should be noted that the Commonwealth responded to these reviews in January 2001 by issuing a major innovation statement, *Backing Australia's Ability*. This statement announced additional Commonwealth outlays for research and innovation of \$3 billion over a five-year period, much of which could be expected to provide support for university research.

Commonwealth support provided through portfolios other than education

In addition to funds provided through the education portfolio, universities attract research revenue from other Commonwealth agencies. These programmes tend to be more oriented towards socio-economic objectives than is typically the case for much of the research supported by the Australian Research Council. As most of the funding supports research in medical science and agricultural science, institutions with strong profiles in these fields tend to attract a substantial share of the available funds. The Table 3.3 compares funding provided through several major Commonwealth competitive grants programmes in 1990, 1993 and 2000. Strong growth occurred over the decade with respect to grants administered by the National Health and Medical Research Council, and to a lesser extent from the rural research and development corporations.

Table 3.3 Commonwealth competitive research grants⁵³ from sources other than the Australian Research Council

	1990 \$m	1993 \$m	2000 \$m
National Health & Medical Research Council	46	68	125
Rural Industrial Research Funds/Grants for Industrial R&D (1990) and Rural R&D Corporates (1993, 2000)	28	36	58
Other Commonwealth Departments	34	38	33
Total	108	141	216

Sources: The National Report on Australia's Higher Education Sector (1992), the Industry Commission report on Research and Development using AVCC survey data (1993) and DETYA's Higher Education Research Data Collection (2001). The table uses 'actual dollars'.

Towards the end of the 1990s, the Commonwealth commissioned a review of health and medical research under the chairmanship of Mr Peter Wills. In responding to the report of the Health and Medical Research Strategic Review, *The Virtuous Cycle*, the Commonwealth announced that it would double the National Health and Medical Research Council's budget by 2005 by increasing funding for health and medical research by \$614 million over the six years from 1999-2000. Universities are likely to win a substantial share of this new funding. In particular, universities with a medical school are likely to be most favoured as they attract some 84 per cent⁵⁴ of National Health and Medical Research Council grants awarded to university researchers.

3.5 Developments in research training

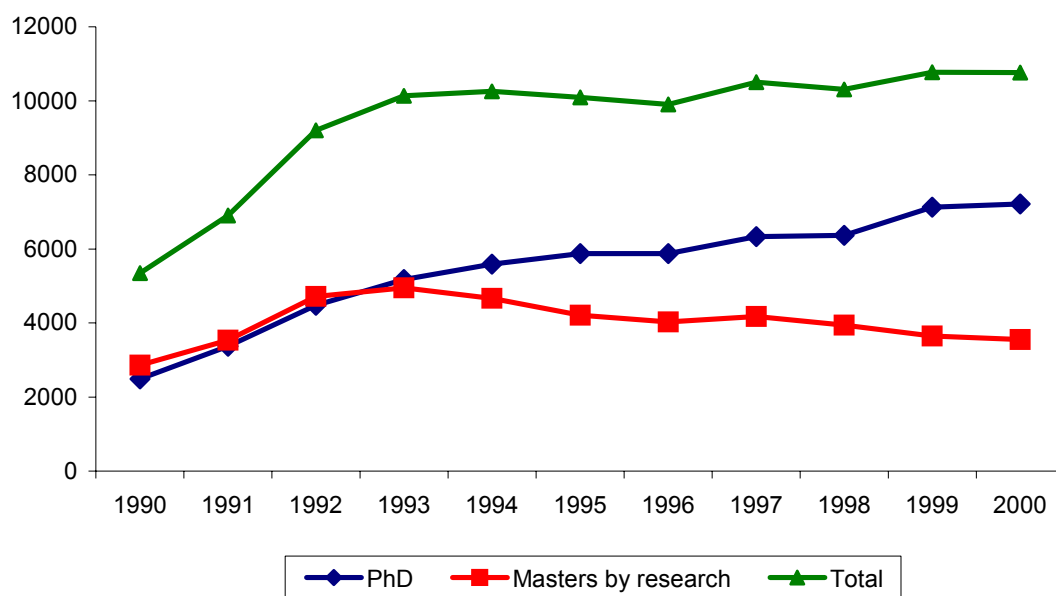
Formal research training is provided by Australian universities through research degrees, of which the most common are the Doctor of Philosophy (PhD) and Masters degree by research. Research training is also often provided within the research component of professional doctorates, and other postgraduate degrees which also include coursework as a significant assessable element. Since the late 1980s, there have been major changes to the higher education research training system. These changes have been reflected in the range and diversity of institutions providing research training, in a vast increase in the range and interests of research training students, and in the emergence of new fields of research.

As noted previously, the presence of large numbers of research students is a distinctive feature of research conducted within universities as opposed to other research performing bodies. As students complete their research qualifications, they commonly move to other institutions, research organisations or industry, within Australia or overseas, in order to pursue their careers. This pattern of movement helps to establish and sustain professional networks, diffuse knowledge and skills, and is an important mechanism for promoting innovation.

⁵³ Excludes competitive research grants from the Australian Research Council, and comprises only Commonwealth competitive research grants regarded as 'Category one' research income for the purposes of the Higher Education Research Data Collection. In addition to competitive research grants outlined in Table 3.3, the Commonwealth provided \$72 million in 'other public sector research grants' known as 'category 2' research funding.

⁵⁴ Based on the 2000 Higher Education Research Data Collection.

Figure 3.2 Commencements in higher degree by research programmes, 1990-2000



Source: Department of Education, Science and Training Higher Education Student Statistics Collection

Over the past decade, research student enrolments grew strongly from 16,334 in 1990 to 37,374 in 2000, an increase of 129 per cent (Figure 3.2). Most of this growth occurred in the first half of the decade as enrolments in both doctoral and masters programmes increased at a significant rate, and as staff in the newly established universities attempted to upgrade their qualifications. However, masters by research enrolments peaked in the mid-1990s and declined thereafter, while doctoral enrolments continued to increase. As a consequence, the number of doctoral candidates had trebled between 1990 and 2001, and accounted for three times as many candidates as masters students. By way of comparison, it is also interesting to note that enrolments in masters coursework programmes also increased by around three times over the decade.

Higher degree enrolments grew by at least 40 per cent in all universities between 1990 and 2000. The highest proportional growth occurred in the post-1987 universities, although off a very low base. However despite this, enrolments continue to be relatively concentrated in a small number of universities. In 1990, 61 per cent of research students were enrolled at Group of Eight universities⁵⁵. By 2001, preliminary data suggest that almost 49 per cent of research students were enrolled in these universities. Further information regarding enrolments by institution is provided in Table 3.4.

Table 3.4 Research degree enrolment, 1990 and 2000, by institution

State/Institution	1990		Doctorate by Research	2000		Share of total (%)
	HDR enrolments ⁱⁱⁱ	Share of total (%)		Master's by Research	Total	
New South Wales						
Charles Sturt University	6	0.0	245	78	323	0.9
Macquarie University	597	3.6	706	229	935	2.5
Southern Cross ⁱ	-	-	233	34	267	0.7

⁵⁵ The Group of Eight comprises the universities of Melbourne, Sydney, Western Australia, Queensland, New South Wales, the Australian National University, Adelaide and Monash University.

University						
The University of New England ¹	456	2.8	493	237	730	2.0
The University of New South Wales	1,449	8.8	1,715	443	2,158	5.8
The University of Newcastle	328	2.0	586	319	905	2.4
The University of Sydney	1,859	11.2	2,593	773	3,366	9.0
University of Technology, Sydney	274	1.7	545	168	713	1.9
University of Western Sydney	104	0.6	714	300	1,014	2.7
Aust Film, Television & Radio School	0	0.0	0	6	6	0.0
Total New South Wales	5,457	33.0	8,518	2,694	11,212	30.0
Victoria						
Deakin University	236	1.4	623	153	776	2.1
La Trobe University	812	4.9	798	419	1,217	3.3
Monash University	1,392	8.4	1,858	735	2,593	6.9
RMIT University	290	1.8	716	745	1,461	3.9
Swinburne University of Technology	141	0.9	302	210	512	1.4
The University of Melbourne	1,587	9.6	2,405	958	3,363	9.0
University of Ballarat	16	0.1	110	31	141	0.4
Victoria University	62	0.4	369	142	511	1.4
Total Victoria	4,536	27.4	7,181	3,393	10,574	28.3
Queensland						
Central Queensland University	32	0.2	125	50	175	0.5
Griffith University	270	1.6	911	181	1,092	2.9
James Cook University	324	2.0	439	165	604	1.6
Queensland University of Technology	138	0.8	656	219	875	2.3
The University of Queensland	1,581	9.6	2,503	612	3,115	8.3
University of Southern Queensland	13	0.1	139	53	192	0.5
University of the Sunshine Coast	0	0.0	23	10	33	0.1
Total Queensland	2,358	14.3	4,796	1,290	6,086	16.3
Western Australia						
Curtin University of Technology	370	2.2	635	125	760	2.0
Edith Cowan University	70	0.4	355	328	683	1.8
Murdoch University	287	1.7	572	73	645	1.7
The University of Western Australia	892	5.4	1,251	388	1,639	4.4
Total Western Australia	1,619	9.8	2,813	914	3,727	10.0
Australia						
South Australia						
Flinders University of South Australia	344	2.1	550	137	687	1.8
The University	729	4.4	998	223	1,221	3.3

of Adelaide									
University of South Australia	119	0.7	658	193	851	2.3			
Total South Australia	1,192	7.2	2,206	553	2,759	7.4			
Tasmania									
Australian Maritime College	0	0.0	7	18	25	0.1			
University of Tasmania	357	2.2	659	220	879	2.4			
Total Tasmania	357	2.2	666	238	904	2.4			
Northern Territory									
Northern Territory University	87	0.5	137	34	171	0.5			
Total Northern Territory	87	0.5	137	34	171	0.5			
Australian Capital Territory									
Australian Defence Force Academy	91	0.6	105	24	129	0.3			
The Australian National University	660	4.0	1,187	118	1,305	3.5			
University of Canberra	175	1.1	178	95	273	0.7			
Total Australian Capital Territory	926	5.6	1,470	237	1,707	4.6			
Multi-State									
Australian Catholic University	3	0.0	179	55	234	0.6			
Total Multi-State	3	0.0	179	55	234	0.6			
TOTAL	16,535	100	27,966	9,408	37,374	100			

