



Australian Government

**Department of Education,
Science and Training**

The emerging business of **knowledge transfer**

Creating value from intellectual
products and services

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products and services

Report of a study commissioned by the
Department of Education, Science and Training

John Howard
March 2005

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ISBN 0 642 77511 7

ISBN 0 642 77512 5 (online version)

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Preface

This is the report of a study commissioned by the Department of Education, Science and Training as a 'think piece' on research commercialisation processes and measures. It has provided an opportunity to draw together insights, perceptions and concepts, developed over a number of years, arising from work in the evaluation of science and innovation programs and in the relationships between higher education institutions, research organisations, government and society.

In addition to work from previous projects, the study has drawn on research at the Australian Centre for Innovation at the University of Sydney, as well as that resulting from many years in the commercial sector as a partner in a professional services organisation involved in the creation, marketing and delivery of knowledge services to the public and private sectors.

In the initial stages, the project looked relatively straightforward: it was a matter of assembling a large amount of pre-existing knowledge and presenting it in a new format. Unfortunately, it was not as simple as that.

Like most research projects, the study involved looking for patterns, developing hypotheses, testing these through consultation, interview and measurement, and presenting findings and conclusions. Through that process, the study has identified four quite distinct research commercialisation processes which capture knowledge transfer and measurement characteristics. These are detailed in the report.

I would like to thank the many people in the higher education sector, research organisations and business with whom I consulted during the study. I would also like to thank Dr Mark Matthews and Professor Ron Johnston for helpful comments and contributions, and Anne Howard for research and editorial assistance.

Thanks are also due to Dr Russell Ayres in the Department of Education, Science and Training for his support and patience in the drafting process of this report.

Dr John Howard
Canberra
March 2005

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Executive summary

The ways in which universities and research organisations benefit the economy and society is a long-standing and important concern both for policy-makers and the general community. Over recent decades a particular perspective has arisen in prominence—the notion of research commercialisation. ‘Research commercialisation’ refers to the treatment of knowledge as a commodity—an asset over which property rights can be, and are, asserted. The increased prominence given to this ‘capitalised’ knowledge and the role played by universities and research organisations in generating this asset mirrors the attention paid to the ‘knowledge economy’ by economic and social commentators.

This report has been prepared for the Department of Education, Science and Training by Dr John Howard, the founder and Managing Director of Howard Partners. The report proposes a framework for identifying, tracking and understanding the economic contribution of universities and research organisations in the twenty-first century. This framework is characterised by the emphasis placed upon the plurality and the complexity of the channels and mechanisms through which universities and research organisations generate economic benefits.

The report argues that the ‘standard’ research commercialisation model, associated with a linear sequence linking basic research to commercial outcomes, is largely specific to the biomedical sciences. Like the ‘linear model’ of research and development (R&D) itself (basic research—applied research—experimental development) to which it relates, the standard model is easily grasped, and the outputs easily measured, which in turn helps to secure funding. A range of external interests also benefit from the promulgation of this model as *the* model of how universities and research organisations generate economic benefits.

Lawyers, consultants, venture capitalists and the biomedical researchers themselves all stand to gain from increased resources devoted to this type of commercial focus within universities and research organisations. The standard model also has the advantage that it is compatible with the current emphasis on performance metrics within government. As ‘capitalised knowledge’, patents and licenses are easy to count—and the temptation to set targets, such as a planned numbers of patents and associated spin-out companies, can be hard to resist.

The challenge for policy-makers is that the standard model does not in fact adequately reflect the wide range of circumstances through which universities impact upon the economy. Consequently, if performance measures are based exclusively on this standard model, then there is a risk that other, perhaps more important channels for generating economic benefits, will be given insufficient recognition, thereby potentially distorting policies and practice, including misallocation of resources across the spectrum of research-industry interaction.

The report addresses this challenge by proposing a more comprehensive and realistic framework for understanding research commercialisation and knowledge transfer. The framework consists of the following four ideal typical models:

- Knowledge diffusion Universities and research organisations generating useful economic and social outcomes via encouraging the broad industry-wide adoption of research findings through communication, building capacity within industry through extension, education and training, creating standards relating to production and distribution.
- Knowledge production Universities and research organisations generating useful economic and social outcomes by selling or licensing the results of research in the form of commodified knowledge—directly exploiting ‘knowledge products’ embedded in intellectual property and other explicitly codified formats. This is a ‘standard’ model of research commercialisation.