- i Research students at what subsequently became Southern Cross University are included in UNE totals in 1990. Percentage increases over the period 1990 to 2000 are misleading for both institutions and are not provided. State and total increases are correct.
- ii Research students at colleges that were subsequently merged with universities have been attributed to the universities with which they merged.
- iii The Selected Higher Education Statistics for 1990 does not provide a breakdown between masters, PhD and higher doctoral programmes at the institution level.

Source: Department of Education, Science and Training Statistical Collection

Over the decade to 2000, the strongest growth occurred in the fields of business, administration and economics (281 per cent), arts, humanities and social sciences, and education (both with 160 per cent), architecture (158 per cent) and health and medical research (156 per cent). Science enrolments grew by 82 per cent and engineering by 81 per cent (Table 3.5).

Table 3.5 Higher degree by research enrolments, by field, 1990 and 2000

1999	Agri're & vet science	Arch're, & building	Arts, human's & social sciences	Business, admin, economics, law	Educ'n	Engin.	Health	Science	Total
Masters by research	382	137	2,071	535	754	899	600	1,654	7,032
PhDs	501	91	2,228	463	654	1,062	1,242	3,057	9,298
Total research degrees	883	228	4,299	998	1,408	1,961	1,842	4,711	16,330
Share of research total (%)	5.4	1.4	26.3	6.1	8.6	12.0	11.3	28.8	100.0

Enrolments all levels ⁱ	10,093	10,724	109,551	118,960	74,772	36,019	54,498	67,330	485,075
Share of Total (%)	2.1	2.2	22.6	24.5	15.4	7.4	11.2	13.9	100.0

2000	Agri're & vet science	Arch're, & building	Arts, human's & social sciences	Business, admin, economics, law	Educ'n	Engin.	Health	Science	Total
Masters by research	368	240	3,471	782	941	1,051	916	1,639	9,408
PhDs	974	349	7,688	3,023	2,717	2,491	3,809	6,929	27,980
Total research degrees	1,342	589	11,159	3,805	3,658	3,542	4,725	8,568	37,388
Share of research total (%)	3.6	1.6	29.8	10.2	9.8	9.5	12.6	22.9	100.0
Enrolments all levels ⁱ	13,000	15,463	170,237	216,834	73,680	50,780	79,731	115,396	704,292
Share of total (%)	1.8	2.2	24.2	30.8	10.5	7.2	11.3	16.4	100.0
Increase in total (%)	52.0	158.3	159.6	281.3	159.8	80.6	156.5	81.9	129.0
Increase in PhDs (%)	94.4	283.5	245.1	552.9	315.4	134.6	206.7	126.7	200.9

i Includes undergraduate and postgraduate programmes. Total includes students enrolled in non-award courses.

ii The data takes into account the coding of combined courses to two fields of study. As a consequence, counting both fields of study for combined courses means that totals may be less than the sum of all Broad Fields of Study.

Source: Department of Education, Science and Training Statistical Collection

A study of postgraduate research students at the end of 1999 who commenced between January and March 1992 (Karmel, Maclachlan and Martin 2001) showed that during that period 5,552 domestic students commenced a postgraduate research award. Of these, 2,647 commenced a doctorate and 2,905 began a masters degree. Approximately 53 per cent of the doctoral students and 43 per cent of the masters students had completed their degree. Roughly the same proportions of both groups were still studying in 1999 (18 and 16 per cent respectively) and a considerable proportion of each group (27 and 39 per cent respectively) were not studying and had not completed any course. Of those doctoral students who had completed, 36 per cent completed within four full-time study years. The report concluded that the high non-completion rates were a cause for concern as they represented a considerable waste of resources.

During the 1990s, universities invested considerable resources to an attempt to improve the experience of research students and to satisfy industry concerns that research graduates acquired skills which were of limited value to employers. There was considerable discussion about the traditional model of the university research degree and universities attempted to broaden the range of skills acquired by research students. By the late 1990s, many universities were taking steps to develop a range of new training options, including professional doctorates and other postgraduate qualifications. Short courses were being delivered to students on specific topics, such as project management, written communication, and intellectual property management to enable them to acquire a wider range of skills and knowledge.

Many Australian universities have established graduate schools in the style of the North American 'whole of university' graduate school. Normally headed by a dean of graduate studies, graduate schools provide centralised management, services and programmes to enhance the research training experience for graduate students and supervisors. The Australian National University was the first research intensive university in Australia to establish such a school in 1990. Some eight

universities had followed suit by December 2001, with other institutions adopting varying degrees of centralisation of graduate student support.

Most graduate schools offer a range of activities including orientation and induction programmes for graduate students, workshops on research and thesis writing, graduate student newsletters, professional development for postgraduate supervisors and pastoral care services. Some graduate schools have moved into the coordination of programmes that cater for the development of generic skills in graduate students. The increase in the number of graduate schools in Australian universities and the move to a 'whole of university' management approach to graduate students, is one reflection of an increased focus on the quality of research training within the sector.

Many universities had developed guidelines to outline the expectations and responsibilities of students, their supervisors, and other relevant parties. Institutions started to survey their postgraduate students to establish the extent to which they were satisfied with their courses, and instituted remedial action as appropriate. Some universities went to great lengths to provide a high quality research training environment, introducing minimum requirements in terms of provision of facilities, space and support for postgraduate students. Other developments in this area included providing support for research students in terms of financial support to attend national or international conferences, establishing registers of 'approved' supervisors, and ensuring that supervisors are provided with appropriate professional development. Inter-institutional networks were becoming established to support staff development in supervision practice.

In 1998, the Commonwealth commissioned the Graduate Careers Council of Australia in conjunction with the Australian Council for Educational Research to develop a survey instrument capable of measuring research graduates' satisfaction with the quality of their research experience (Australian Council for Educational Research 1999). The trials suggested that the key dimensions of postgraduate research training are supervision, intellectual climate, skills development, infrastructure, thesis examination and clarity of goals and expectations. Following on from the trial surveys, the first annual survey measuring postgraduates' satisfaction with their research experience was conducted in 2000 (Australian Council for Educational Research 2001). One common area of concern by students is a sense of disappointment with their experience of the research culture of the institution, and a sense of not having been embraced by the culture of the discipline.

Towards the end of the decade the Commonwealth recognised the concerns about the suitability of some research training programmes for the future work environment, the high attrition rates and long course completion times, and the general quality of the research training and supervision. It also noted that many universities made little attempt to align student places with their areas of research strength. The Commonwealth's policy statement *Knowledge and Innovation*, attempted to encourage universities to improve the quality and suitability of research training by introducing performance based funding for research training places. This mechanism would reward universities for achieving high rates of student completions within an acceptable period of time. Furthermore, the newly introduced Research and Research Training Management Reports required universities to focus at length on research training issues.

Postdoctoral training

For those wishing to pursue a career in academia, the next stage following the completion of a doctoral degree is often achieved by obtaining a postdoctoral research position at a university. The postdoctoral experience is viewed by postdoctoral candidates and supervisors as a bridge to a permanent academic position or simply as an opportunity to engage in further research.

A study on postdoctoral training and the employment outcomes of postdoctoral candidates found that training and supervision are considered important features of the postdoctoral experience

(Thomson, et al 2001). The report found that out of the former postdoctoral candidates surveyed, 35 per cent were employed in university research positions (mostly in further postdoctoral positions), and 24 per cent in university teaching/research positions, 16 per cent were in research positions outside universities and 10 per cent were in non-research positions (Thompson et al. 2001, p. 89). The report suggests that a postdoctoral research position should be seen as much more than a stepping stone to a tenured academic position, as academic work becomes more flexible and driven by market expectations, and as research settings are increasingly located outside universities.

A recent OECD report (1999) suggests that this is not just an Australian phenomenon, claiming that:

...in the United States, young researchers have increasingly found it necessary to move from one post-doctoral position to another, often spending up to six years in this way before finding a faculty appointment, which is usually an untenured one.
(OECD 1999, p. 65)

While recent government decisions to double the number of postdoctoral research fellowships and to increase funding for Australian Research Council and National Health and Medical Research Council competitive grants research will provide some additional opportunities for early career researchers seeking a career in academia, postdoctoral researchers can no longer be assured of a tenured academic position within a university.

3.6 Managing research and research training performance

The context in which higher education research and research training were conducted during the 1990s was characterised by high levels of competitiveness, and increasing size and complexity. Even in institutions with relatively small research profiles, the management of research and research training functions had become complex. Research management functions are diverse, and include building and maintaining a strong research culture, achieving sound levels of research performance across the institution, with very high levels of performance in key areas, ensuring effective and strategic resource allocation, planning for the future, improving the quality of research training, ensuring appropriate levels of infrastructure, and managing human resources (Box 3.7). Important administrative and specialist functions include managing the institution's grant application processes, managing intellectual property and commercialisation activities, providing advice and support for research groups, monitoring contractual arrangements, collecting and analysing data for internal and external audiences, and monitoring and evaluating performance.

Box 3.7 Research at the University of Melbourne 1991–2000

Frank P Larkins, the University of Melbourne

The last decade of the twentieth century was one of remarkable change for higher education in Australia. At the University of Melbourne during this period student enrolments increased by around 30% while staffing levels actually fell slightly. The University's revenue from all sources more than doubled while its reliance on Commonwealth operating grants more than halved. Despite these dramatic changes the University was able to strengthen its research and training activities. The number of students undertaking and completing research higher degrees increased considerably. Research income almost tripled through the decade with a greater proportion of funds coming from non-Commonwealth sources.

The primary factors in the University of Melbourne's research success were the University's investment in world-class people as research leaders and supporting them with the best infrastructure, libraries, laboratories, equipment and technical support and information systems that could be reasonably afforded. The University's 85 research centres, (including 15 Co-operative Research Centres and 5 Australian Research Council Special Research Centres) provided a focus to concentrate research effort, to facilitate cross-disciplinary collaborative research and to build a sense of identity and recognition for staff and students.

Staff development strategies were also important. Early career staff were nurtured and assisted to be competitive in winning external research grants. Achievement was recognized through promotion criteria, travel awards, research grants and incentives and this helped to build a strong research presence.

Internal research funding initiatives were designed to provide seed funding for staff to establish new research directions and to build strategic partnerships at the regional, national and international levels. Initiatives were also put in place to support gender-related programs notably for women returning to the research workforce. The University's priority was to target funding to areas of research strength. At the same it sought to maintain flexibility in the research profile through a balance between individual and team research encompassing fundamental, strategic and applied research.

Integral to the success of research at the University of Melbourne has been the recruitment of quality students and the provision of quality supervision and quality infrastructure. A central part of the University research activities has been the intellectual development of research higher degree students. The primary outputs from research programs are people with internationally competitive skills and new knowledge to contribute to the global pool of talent available for the advancement of society. In addition, the provision of quality administrative support services for research and research training has been an essential part of research management. The University also closely monitors research performance including benchmarking against like institutions.

Universities vary in terms in terms of their structural arrangements and scale (Box 3.8). All universities have a deputy vice-chancellor or pro-vice chancellor with primary responsibility for managing research, an associated research office, and a range of committees which oversight various research and research training activities. Many have a graduate school and many also have a commercialisation arm (the specialist area of managing research commercialisation is addressed separately). All universities have established policies and procedures to address various aspects of research and research training, such as the responsibilities of research students and their supervisors, the management of intellectual property, and the ethical use of human and animal subjects in experimentation. Research management responsibilities extend to faculties, schools, and centres, particularly in those institutions with devolved decision-making processes.

Box 3.8 How to think in two dimensions - Research and Research Training at the University of Wollongong during the 1990s

Chris Brink

Wollongong has nine faculties organised around traditional disciplinary groupings: Arts, Commerce, Creative Arts, Education, Engineering, Health and Behavioural Sciences, Informatics, Law, and Science. Since research naturally runs across these disciplinary divisions, the University has aimed to foster cross-disciplinary synergies by packaging practically all research into two dozen research units, typically with membership, interests and goals running horizontally across departmental and/or faculty boundaries. These units fall into four thematic groupings:

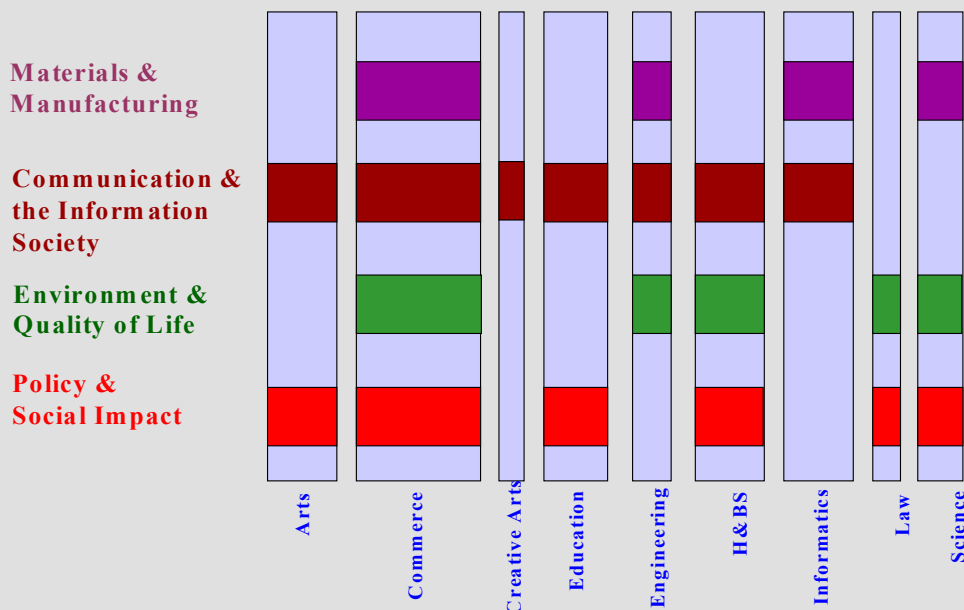
- Materials and Manufacturing
- Communication and the Information Society
- Environment and Quality of Life
- Policy and Social Impact.

The matrix below shows how these research themes are integrated across the nine faculties. The matrix is indicative only of research presence, not of intensity. For example, the theme of Materials and Manufacturing has high intensity in Engineering, low in Commerce.

Materials and Manufacturing can be used to illustrate how the system works. Its group consists of research units focusing on such topics as intelligent polymers, steel products and processes, superconductors, bulk materials handling and intelligent manufacturing. A particular unit such as the Intelligent Polymers Research Institute draws members and collaborators from Chemistry in the Science Faculty, from Engineering, and from Biomedical Science.

A research project in the Institute typically draws on a wide range of expertise from any number of disciplines. This is harnessed through a goal-directed focus on a particular topic. One current example is the Smart Bra project funded by Marks and Spencers. The Institute has developed a method of polymer-coating stretch materials in such a way that they become sensors, actuators or even energy storage devices. This is applied through a Smart Bra for joggers. As gravity generates a downward force on the straps of the bra, these sense the increasing force and actuate a response that firms the cups, thereby storing the energy thus generated for continued use.

Research units report to both the Dean of a particular faculty and the Pro Vice-Chancellor (Research): with emphasis on the former for operational issues, the latter for strategic ones. Research students register for a research degree with a specific faculty, yet over 90% are actually supervised from a research unit. This sometimes causes confusion and tension, but the relatively small scale of the University allows these to be resolved relatively easily.



Continuity in institutional leadership has meant that the basic strategies were sustained over time. The most enduring of these strategies was to focus on areas of strength. In the 1980s when the ethos of the individual curiosity-driven researcher was still strong, this was innovative, even controversial. A second strategy was to collaborate with business and industry. This was a pragmatic decision, inspired by financial need. The University's Institute for Steel Processes and

Products, for example, received funding for three professorships from BHP on the understanding that the professors would do work of benefit to the steel industry. The third strategy was that disciplinarity and cross-disciplinarity should compliment, rather than oppose, each other

An important issue for all universities is managing financial resources for research. All universities attempt to achieve an appropriate balance between devolving decision making to the faculty or research centre, and retaining funding centrally to support strategic initiatives, institution-wide resources (such as libraries and information and communications technology facilities), and incentives to reward strong individual or group performance. The approach adopted by individual universities tends to reflect their history and general ethos, but shifts occur over time in line with changes in the overall management practices of the institution (Box 3.9).

Box 3.9 Research Management in the 1990s – A Case Study of the University of Tasmania

Andrew Glenn

All universities face the challenge of developing the critical research mass, quality infrastructure and scholarly engagement across disciplines that lead to productive research concentrations. It is a particular challenge for a regional university seeking to remain internationally competitive in research. Recognising its research strengths and potential the University of Tasmania has set its goal for research ‘to be one of the top-ten research universities in Australia producing scholarship of national and international standard’.