- Knowledge relationships Universities and research organisations generating useful economic outcomes by providing services that indirectly exploit broad intellectual property (IP) platforms consisting of trade secrets, know-how and other forms of tacit knowledge. This approach centres on cooperation, collaboration, joint ventures and partnerships.
- Knowledge engagement Universities and research organisations generating useful economic outcomes as a by-product of shared interests and concerns that transcend the boundaries of the university *per se*.

The report shows how current Australian Government support for science and innovation covers all four of these areas. It is therefore not desirable to restrict measures of performance to ‘knowledge production’ processes—the easiest area to measure performance.

The report argues for separate approaches to performance measures and performance indicators. Performance measurement is undertaken on the basis of assessment of overall program performance, having regard to purpose, resources, processes, impacts and effects. This involves using a range of program evaluation methodologies and techniques.

Performance indicators, by contrast, are intended to inform policy-makers, managers and stakeholders at regular intervals about progress in relation to purpose and objectives. Typically, performance indicators relate to processes (throughput) and outputs, and substantial movements in those categories, which can provide comfort—or raise concerns—about the extent to which program performance results will be achieved in the medium-to-longer-term. Interpretation of performance indicator information is often a skill in its own right.

The report argues that indicators should be kept to a minimum and adopted only when they can provide relevant and useful information about program performance. Indicators should not be seen as performance measures in their own right. Moreover, availability of large amounts of information generated through administrative processes should not necessarily be seen as constituting performance indicators. *It does not follow that just because data are available, they are going to be useful in assessing performance.* It may be necessary to establish cost-effective data collection procedures to obtain relevant, accurate and timely data.

The categories of output indicators for the four research commercialisation processes are summarised as follows:

- Knowledge diffusion Communication activities
Capacity-building activities
Extension and education activities
Standard setting activities
Industry output data
- Knowledge production Academic publication activities
Patenting and licensing activities
Income streams relating to the above
Spin-off company formation activities
- Knowledge relationships Contract research and consultancy activities
Income streams
Staff and students working on interchange with industry
Industry research staff with sessional and adjunct appointments in universities
University-appointed ‘visitors’ from industry

- Knowledge engagement Participation in non-academic community and economic activities
 Jointly owned and operated technology property infrastructure—technology and research parks, buildings, equipment, instruments etc.
 University-organised events for community and regional economic and social benefit (workshops, seminars etc.)
 University facilities available for non-academic purposes (for example, libraries, cultural centres, sportsgrounds)

The report argues that performance measurement for research funding programs should be approached at four levels, depending on the purpose of the program:

- the level of the *economy*: covering contributions to wealth, indicated by growth in national production (output), investment, and the contribution to research to economic performance
- the level of the *industry*: relating to factors such as industry productivity and enhanced industry competitiveness and indicated by reference to baseline industry measures
- the level of the *enterprise*: relating to specific commercial outcomes relating to profitability, viability and sustainability and indicated by factors such as sales, employment, exports and investment
- the level of the *region*: relating to regional performance through clustering of activities and the formation and performance of networks and networking.

All of the classifications and typologies involve measurement issues. The forms of measurement are identified as:

- analytical/conceptual modelling of underlying theory
- surveys
- case studies—both descriptive and economic simulation
- econometric and statistical analysis
- sociometric and social network analysis
- bibliometrics—including counts, citations and content analysis
- historical tracing
- expert judgement.

Each measurement approach has a specific relevance to the level of analysis and the commercialisation processes identified in the report. Moreover, the level of analysis and the measures will vary in their significance among universities and research organisations. Universities that receive a substantial amount of public funding through competitive grants might have a different indicator and measurement profile from institutions that receive substantial levels of funding from state governments and through project research and consultancy.

Universities and research organisations should be encouraged to develop measurement and indicator profiles that are representative, and indicative, of their missions and strategies. Universities in particular should be encouraged to develop profiles relevant and appropriate to their core competencies and distinctive capabilities in the increasingly segmented higher education industry.

It is a matter for funding agencies to decide on the structure, timing and resourcing of program performance measurement and evaluation approaches, and the indicators they wish to collect on a national basis. Those indicators should be limited in number, be consistent in definition, free from ambiguity in interpretation, and relevant to assessing program performance. A ‘minimum data set’ should be developed with a requirement that universities and research organisations design systems that will generate sought-after information in an efficient and timely manner.