To help achieve this goal, in 1996, the University identified research areas where it had a strategic advantage. These were Antarctic and southern ocean studies, national and state development, natural environment and wilderness; and population and community studies. Another step was to establish partnerships to provide the critical mass necessary for success. For example, the University entered into a Partnership Agreement with the state government. They jointly established the Tasmanian Institute of Agricultural Research in 1997 and the Tasmanian Aquaculture and Fisheries Institute in 1998. By 2001 the total external research incomes of the Institutes was close to \$11m. In 2001 the Tasmanian Law Reform Institute was established. The current Partnership Agreement aims to extend further such cooperation.

Another strategic decision was to develop a budget model that allocates research income on a performance basis. In addition, strategic research funds (\$0.5-1.0m annually) are used to foster new research initiatives and enhance facilities. For example, in 2000 the University established the Centre for Food Safety and Quality and the Australian Centre for Research on Separation Science, the latter in collaboration with Monash and RMIT.

The University also gave a high priority to establishing central research infrastructure facilities. The Central Science Laboratory is a major research facility with approximately \$12m of scientific equipment, an annual budget of approx \$1m and 14 research staff who offer specialist analytical measurement and technique development expertise to researchers. The Social Science Research Laboratory provides support for research in the Social Sciences.

Another strategic decision was to invest in postgraduate research training. Postgraduate research students are an integral part of any research-active university. The quality of supervision, infrastructure and environment will contribute significantly to the training experience. Recognising the importance of postgraduate research the University of Tasmania invests over \$2.35m annually in postgraduate research student scholarships. A number of workshops are held to support supervisors. In addition generic skills workshops and courses are available to enhance the skills of research students.

The commercial exploitation of innovation is important for the University of Tasmania. It has established a mechanism for regularly updating its Intellectual Property register through its Commercialisation Unit. Projects on the Register are evaluated internally before engaging external consultants to provide expert advice. The University claims Intellectual Property developed by its employees. In exchange, 50 per cent of the returns that accrue to the University from successful commercialisation of innovation will be returned to relevant employee/s. The University has recently established a \$2.5m fund to assist in developing promising technology to proof of concept stage and thus facilitate commercialisation.

The Australian Research Council (2000a) examined the degree to which decision making, especially in relation to the allocation of internal funds, is devolved or centralised within universities. The study identified three broad typologies for managing internal resources based on an analysis of 12 universities in 1998. The report found that:

- *Research intensive universities* tend to adopt a very decentralised system of allocating research funds at the faculty level; retain only a small proportion of their funds at the centre to support university-wide infrastructure, such as libraries and information technology, and strategic initiatives; use structural and thematic priorities for expending centrally retained funds; generally distribute research support funds (such as the Research Quantum) on the basis on which they are earned; and maintain a high level of structural and resource linkages between research, research training and teaching.
- *Research-group focused universities* tend to adopt decentralised funding practices, but largely to research groups rather than faculties; disperse a high proportion of their funds to the research groups and retain only a small proportion at the centre; adopt thematic priorities for expending centrally retained funds; distribute research funds largely on the basis on which they are earned; and have a significant degree of separation of research from teaching structures.
- *Evolving research universities*, which encompass a diverse range of institutions, tend to adopt a substantially centralised approach to distributing resources, frequently through the use of competitive schemes operating across the university; use structural priorities in planning and resource allocation; distribute research income 'as earned'; and research structures are generally closely linked to teaching.

Research and research training management reports

The White Paper of 1988 announced that universities would be required to submit research management plans to the Commonwealth, outlining the range and scale of their research activities, their research management strategy for the triennium and areas of specialisation. The documents were intended to assist institutions to set their own priorities and allocate funds, and to provide an accountability mechanism to ensure that institutions were making the best use of Commonwealth funds. The plans were to comprise an important element of institutions' academic profiles for discussion with the Commonwealth in profiles negotiations (Department of Employment, Education and Training 1993, p. 273). However, despite these expectations, the requirement for institutions to submit research management plans to the Commonwealth lapsed, although many universities continued to develop plans for their own management and marketing purposes.

At the end of the decade, this requirement was revived and modified (*Knowledge and Innovation*) to encourage universities to adopt a more strategic approach to managing their research and research training activities, and to provide greater transparency and accountability for their outcomes in these areas. With these objectives in mind, the approach adopted was intended to be less intrusive and onerous than mechanisms such as the Research Assessment Exercise used in the United Kingdom. Starting in 2000, universities were required to report to the Commonwealth on how they direct their research efforts, their areas of strength and their performance in these areas. The Research and Research Training Management Reports would be published and

provide an overview of each institution's distinctive contribution to the national research and innovation systems and inform prospective students, collaborative research partners and industry as to the way each institution directed its research and research training activities.

Under the new arrangements, institutions are required to outline their objectives for research and research training, areas of strength, future directions for research and research training, approaches to managing research performance, ensuring a quality research training experience, collaboration and partnerships, and to managing intellectual property and research commercialisation. Institutions report on their performance and promote their research achievements.

The research and research training management reports differ from the earlier research management plans in three key areas: firstly, in keeping with the strong focus on research training that underpin the reforms announced in *Knowledge and Innovation*, there is a much stronger emphasis on research training. This is immediately apparent from the title 'Research and Research Training Management Reports'. References to research training permeate the report guidelines: institutions are required to report on their current objectives for research training, the expected attributes of graduates of their research training programmes, future directions for research training, mechanisms to ensure a quality research training experience, and the results of student satisfaction surveys.

The second major area of difference relates to the institutions covered by the new arrangements. The range of institutions has been expanded to encompass not only public universities, but also the two private universities and several other higher education institutions that are potentially eligible for public funding for research and research training. More significantly, research and research training management reports are an explicit feature of the relationship between higher education institutions and the Commonwealth. *The Higher Education Funding Act 1988* has been amended to require all institutions to furnish an acceptable research and research training management report to be eligible for funding for research and research training under the Act. This development highlights the importance with which the Commonwealth views the effective management of research and research training and accountability for expenditure of public funds for these purposes.

Finally, the research and research training management reports are intended to be an important public accountability and quality assurance tool. Over time, information extracted from the reports will be compiled into a publicly accessible database that will enable users to compare trends in performance and orientation. The reports will also form an important resource for the deliberations of the Australian Universities Quality Agency for the purposes of conducting audits of the quality of Australia's higher education system (see chapter on quality issues). These accountability and quality assurance processes are intended to complement the performance-based allocation of funds to institutions through several of the Commonwealth's research and research training programmes.

3.7 Trends in research performance

Sectoral changes: research expenditure

Movements in the share of expenditure on research and development between sectors provide an insight into their relative importance to Australia's overall research performance. As already noted, the higher education sector performed a growing share of Australia's research over the 1990s. Tables 3.6 and 3.7 compare the contribution of Australia's higher education institutions, public research agencies, industry and the private, non-profit sectors for basic and more applied

research between 1988-89 and 1998-99. They reveal that universities, and the small but influential private non-profit sector, increased in importance with respect to both basic and applied research during the second half of the decade. The business sector, which is the dominant player in the more applied end of the research continuum, increased in importance during the middle of the decade before declining towards the end. The contribution of public research agencies declined in significance for both basic and more applied research.

Table 3.6 Share of total expenditure on basic research, by sector

	1988-89	1990-91	1994-95	1996-97	1998-99
	%	%	%	%	%
Universities	58.4	56.3	55.0	60.2	64.0
Business	9.0	8.4	10.6	9.0	5.9
Government research agencies	29.6	31.8	28.9	26.0	25.0
Private non-profit	3.1	3.5	5.5	4.7	5.1
Total	100.0	100.0	100.0	100.0	100.0

Columns may not total to 100% due to rounding

Source: Australian Bureau of Statistics (1993b, 1995b, 1998b, 2000b)

Table 3.7 Share of total expenditure on applied research and experimental

	1988-89	1990-91	1994-95	1996-97	1998-99
	%	%	%	%	%
Universities	13.0	13.5	13.2	14.4	16.7
Business	54.1	53.5	60.3	61.8	59.5
Government research agencies	32.3	32.5	25.7	22.7	22.8
Private non-profit	0.5	0.5	0.8	1.0	1.0
Total	100.0	100.0	100.0	100.0	100.0

Source: Australian Bureau of Statistics (1993b, 1995b, 1998b, 2000b)

In interpreting these data, it is important to recognise that the different sectors tend to focus on different fields of research, so that fluctuations in sectoral performance may influence the health of their respective fields. Australian universities conduct research across a broad spectrum of fields, of which the four largest in terms of expenditure in 1998-99 were medical and health sciences (23 per cent), social sciences (19 per cent), biological science (12 per cent), and the humanities (8 per cent). By international standards, Australia's universities invest heavily in the social sciences (and are achieving strong impact in terms of frequency of citations), and less heavily in engineering and the physical sciences.

Commonwealth research agencies also invest across a broad range of fields, of which agriculture (16 per cent), applied sciences and technology (14 per cent), earth sciences (14 per cent) and engineering (13 per cent) are the most significant. The other research sectors tend to be more focussed: business concentrates on information and communications technology (35 per cent), engineering (28 per cent), and applied sciences (20 per cent). The private non-profit sector focuses on health and medical sciences (68 per cent) and biological sciences (22 per cent), while state government research agencies focus on agriculture (54 per cent) and health and medical research (19 per cent).

Sectoral changes: human resources

Australian Bureau of Statistics data reveal that while all sectors except government research agencies expanded their workforce engaged in research activities (expressed in 'person years') over the decade, the strongest growth occurred in the higher education sector. By the end of the decade, the higher education sector had assumed a pre-eminent position, accounting for half of all human resources devoted to research (Table 3.8). This is largely attributable to the inclusion of research students in the higher education sector's contribution, with the Australian Bureau of Statistics suggesting that postgraduates accounted for some 70 per cent of researcher effort in the higher education sector in 1998. While the output of student researchers may not equate to the output of more experienced researchers, the comparatively modest cost of research students means that despite accounting for half of all human resources devoted to research, the higher education research sector accounted for slightly less than 30 per cent of the total research expenditure. This cost differential also explains why the proportion of researcher effort in the social sciences and humanities exceeds these areas share of research expenditure. By 1998, the social sciences accounted for 24 per cent of the higher education research effort, but only 19 per cent of expenditure, and the humanities accounted for 12 per cent of research effort, but only 8 per cent of expenditure.

Table 3.8

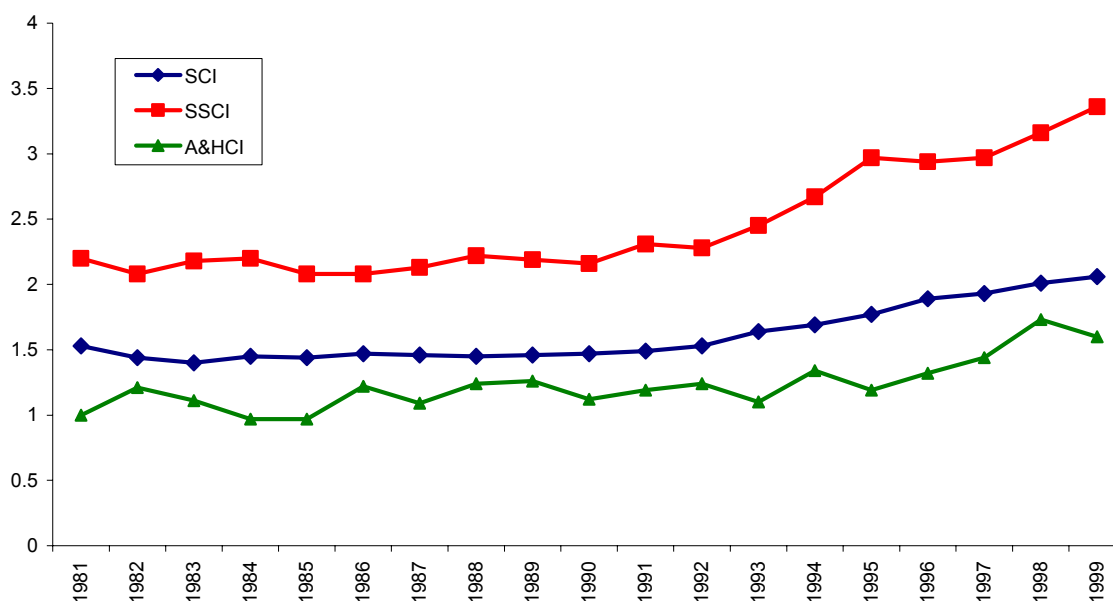
Sector	1988-89 person years	1990-91 person years	1992-93 person years	1994-95 person years	1996-97 person years	1998-99 person years
Business	20,803	21,025	22,919	25,812	26,498	24,201
Government	19,198	19,660	19,804	19,309	19,388	18,946
Higher Education	24,902	27,081	35,418	40,096	42,739	45,502
Private non-profit	1,203	1,282	1,369	1,666	2,171	2,068
Total	65,926	69,048	79,510	86,883	90,796	90,717
Share higher education %	37.8	39.2	44.5	46.1	47.1	50.2

Source: Australian Bureau of Statistics (1998b, 2000b)

Sectoral changes: Research publications

In many fields of research, the most tangible evidence of research activity and the dominant form of formal communication is the production of papers in academic journals. Over the 1990s, Australia's contribution to the global share of knowledge increased significantly. Australia's share of publications indexed by the Institute for Scientific Information on the Science Citation Index (SCI) grew from 2.2 per cent to nearly 2.8 per cent between 1991 and 1999. This increase is largely attributable to increased output by higher education researchers, whose contribution increased from 1.47 per cent to 2.06 per cent over the period (Butler 2001b). Citations increased in line with this increased output. Strong growth also occurred in the social sciences, and the arts and humanities, as measured by the relevant citation indices. Figure 3.3 charts movements in the share of scientific, social science, and arts and humanities publications produced by Australia's higher education researchers, as a share of the global total.

Figure 3.3 Share of world academic publications authored by Australian researchers⁵⁶



Source: Butler (2001)

The growth in publications⁵⁷ output by Australia's higher education sector may be the result of increased productivity, the number of active researchers and the number of Australian universities. For example, the contribution made by the post-1987 universities increased nearly three-fold over the 1990s, from 0.06 per cent to 0.22 per cent of the world total. The Research Quantum which rewards universities for publication output is likely to have boosted publications, however, the absence of a strong quality criterion to the Research Quantum publications measure may adversely affect the impact of journals produced by the sector.

Higher education researchers contributed to three quarters of Australia's output of scientific publications by the end of the 1990s, up from around two thirds of the scientific output at the beginning of the decade. While recognising that the coverage of publications indexed by the Institute for Scientific Information varies between fields, the strongest growth appears to have occurred in agriculture, veterinary and environmental sciences, and engineering and technology, which are fields in which the activity of other public research providers has declined (Butler, 2001b).

Table 3.9 Universities' share of Australian publications on the Scientific Citations Index, 1981, 1991 and 1999

	1981	1991	1999	Growth	Growth
	%	%	%	1991-99	1981-99
				%	%
Mathematical Sciences	87.0	94.7	95.1	0.4	9.3
Physical Sciences	82.9	83.7	88.6	5.8	6.9

⁵⁶ SCI – Science Citation Index, SSCI – Social Science Citation Index, A&HCI – Arts and Humanities Citation Index.

⁵⁷ ISI bibliometric data does not provide a comprehensive picture of journal output. It does not collect data on all academic publication and the extent of coverage varies between disciplines. Extensive data 'cleaning' is necessary before attempting to compare the relative performance of individual institutions. Furthermore, there is considerable variability between disciplines as to the extent to which publication represents the preferred medium for communicating research findings.

Chemical Sciences	85.2	83.9	90.1	7.3	5.7
Earth Sciences	63.3	70.2	72.9	3.9	15.2
Biological Sciences	67.8	64.8	73.6	13.5	8.5
Information, Computing & Communications Science	88.0	86.1	87.3	1.3	-0.8
Engineering and Technology	63.9	69.6	83.7	20.2	30.9
Agriculture, Veterinary & Environmental Sciences	46.1	47.0	65.0	38.2	41.1
Medical & Health Sciences	60.2	59.0	66.9	13.4	11.2
Total	66.6	64.9	74.9	15.5	12.5

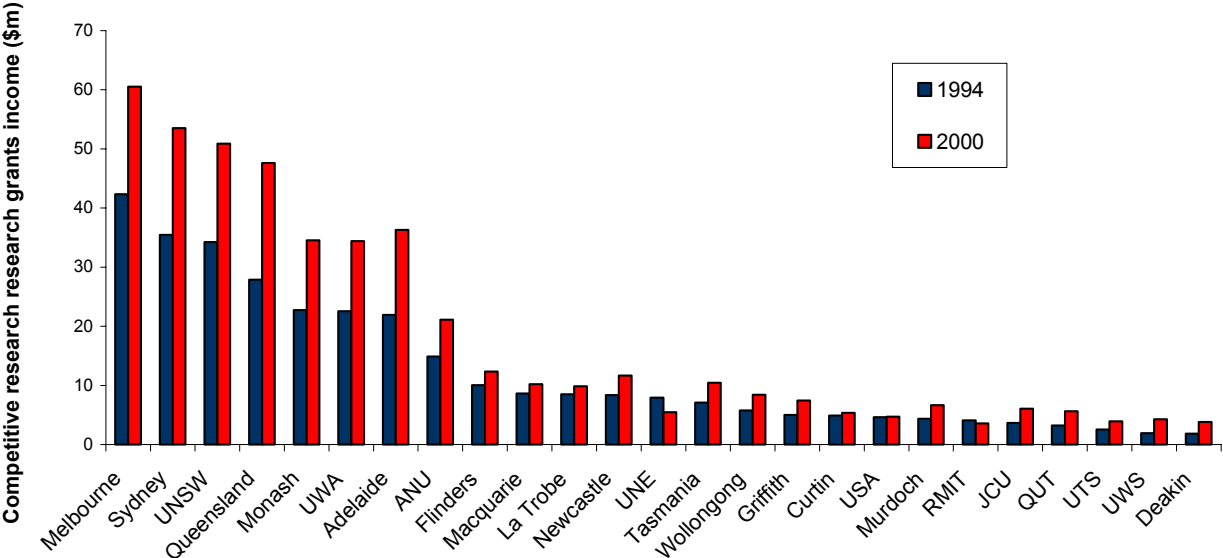
Source: Butler (2001b)

The contribution to research and research training made by Australia's universities grew relative to other research performers within Australia, both in relation to basic research — its traditional area of focus — and to more applied research. There is little evidence to suggest that other research providers are displacing universities from their long-standing knowledge creation and research training functions. This helps to allay concerns, at least for the short to medium term, that the rise of the Mode 2 knowledge mentioned previously would lead to the emergence of a raft of new research producers. There is little evidence in Australia to suggest that the commanding position enjoyed by universities with respect to research is under threat.