Recognition of the different research commercialisation processes creates the conditions for richer and more powerful economic (and social) impacts from universities and research organisations. This will be achieved by avoiding the imposition of a single, and often inappropriate, model of what research commercialisation and knowledge transfer involves in practice, and by encouraging effective *proprietary* strategic management in our universities and research organisations.

Chapter 1: Introduction

Objectives

The project objectives set out in the study brief are:

- To develop a definition of research commercialisation that is capable of registering the economic benefits of publicly funded research
- To identify the full range of knowledge commercialisation processes
- To identify if, and if so, how these processes are currently measured, and identify gaps
- To suggest methodologically robust and cost-effective strategies for ensuring that we can:
 - systematically develop a rich understanding of how publicly funded research leads to economic benefits
 - chart progress in commercialisation success across sectors of the economy and through time.

In the study brief, research commercialisation is taken to refer to an exchange of knowledge generated by research between universities/publicly funded research agencies and the commercial world, and leading to economic benefit. However, the brief noted that current measures of research commercialisation focus on licensing, patenting, 'spin outs' and the income generated thereby.

In this context, the purpose of the study is to provide a more complete picture of the value of scientific and commercial activity in terms of the full range of ways in which knowledge is exchanged between universities/publicly funded research agencies and commercial enterprises, and to consider the flow between the two.

The public policy environment

Universities and publicly funded research organisations are seen by policy-makers, industry advocates and the research community as a significant source of knowledge and capability within the knowledge economy. There is a growing interest in the ways in which capabilities created in these organisations can contribute to economic and social development (Molas-Gallart et al. 2002).

The interest is reflected in numerous studies and papers that report on the commercialisation of research and the way in which intellectual or knowledge products are transferred into industrial application. However, the meaning of commercialisation is not always clear across sectors, and the processes by which knowledge is transferred have not been readily understood.

Better understanding of knowledge commercialisation and the processes through which creators and users of knowledge interact and interrelate will provide a sounder basis for policy actions and initiatives. Moreover, better understanding of commercialisation processes will provide a more informed basis for measurement and assessment of performance in this important dimension of the knowledge economy.

Policy advisers around the world are grappling with these issues, both in terms of policy settings and the measures and indicators of performance. These occur in a broader context concerned with methodologies for the review and evaluation of public programs.

Approach

The study was undertaken using a methodology based on the following processes:

- identification and review of documentary material relating to research commercialisation and relationships between universities, research organisations, business and government

- stakeholder discussions and consultations over a period from June to November 2004; in many cases, follow-up meetings and discussions were arranged
- development and articulation of a model and framework for research commercialisation processes
- testing and validation of the model through further discussions and consultations
- development of process measures and indicators
- preparation of this report.

Considerable prior knowledge, developed through previous research studies and consulting assignments, was also brought to the study.

Further detail relating to the methodology is provided below.

Identification and review of documentary material

The study involved a comprehensive review of the academic, business and official literature on research commercialisation. This material is quite extensive and reflects a number of perspectives about the roles of universities and publicly funded research organisations in the commercialisation of their research outcomes. Material referenced in the study is included in the list of references given at the end of the report.

From this literature it was possible to identify a number of interpretations and emphases vis-a-vis the processes of research commercialisation.

Stakeholder discussions and consultations

Discussions were conducted with people in universities, publicly funded research organisations, industry associations, business and government.

Discussions were held with executive management in universities and research organisations in order to capture strategic perspectives on commercialisation, and with people with specific responsibilities for protecting intellectual property technology and technology licensing.

Development of a model and framework for research commercialisation

From the review of the literature and consultations, a model and framework for commercialisation was identified. This involved identifying four distinct, but interrelated processes, based on:

- the concept of knowledge production, where knowledge is seen as a commodity which can be valued, exchanged and applied in business situations
- the sharing of knowledge through diffusion processes aimed at ensuring widespread adoption and application within industries
- the creation and utilisation of knowledge through relationships built around joint ventures, partnerships and alliances between research organisations, industry and individual businesses
- engagement processes, reflecting the emergence of a social contract between science and society.

Testing and discussion of the model and framework

The model and framework were tested through discussions with colleagues, officers in the Department of Education, Science and Training and key stakeholders through a series of meetings, and presentations and circulation of draft material for comment and feedback.

Development of process measures and indicators

The process models provided a basis for the development and articulation of measures of performance and performance indicators that could point to progress in achieving economic outcomes.