Changes in institutional performance

As already noted, Commonwealth funding for research in the late 1980s was highly concentrated in the hands of a relatively small group of universities. The policy and funding framework established by the 1988 White Paper rewarded universities and individuals on the basis of their recent performance through a web of interdependent research programmes. Over time, this provided for incremental change, funding allocations in line with movements in universities' and individual researchers' capabilities. However, by the end of the decade, movements in funding shares had been fairly modest, and funding allocations continued to reflect a differentiated higher education sector with respect to research. Many universities expressed concern with the funding mechanisms: some universities called for a system which would direct a greater share of Commonwealth funds to research intensive universities, either on a mandated basis or through allocative measures that would, in effect achieve, similar outcomes. Other universities felt that the allocative mechanisms took excessive account of past performance and failed to recognise their rapidly changing capabilities.

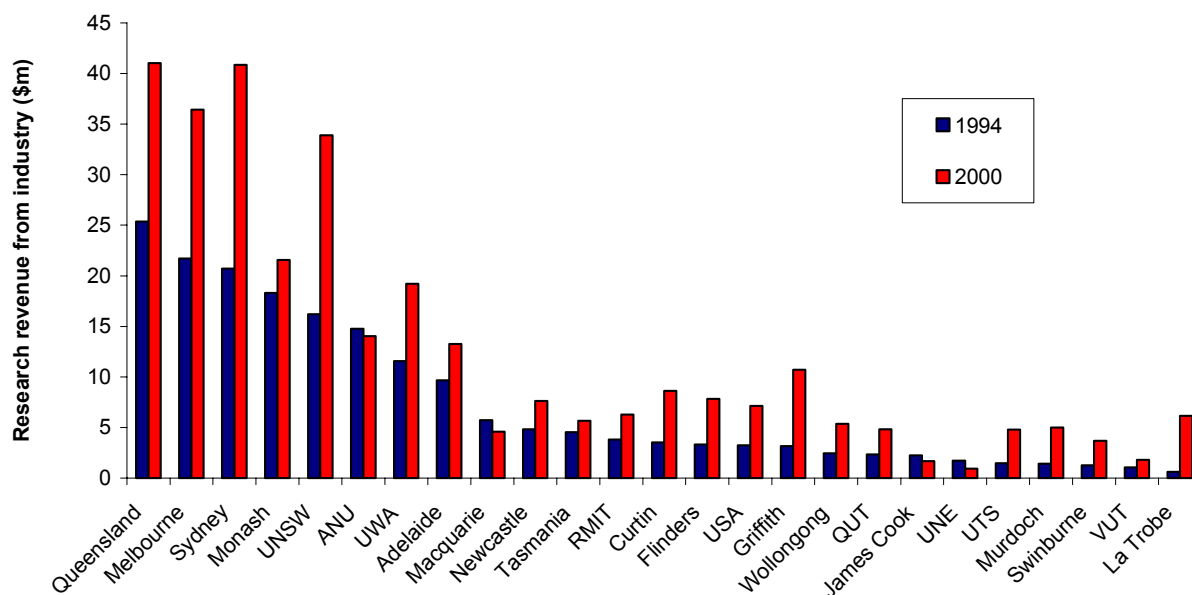
Figure 3.4 Competitive research grants in the largest 25 universities (by value of competitive research grants in 1994), 1994 and 2000



Source: Department of Education, Science and Training

To demonstrate changes in overall performance, two graphs are presented. The first (Figure 3.4) demonstrates growth in competitive research income among the largest 25 universities (as determined by competitive research grant income in 1994), between 1994 and 2000. It is apparent from the graph that virtually all of these universities increased their competitive grant income over the period. The smaller universities, which are not shown here, also demonstrated growth in competitive research grants income over this period, including some that demonstrated very strong growth indeed. Southern Cross University, Charles Sturt University and Victoria University of Technology, for example, achieved growth in research income from competitive grants of more than 200 per cent.

Figure 3.5 External research income from industry and ‘other sources’, 1994 and 2000



Source: Department of Education, Science and Training

The second graph (Figure 3.5) is similar and portrays growth in research income from ‘industry and other sources’ between 1994 and 2000 among the 25 largest research universities (measured by the value of their industry income in 1994). Again, the majority of universities demonstrated strong growth over the period, and smaller universities also improved their overall performance. Among the smaller universities not shown here, the University of Ballarat, Deakin University and Edith Cowan University, achieved growth of more than 1,000 per cent over the period. This graph demonstrates greater movement in relative performance than with respect to competitive grants. As performance in attracting industry sourced income will be rewarded more highly in the future, it will be interesting to observe future trends in this area.

Besides performance measures that focus on universities’ total levels of research income or expenditure, publications output, or research degree completions, other measures attempt to moderate for the size of institutions, that is, to compare their ‘research intensity’. One such measure is known as the Brennan Index, named for a former Chair of the Australian Research Council. The Brennan Index is derived by dividing a university’s allocation under the Research Quantum⁵⁸ by its operating grant. In 1995, the earliest year for which data is available, institutional scores under the Brennan Index ranged from almost 10.9 per cent for the highest ranked institution, to less than 0.3 per cent in the case of the lowest. According to this Index, the top ranked positions are filled by the ‘Group of Seven’ universities (the Australian National University has been excluded from the analysis as the Institute for Advanced Studies was not formerly eligible for funding under the Research Quantum)⁵⁹ and Flinders University – suggesting that their staff tend to be more research active than their peers in other universities (Table 3.10). The first two places are occupied by medium-sized research intensive universities that would tend to be overshadowed by larger universities using measures that do not take account of size.

⁵⁸ The Research Quantum was allocated on the basis of a formula which varied slightly over the second half of the 1990s. In 2000, it was allocated on the basis of institutions’ share of research income (80%, with income from competitive research grants being double weighted relative to income from other sources), publications (10%) and higher degree research completions (10%, with PhD completions being weighted three times as heavily as Masters degrees).

⁵⁹ The ‘Group of Seven’ comprises the universities of Melbourne, New South Wales, Sydney, Queensland, Adelaide and Western Australia, and Monash University.

Table 3.10 Top 15 ranking institutions according to the Brennan Index, 1995 and 2000

	1995	2000
University of Western Australia	1	1
University of Adelaide	2	2
University of New South Wales	3	4
University of Melbourne	4	3
University of Queensland	5	5
University of Sydney	6	6
Flinders University	7	7
Monash University	8	9
University of New England	9	13
Murdoch University	10	14
Macquarie University	11	10
University of Tasmania	12	11
James Cook University	13	15
University of Newcastle	14	12
University of Wollongong	15	8

Source: Department of Education, Science and Training Higher Education Research Data Collection

Most institutions show little movement in their rankings from one year to the next, but the University of Wollongong has shown pronounced improvement, as have several universities that fall outside the list (University of Canberra, Southern Cross University and Edith Cowan University).

It should be noted that from 2002, the Research Quantum was replaced by the Institutional Grants Scheme (IGS). The IGS funding is formula-based and provided to institutions to support their research and research training activities.

For interest, another measure of relative performance is also provided (Table 3.11). The top 20 institutions are ranked in terms of their external research income per staff member, averaged over the years 1998-00. This list reveals some surprises, the most notable of which is the highly ranked position of the Australian Maritime College. Post-1987 institutions are highlighted.

Table 3.11 External research income per staff member averaged for 1998-00

University of Melbourne	1
University of Adelaide	2
University of New South Wales	3
University of Western Australia	4
University of Queensland	5
University of Sydney	6
Flinders University of South Australia	7
University of Tasmania	8
Australian Maritime College	9
Monash University	10
University of Newcastle	11
University of Wollongong	12
Murdoch University	13
Macquarie University	14
Northern Territory University	15
Australian National University	16
University of Canberra	17

James Cook University	18
Griffith University	19
University of South Australia	20

Source: Department of Education, Science and Training Higher Education Research Data Collection

Concentration versus broadly based research capacity

The 1988 White Paper reforms promoted the benefits of research concentration and of achieving critical mass in research but it was not at all certain that universities would adopt these principles. The research-intensive universities had already achieved strengths across many, though not all fields of research, and could be expected to continue to pursue this goal as it was central to their research mission. However, it is important to recognise that some fields such as law, architecture and music did not have a strong established research culture, and their teaching staff tending to be drawn into research in a similar way to many teaching staff in the former colleges of advanced education.

For the newly established universities there were choices to be made whether to attempt to develop research capabilities across a broad range of disciplines, or to adopt more selective, targeted approaches. There is a substantial literature extending over four decades on the phenomenon of 'academic drift' which postulates that less prestigious institutions will emulate more prestigious institutions, resulting in less institutional diversity and greater homogeneity over time (Morphew 2000). This phenomenon suggests that Australia's newer universities could be expected to attempt to emulate the broadly-based research profiles of the more established universities. There is some evidence to suggest that this may have occurred (Meek et al 1996). Furthermore, the fact that universities were not uniformly successful in implementing strategic and focussed approaches to managing their research and research training activities was a factor for the Government in developing the policy framework announced in *Knowledge and Innovation* towards the end of the decade.

Nevertheless, despite this, universities are distinctive in terms of their research profiles, reflecting historical, geographic and other factors. The universities with an established research tradition perform research of a high quality across a broad range of fields. Much of Australia's research in health and medical science is concentrated in universities with medical schools. Many of the smaller or newer universities adopt a more focussed, and often innovative, thematic approaches to their research effort in line with their strategic objectives and specific circumstances. A number of the universities that were formerly institutes of technology continue a tradition of strength in areas of applied science and technology, while regional universities commonly develop areas of strength in fields of particular interest to their communities.

Bibliometric analysis indicates that while the research intensive universities dominate overall research performance, many universities were able to claim to be among Australia's leading institutions in certain fields (Butler 2001b). In a similar vein, the Australian Research Council (2000b) found that the larger research intensive universities dominated most fields of research in terms of attracting research income but that other universities also performed strongly in particular fields. Among the smaller research intensive universities, the University of Adelaide, for example, attracted the most research income in agricultural science and third highest in mathematical sciences. The Australian National University ranked first in the humanities and earth sciences, second in the physical sciences, and third in health and medical sciences. Among the intermediate-sized institutions in terms of research performance, Macquarie University ranked second in the humanities, and sixth in each of mathematical sciences, applied sciences and technology and information and communications technology. Among the less research intensive institutions, RMIT ranked fifth in engineering and information and communications technology, and ninth in the social sciences. Victoria University of Technology and Swinburne ranked 12th and

13th respectively in applied sciences and technology, while Central Queensland University and the Northern Territory ranked 14th and 16th in the chemical sciences.

3.8 Realising the benefits of research outcomes

Commercialisation is the process of converting knowledge or inventions into marketable products or industrial processes. Examples of commercialisation routes include collaborative research, contract research, industrial, licensing arrangements and assignment of intellectual property, spin-off companies and joint ventures. (A license is an agreement to transfer knowledge, expertise or technology from one party, such as a university, to industry partners willing to develop, utilise and market the intellectual property, while a spin-off firm is a company established for the purposes of commercialising technology.) In Australia, contract research and licensing arrangements have been the more important mechanisms for commercialising research, although in the last few years, there has been greater interest shown in spin-off companies. A number of Australia's high technology business success stories over the past decade, Radiata Communications, Gropep and Cochlear, have been based on public sector research that has been commercialised through these mechanisms.

Over the past two decades, universities have been called upon to become more entrepreneurial. This has been prompted by government policies which have encouraged universities to diversify their funding sources and to be more actively engaged in the innovation system, and by new market opportunities associated with the growth of the knowledge economy and its unceasing demands for new knowledge (Gallagher 2000). Pressures for change have occurred from both within universities and within business:

For universities, the pressures on funding that occurred from the early 1980s led to a greater awareness of the possibilities for commercial exploitation of invention through, firstly technology licensing, and more recently, spin-off companies. It has led to a greater focus on the outcomes of research. For business, the shortening of the product development life-cycle and the competitive pressures of globalisation, meant that it had to look more broadly for new technologies. Few companies now retain in-house all of the necessary capacity and capability for innovation in their product areas... Increasingly..., business are relying, through linkages with public funded research, on access to well trained human resources and to new scientific knowledge to complement their own R&D efforts.

(Australian Research Council 2001, p. 15)

Universities have established offices or independent 'arms' to assume responsibility for the commercialisation of research, and to manage research contracts, consultancies and the exploitation of intellectual property generated by university employees. Many universities have also major partners in technology parks and business incubators. Some of Australia's universities have established very effective and, in some cases, profitable commercialisation operations.

However, Australia has had limited success in translating new knowledge into commercial products. Australia's patenting performance relative to gross domestic product would need to increase by 70 per cent in order to match world average patenting output (Narin et al 2000). The Australasian Tertiary Institutions Commercial Companies Association⁶⁰ found that while Australia's

⁶⁰ Australasian Tertiary Institutions Commercial Companies Association (ATICCA) (which is now known as Knowledge Commercialisation Australasia) is the peak body for university commercialisation arms. The ATTICA survey of its members revealed that participating Australian universities negotiated 63 new licences and option agreements with industry partners in 1998, and managed 231 licences and options in total. During 1996-98, 46 spin-off companies were formed from universities. University revenue from licences and spin-off firms totalled \$31 million.

universities generate licenses and spin-off companies at a rate that is on par with the United States average, United States best practice exceeds Australia's performance by a factor of 5-20 times. Best practice in the United Kingdom also exceeds that of Australian universities. For example, Imperial College establishes a new spin-out firm every month on average, and Oxford University's technology transfer arm spins out a new company every two months and files a new patent every week.

A number of reports, (Australian Research Council 1999, Johnston, Matthews and Dodgson 2000, Australian Research Council 2000c, Australian Research Council 2001, Batterham 2000) have criticised the ways in which universities have approached commercialisation and challenged them to improve their commercialisation practices. The Australian Research Council paper (1999), for example, argues that university performance in relation to research commercialisation and research contract relationships with research users has been highly variable. A factor that is likely to have contributed to this situation is the difficulty that universities (and government research agencies) frequently face difficulties in attracting and retaining staff with the range of specialist knowledge, skills and experience to successfully manage commercialisation activities, particularly as these individuals are also in strong demand by the private sector. This problem is likely to be particularly acute for smaller universities, with modest research profiles, and little capacity to devote significant resources to research commercialisation issues. Knowledge Commercialisation Australasia (formerly Australasian Tertiary Institutions Commercial Companies Association) has identified the provision of development opportunities for staff as a priority for its members.

University commercial arms tend to rely heavily on the researcher to take a leading role in various stages of the commercialisation process, particularly in respect of the early identification of intellectual property with commercial potential (Johnston, Matthews and Dodgson 2000). Studies have found that many researchers do not have the necessary skills, experience or confidence to identify areas of commercial value. To address this problem, many Australian universities are now offering development programmes to assist researchers (Box 3.11). Some universities, such as the University of Queensland, have gone a step further and adopted a more proactive approach to identifying research with commercial potential by relocating staff from their commercial arms to the faculties.

Box 3.11 The University of Adelaide Research Park, Thebarton Commerce Campus

Rex Hunter, Director, Industry Liaison, Adelaide University Research Park

In 1990, the University, with its free private income, purchased a former office, laboratory and manufacturing site at Thebarton, approximately 4km from the University's city campus. Using the model of a university-related research park, the site was developed pursuant to a master plan, in a staged approach, which aimed to provide good quality, lower cost accommodation for university research groups and commercial businesses.

Adelaide University has viewed the steady development of its research park at Thebarton as providing a unique opportunity to promote research associations with commercial tenants on the Park, to foster industry linked programs associated with the Park and to cultivate the growth of university based businesses at Thebarton. The Park has facilitated a number of collaborations with private industry across a range of fields, including geological research and geophysics, mechanical engineering, occupational health, biotechnology, radar technology, remote sensing business activities utilising geographic mapping and communication technology.

In order to realise the potential for commercialisation of student project activities undertaken in final and honours years courses, the University established a Graduate Entrepreneurial Program in 1993 which provides support to graduates with an innovative idea for a product, process or service, to commence a business enterprise.

Through the program, successful applicants receive an Adelaide University scholarship which provides living expenses while they undertake a Graduate Diploma in Business Enterprise specifically designed to give training in small business management, finance, marketing, entrepreneurship and innovation. PhD candidates approaching the end of their candidature may also receive assistance from the program.

All participants are provided with free accommodation at the Research Park for a 12 month period and are given access to free photocopying, fax, telephone and computing facilities together with a small start up grant and access to interest free loans from Luminis Pty Ltd, the University's commercial development company.

The program places graduates with an existing business to undertake project work for a 12 month period. The business meets the cost of the scholarship, the fees for the Graduate Diploma together with a supervisory fee to an academic member of staff.

A Schools-Industry Linked Program has been a development whereby, in cooperation with local schools and industry, 30 high school students are placed with local businesses to undertake a project which forms part of the school assessment. The Park has also participated each year since 1997 in an Enterprise Day where selected high school students have the opportunity to participate in a learning program designed to introduce them to small business, innovation and enterprise activities. Surveys of the participating students have shown that the day has a significant impact on the students, creating a notion of enterprising activity.