Preparation of this report

This report was prepared through a process involving the preparation of a working draft and subsequent drafts leading to the presentation of a final report.

Organisation of this report

In the following two chapters the context of the study is outlined and a discussion of research commercialisation is provided. This is followed, in Chapter 4, by an outline of a framework for considering research commercialisation processes. In Chapters 5 to 9, each of four models of research commercialisation is identified and discussed. The report concludes with a chapter on commercialisation measures and metrics.

There are a number of attachments included in the report covering the scale and scope of knowledge products, the role and function of intellectual property rights, engagement and outreach commitments at Australian universities and a discussion of research commercialisation processes across research fields and industries.

Chapter 2: Study context

The purpose of this chapter is to provide context for the study by drawing attention to issues relevant to the discussion of the 'knowledge economy'.

Much of the discussion about research commercialisation relates to the creation, marketing, and distribution of what are being termed *knowledge products*. This follows from perspectives originating from new growth theory and perceptions about the workings of the new economy in which knowledge is regarded as a *commodity* with an exchange value, and should be recognised explicitly in the national economic processes of production, distribution and exchange.

These perspectives have a number of implications relevant to the commercialisation of research. These are discussed below.

The 'capitalisation' of knowledge

The recognition of a value in relation to the future productive capacity of certain assets is generally referred to as *capitalisation* of those assets. When ownership of land, buildings and some other physical assets can be identified, defined and valued in some way, and ownership can be clearly assigned to some one or some body, they become capital (De Soto 2000). The capacity to secure ownership rights in knowledge, most often in the form of legally sanctioned intellectual property rights is referred to as the *capitalisation of knowledge* (Burton Jones 1999; Etzkowitz, Webster & Healy 1998).

A substantial literature has developed relating to the characteristics of knowledge as capital and what has been termed *capitalisation* of knowledge—that is, the creation of knowledge assets which can be defined, valued and exchanged in market-based transactions (Burton Jones 1999; Etzkowitz, Webster & Healy 1998). There is a view that, just as the definition of private property rights in agricultural land increased the value of agricultural production in the eighteenth century, definition of property rights in knowledge can facilitate its contribution to wealth. The statutory and regulatory framework of intellectual property law is intended to define and clarify ownership rights in ways to facilitate the dissemination of knowledge and bring it into productive use.

Legally sanctioned intellectual property rights contained in discoveries and inventions and capable of being codified and represented in documentation are often referred to as *knowledge or intellectual products*. More broadly, a knowledge product can be defined as an idea, a concept, a method, an insight, or a fact that is manifested explicitly in a patent, copyrighted material, or some other form of intellectual property, right where ownership can be defined, documented, and assigned to an individual or corporate entity. The formal recognition and ownership of property rights in knowledge is also referred to the *proptertisation* of knowledge.

Knowledge proptertisation and rights of access

Proptertisation of knowledge allows for the transfer (commercialisation) of knowledge products through various forms of exchange transaction, including sale and licensing. Many see this as an opportunity for knowledge to be adopted and applied by all businesses in the creation of wealth, and for universities and research organisations to retain and build their place in the increasingly distributed system of knowledge production—and earn income in the process. Others see proptertisation as an 'enclosure of the knowledge commons' where 'huge swathes of knowledge are fenced off into privately owned plots' (Bollier 2002).

Clarity of ownership enables knowledge creators, particularly in the public sector, to have a continued right of access to their discoveries and to ensure open and widespread access to users through *non-exclusive* licensing arrangements for national economic and industry benefit. For example, widespread adoption of new knowledge in the form of improved production processes and techniques has been an important aspect of building and retaining international competitiveness in Australian agriculture and mining. Universities and publicly funded

research organisations have had an ongoing role in the creation, dissemination and the promotion of adoption of discoveries and inventions in this sector.

Propertisation also allows the creators of knowledge to secure and award *exclusive* access rights to knowledge products through licensing agreements. Exclusive access tends to be sought where a knowledge product created through scientific research provides the foundation for a new marketable product or a new business. In health-related fields, such as pharmaceuticals, where extracting the commercial potential of biomedical discovery is long, expensive, risky and heavily regulated, it is argued that companies need an exclusive right (through their own patents, or exclusive rights to patents created in universities and research organisations) to recoup these development costs.

The practices of the pharmaceutical industry are being extended into other industries where patents in scientific discoveries and technological inventions are seen as a basis for new product development and business formation.

Industry versus business perspectives

These differences in approach to technology licensing highlight a distinction between the commodity aspects of knowledge products, which provide *industry-wide* benefits when applied and adopted as a *collective good*, and those aspects which exhibit applicable *private good* features from a business perspective. The distinction is not always appreciated, particularly as the terms *industry* and *business* tend to be used interchangeably in reports, papers and discussions relating to technology transfer. Businesses within industries compete and increasingly on the basis of their intellectual and knowledge capital (Stewart 1997, 2001).

As indicated above, application of knowledge on a collective industry basis is expected to yield broad industry benefits in terms of enhanced industry competitiveness and productivity improvements. This approach is evidenced in the agriculture and mining sectors. In the manufacturing sector, initiatives such as Industry Action Agendas seek to create and disseminate knowledge with broad industry application. Formation and support for knowledge networks and clusters also has a collective orientation. Non-exclusive licensing of technology and broad dissemination as a basis for adoption tends to be advocated and followed in these contexts.

From the point of view of *individual businesses*, however, where business plans and corporate strategies are based on differentiation and distinctiveness, knowledge products are valuable only to the extent that they cannot be easily acquired and adopted by competitors and imitators. In the wine industry for example, production-related knowledge is widely shared, but business-related marketing knowledge is tightly held. Patenting and exclusivity are sought where it is difficult for the content of discoveries and inventions to be concealed. Where intellectual property can be concealed, companies tend to protect it through secrecy and secure it in covenants in employment and service contracts and various forms of non-disclosure agreements.

As it is often difficult for universities and research organisations to conceal discoveries and inventions (it is actually contrary to academic policies which anticipate publication of research results), businesses may seek to acquire knowledge through patents and other forms of codified intellectual property right ('know what'), but preferably under exclusive licensing arrangements. In Australia, a substantial proportion of technology licenses are made on an exclusive basis (Australia, Department of Education, Science and Training 2004).

More often however, and particularly in engineering and service-related industries, businesses and research managers wish to gain access to the 'know-how' and expertise associated with codified intellectual property (patents and secret material such as source code, databases etc.) through informal dialogue leading to more formal contract research and consultancy arrangements. These arrangements tend to be negotiated at senior levels in business and faculty and are built on strong foundations of trust. Codified intellectual property becomes a platform that provides a basis for forming knowledge-based relationships.

While businesses (and individuals) tend to be interested in knowledge products capable of delivering firm-level competitive advantage, governments and industry leaders are interested in knowledge that will raise the productivity and performance of an industry in an internationally competitive environment. This creates a dilemma for universities, research organisations and policy in terms of deciding whether to undertake or advocate:

- creating and disseminating knowledge for broad industry application, made available through non-exclusive licensing and general courses and programs, with a potentially small financial return
- producing knowledge for specific business applications or needs, to be licensed or delivered exclusively, with a potentially larger return.

This raises an issue that centres on whether more wealth will be created for taxpayers by broadly disseminating knowledge to all businesses in an industry on the basis of non-exclusive licensing, or by encouraging the growth of individual businesses through exclusive licensing of technologies.

Resolving this dilemma centres on acknowledging that there is more than one process for technology commercialisation. These processes differ across research fields and disciplines and across industries. This study endeavours to provide perspectives on the processes and provide a basis for measurement.

Knowledge products and their commercial potential

The marketing and sale of knowledge products funded from public expenditure on research is the essence of research commercialisation, which has attracted so much attention in universities, research organisations and in public policy. Most of this attention is focused on creation of intellectual property rights—knowledge property in the form of patents, copyrighted material, designs, plant variety rights and other codified and/or documented representations of knowledge.

However, in addition to patents, there are several other readily identifiable knowledge product and service categories:

- academic publishing: production, marketing, distribution and sale of books, papers, electronic material through academic presses established for this purpose
- knowledgeable graduates: people possessing knowledge and skills capable of development application in a business and commercial context
- industry-targeted teaching: accredited courses, qualifications and certifications involving the preparation, marketing and sale of courses and programs that meet a specific user need for professional recognition and career advancement
- contract research and consultancy: project-based research, advisory and consultancy services involving the sale of explicit and tacit professional knowledge as a service
- staff interchange and faculty appointments in industry: members of staff available to assist businesses in the development of strategies, particularly in complex science and engineering areas
- research publication: publication of the results of research in peer-reviewed academic journals
- formation of spin-out companies: knowledge-based start-up companies, created to own and market a discovery or technology and (possibly) a product or service based on them.