Adelaide University Research Park offers a unique environment for collaborative research activities with industry, research training at a practical and applied level, development of student based ideas into business enterprises and commercialisation of research work through collaborative activities and a program of community schools and industry involvement and interaction.

Information about the scale of Australia's research commercialisation activities is sparse and has suffered from a lack of definitional consistency. As a result, Australia has not been able to track performance on key data such as the number and value of licences issued and spin off companies formed over time. While the Australasian Tertiary Institutions Commercial Companies Association acquired some information from its members, the adequacy of trend data remains problematic. To improve understanding of trends in the commercialisation of university research, the Australian Research Council and National Health and Medical Research Council intend to survey universities and health and medical research institutes on an annual basis using a modified version of the survey instrument used by the Association of University Technology Managers in the United States and Canada. The findings will enable trends to be identified and Australia's performance to be compared with international standards. In addition, universities will be required to submit detailed information about the research commercialisation practices in their Research and Research Training Management Reports.

Other areas of concern (Johnston et al 2000, ARC 2000, ARC 2001) have been identified:

- inefficiencies in business processes in universities seriously impede successful commercialisation;
- there are few incentives to reward university staff for their commercialisation achievements. Researchers generally have access to a share of the royalties received by the university where the intellectual property they create is licensed, (and in some cases, access to equity in spin-off firms). However, criteria for recruiting and promoting staff may give less weight to research commercialisation achievements than a strong publications record. Furthermore, while the benefits of collaboration between industry and universities is widely recognised there are a range of disincentives for university staff to hold management positions in companies on either a part-time or secondment basis; and

- not all Australian universities have formal conflict of interest policies, despite the fact that conflict of interest considerations may arise in a wide range of situations, including when staff hold equity, or are appointed as executive or non-executive directors to firms, or are involved in industrial secondments.

There are a number of 'demand-side' factors that have impeded the chances of success for the commercialisation of university and public sector research. Business expenditure on research and development as a proportion of gross domestic product remains relatively low in Australia. A number of reports have stressed the importance of pre-seed funding to provide proof-in-principle, to exemplify patents and to prepare business plans. The Government addressed some of these concerns through the *Backing Australia's Ability* package, however, the availability of venture capital for much public sector research is limited by the size of the Australian venture capital market, the uncertainty of returns, the high risks and the likely long lag time between initial investment and returns.

The limited interest of venture capitalists in early stage commercialisation, which has led to an 'innovation progression gap', and the realisation that no one university in Australia has sufficient 'critical mass' of intellectual property for development of major commercial endeavours, led the University of Melbourne and the University of Queensland to establish their own venture capital fund, UniSeed Pty Ltd in 2000. The company was established with an initial capitalisation of \$20 million to create and facilitate a family of funds in a joint equity and management venture between the respective commercialisation arms of the two universities – UniQuest Pty Ltd and Melbourne Enterprises International Ltd (MEI). Other universities are currently in discussion with the UniSeed partners. This is a model that provides useful benchmarks for universities in terms of future collaborations in research commercialisation.

Box 3.12 Southern Cross University Business Precinct

Peter Baverstock

Begun in 1998, the Business Precinct is a project of Southern Cross University focussing on research, development, primary production, and value-adding of natural plant products. In much the same way as Silicon Valley brings together the expertise of Stanford University in Information Technology to stimulate co-location of IT businesses, so the Business Precinct aims to bring together the research and development capacity of Southern Cross University in natural plant products to attract companies to the region, to promote synergies amongst those companies, and to provide opportunities for high-value primary production. Ultimately, it hopes to position the Northern NSW region and Australia as the global hub of primary production, manufacturing, and research for natural plant products.

In order to establish the appropriate research and development capacity that would attract relevant companies and businesses, Southern Cross University has strategically established three core Research Centres – in Plant Conservation Genetics, Phytochemistry, and Natural Medicine – since 1996. By 2000, over \$11 million worth of research and development has passed through the Business Precinct and it currently employs more than 80 staff, and has enrolled more than 20 PhD students funded by industry.

Southern Cross University Business Precinct is the first attempt in Australia to develop a technology park with a specific focus. A number of impediments have been encountered along the way. For example, most large tenants establishing specialised facilities seek 40 year tenancies but because the land is owned by the University, the NSW Minister for Education and Training must approve all tenancies beyond 21 years on a case-by-case basis. This could take up to nine months! Fortunately this particular issue has now been resolved.

Many businesses recognise that one of the major benefits of being located on the Precinct is co-location with like-minded businesses, thus generating opportunities for synergistic relationships.

However, rather naturally there is a reluctance by businesses to take the risk of being first on the Precinct. The University is therefore exploring the possibility of contributing to the initiation of the process by establishing spin-off companies on the Precinct at an early stage.

The development of the Precinct has involved a significant investment and support by the University, the State and Commonwealth Governments as well as the Lismore City Council. However there is a limit to the funding that can be committed before returns can be expected. The Precinct must ultimately operate as a non-loss entity. Yet many of the benefits of the Precinct to the University will be seen as enhanced activity in research and research training off-Precinct. A mechanism needs to be established to ensure appropriate recognition reverts to the Precinct from these activities.

The project has had significant benefits in providing research and research training opportunities for the University, created significant new employment for the region, and promoted significant national and international collaborations including participation in two Co-operative Research Centres (Molecular Plant Breeding and Sustainable Forestry), research partnerships with several major companies, several major ARC-Linkage grants (one involving an international company) and the establishment of joint facilities with other institutions.

In concluding, it is apparent that many universities have been innovative and entrepreneurial in the ways they have forged links with industry (Box 3.12). Recent studies have suggested that these links are dynamic processes that yield a range of different but interrelated benefits for both sectors. However, going beyond the maintenance of linkages with industry to the pursuit of research commercialisation has the potential to yield substantial returns for the institution and the individual researcher while being a complex and risky activity. At the time of writing, universities and governments are actively exploring ways to better manage research commercialisation. This is an area in which considerable progress may be expected in the coming years. Nevertheless, despite these findings, an OECD study (2001) notes that recent structural and organisational reforms affecting universities and the broader Australian economy are consistent with the potential to enhance performance in this area.

3.9 Conclusion

This chapter has explored developments in research and research training in Australia's higher education institutions over the 1990s on a thematic basis. It notes there has been substantial growth, particularly in relation to the scale and complexity of the research and research training effort. By the late 1990s, the university sector performed a greater share of Australia's total research effort than it did at the outset, largely at the expense of the relative decline of research performed in public research agencies. Expenditure on higher education research as a share of gross domestic profit grew significantly between 1990 and 1998. Commonwealth funds for research and research training are projected to grow at least until 2006 as a result of *Backing Australia's Ability*. The higher education sector has also succeeded in increasing its funding from 'industry and other sources' every year since 1993 when the data were first collected. This looks encouraging for the sector as a whole. Those universities with a sound capacity to respond to the drivers that underpin the policy statement *Knowledge and Innovation* should enjoy continuing growth.

There are, however, a number of emerging issues that will exercise the minds of university researchers and governments into the future. The first of these is the tension that exists between academic values and commercialisation. For many researchers, the pursuit of industry funding is something which causes unease. This may be the result of beliefs that new knowledge should be publicly available, rather than restricted to privileged parties, or due to concerns that industry

funding creates internal discord by giving some researchers, particularly in certain fields, access to vastly superior resources to their peers. Industry funding can cause difficulties for researchers who must attempt to balance academic rigour and impartiality with the needs and interests of the commercially motivated funding body. It can also result in financial loss if research commercialisation proves unsuccessful.

A second area is support for research in the humanities and, to a lesser extent, to the social sciences. The humanities and social sciences make a major contribution to the intellectual and cultural life of the nation, and are important in maintaining social welfare, understanding of other cultures and the consequences of change. Over the decade, expenditure on humanities research in particular declined as a share of total higher education research.

A third area of potential concern is the possibility that the allocative mechanisms announced in *Knowledge and Innovation* could yield unintended consequences in the longer term. One possible issue is that the performance based funding programmes (and the former Research Quantum) reward the quantity of publications output in determining institutional allocations, but do not take account of any direct measures of quality or impact. Some people have argued that it is necessary to incorporate quality or impact measures to remedy this perceived deficiency.

The final issue is Australia's position in the emerging global research system. The Australian Research Council paper (2001) suggests that in a global context, Australia's national public sector research system — of which universities play an important role — is becoming increasingly fragile. The paper argues that the high level of overseas ownership of Australian industry means that decisions made overseas as part of global technology strategies can have a major impact on Australia's innovative capacity. It also notes that competition among nations for direct foreign investment is intense, and that until recently Australia has put little effort into promoting the capabilities of our universities and their willingness to participate in collaborative research and development arrangements. The threats and opportunities available to Australian university researchers in this context are significant.

In concluding, then, research and research training in Australia's universities are generally well placed to face the future. However, in a highly competitive, global research environment, insularity and complacency are likely to have significant negative impact on Australia's position in a global research environment and every effort should be made to ensure that Australia's higher education research and research training remains internationally competitive.