Features of these knowledge products and aspects of their commercialisation are discussed in Attachment 1.

It is useful to make a distinction between a 'pure knowledge product' (or an 'intellectual product') and a product that 'contains and embeds knowledge'. A pure knowledge product is created by the action of knowledge upon knowledge. This differs from products created by the action of knowledge on materials (McSherry 2001). The concept of pure knowledge products has arisen in the context of the knowledge economy and a view that knowledge is itself a factor of production and can be valued independently of its application and use.

In some situations and circumstances, pure knowledge products may have a value that reflects a potential use, such as in the discovery of a gene or molecule with therapeutic properties. IP lawyers and patent attorneys see patents, as a registered intellectual property right, as a base from which to approach valuation. But, as has been argued, value is most often created when a knowledge product is combined with other forms of capital and materials—and quite often other knowledge products—to make products and deliver services that customers want to purchase and are prepared to pay for. These investments can be and often are substantial.

Much of the work involved in managing intellectual property created in universities and public research organisations is based on an assumption that there is some objective value for intellectual property separate from its application and use. The result is that proactive IP management misses some key issues. Specifically:

Technologies acquire economic value when they are taken to market with an effective business model. When research discoveries are driven by scientific inquiry and not connected to any business purpose, the commercial value of the resulting discoveries will be serendipitous and unforeseeable. Unsurprisingly, most of these discoveries will be worth very little, although a few may be worth a great deal—once they are connected to the market through some viable business model. (Chesbrough 2003b)

Businesses argue that research providers need to understand more about the way research relates to the business contexts of the research users so that researchers can understand the potential connections early on in the process. At the same time, research users become concerned when researchers endeavour to develop business models that do not fit the models of the participants, or in which participants see no economic or commercial merit.

Researchers and research organisations will, except in very rare situations, earn more from being paid for their work input (contracts and consultancy) than from licenses and royalties flowing from intellectual property or from income earned in spin-out companies. Studies and data consistently show that, except in a limited number of cases, universities and research organisations earn very little from licensing intellectual property. Moreover, many of the major revenue streams have been generated from non-exclusive licensing arrangements.

Increasingly, companies are adopting an 'open source' licensing that implicitly recognises that unused intellectual property has no value explicitly and is available for sharing under standardised forms of collaborative research agreements (National Academy of Engineering 2003). Collaborators can then concentrate on creating value through building sustainable business propositions while recognising the relational value of intellectual property. Companies such as IBM have an active licensing program.

Even companies such as Microsoft are moving away from a strategy of secrecy to one based on patents and non-exclusivity in an endeavour to become part of the 'open source' approach to innovation.

Nonetheless, the recognition of knowledge as capital has meant that universities, research organisations and businesses are becoming more protective of their intellectual property rights. But the processes of working out licensing and sharing arrangements can actually impede the free flow of ideas necessary for research and innovation to flourish. Whenever universities get together in a research consortium, or when single university–industry collaboration is initiated, lawyers spend a great deal of time, energy and money working out fine details of intellectual property agreements. This raises the more general issue of why registration of intellectual property rights is sought.

Why universities and research organisations register intellectual property rights

Fundamentally, universities and research organisations have developed and implemented intellectual property management policies to facilitate the transfer of knowledge to the community. From various sources, the purposes of these policies centre on:

- services to faculty: to assist faculty in developing, negotiating and maintaining relationships with industry, negotiating IP rights and contracts, as well as ensuring consistency across the institution and, above all, to protect the interests of the institution including minimisation of risk
- knowledge dissemination: to assist in the task of getting new knowledge into the public domain and community; this activity involves universities fulfilling a 'social contract' in return for public funding
- service to industry: to ensure that industry has access to university and research organisation facilities and services; for some universities and research organisations this has been a specific objective (for example, the CSIRO, agricultural research institutes and the institutes of technology); research organisations such as Australian Nuclear Science and Technology Organisation (ANSTO) and the Defence Science and Technology Organisation (DSTO) are developing closer relationships with industry
- local and regional economic development: universities are now seen to have a key role in economic and industrial development, which means developing processes and procedures for effective engagement with business and government. The way in which universities, industry and government manage this role is an important issue internationally and in Australia
- revenue generation: through income from technology licenses, academic publishing, contract and collaborative research and consultancy; data indicate that only a very few universities make money from licensing technology; few universities receive sufficient royalties to cover costs of administration; greater contributions emanate from consultancy and contract research.

Further discussion on why universities and research organisations register intellectual property is contained in Attachment 2.

The strategies adopted in relation to policies in each organisation will have a major influence on the way in which universities and research organisations interact with industry and businesses. There are various formal mechanisms for this interaction, including technology transfer offices and research offices (sometimes combined); stand-alone major research facilities; faculty business units, and industry; government-funded and specifically designated research centres. More recently, universities and research organisations have established a broader commercial management capability to address all aspects of commercial activity.

Chapter 3: What is research commercialisation?

Research commercialisation is a term that is used widely and diversely within research organisations, industry, and government. In application, it has slightly different interpretations and meanings. Three perspectives are readily identifiable:

- for research organisations: selling the results of research for a profit
- for businesses: taking ideas and concepts to market—it is about innovation
- for government: interest in creating wealth from investments in public research—reflected in jobs, productivity growth, and international competitiveness.

The perspective depends to a large degree what each of the above institutional categories sees as 'being commercial'. The context of each perspective is discussed further below. This is followed by a short discussion of the linkages between research and innovation. As a way of providing some context for the report, summary data on the level of public expenditure on research in universities and publicly funded research organisations are provided. The chapter concludes with a short discussion on identifying, defining and measuring the benefits of publicly funded research.

Perspectives on research commercialisation

Research organisation perspective

From a research organisation perspective, research commercialisation is concerned with providing capability and input into industrial innovation.

Derek Bok, former President of Harvard University, describes commercialisation 'in the strict sense of the term ... as efforts to sell the work of universities for a profit'. Bok argues that commercialisation became more prevalent in universities after 1980 due to 'the rapid growth of opportunities to provide education, expert advice, and scientific knowledge in return for handsome sums of money'. These opportunities were provided by a more technologically sophisticated, knowledge-based economy (Bok 2003).

For universities and research organisations, research commercialisation relates to the distribution and/or sale of the results of research, usually identified in terms of a knowledge product (licensing or sale of an intellectual property right contained in copyrighted materials, patents, designs, plant variety rights etc.) and/or the sale of services based on the application of knowledge (contract research and consulting).

Contemporary definitions and usages of the term 'research commercialisation', from within the research community, and from people and organisations who work with the research community (early stage venture investors, IP lawyers and patent attorneys, for example), also include:

- planning how to take a good idea to the marketplace; it involves working the idea into a business plan, consideration of protection options and considering how to market and distribute the finished product
- licensing patents and/or software to an independent company, licensing software and patents to a company that is formed by researchers, commercialising researcher experience and time as a consultant to an independent company or start-up company
- fostering start-up companies based on research generated technology, identifying, assisting, and accelerating commercial opportunities resulting from knowledge created by faculty, staff, and students
- transferring university technologies to the private sector to create jobs and increase industry competitiveness
- converting life science discoveries from the lab to the commercial market.

The capacity for universities and research organisations to earn revenue from the sale of knowledge products and services has led some to interpret their roles as business enterprises, or ‘knowledge factories’ engaged in an economic activity relating to the production, distribution, and exchange of knowledge (Aronowitz 2000). The term ‘entrepreneurial university’ also reflects this perception (Clark 1998; Gallagher 2000; Rosenberg 2003). This misrepresents the roles of universities and publicly funded research agencies in terms of their characteristics as ‘non-government organisations’ (NGOs).

While most universities, and particularly research universities, might be expected to be businesslike, they are *not* business enterprises to the extent that they have a core mission and purpose to create customers through the processes of marketing and innovation (Drucker 1985). In general, universities and research agencies do, of course, promote their reputation and capability, as a basis for attracting high-quality students and research funds, but this is not the same as selling academic awards or research results. Those institutions that do sell degrees and provide predetermined research results do not fit the model of a university.

The fundamental mission of universities and research organisations relates to education and research. More recently, a third mission relating to ‘outreach’ has become more prominent. The success of these institutions is judged by the extent to which they are able to create new knowledge and pass it on (transfer it) to others. Traditionally, transfer has been through dissemination of research findings and methods in scholarly and peer-reviewed publications and through teaching and learning. Transfer through the sale of knowledge products and services has become an important, but by no means dominant form of knowledge transfer.

Industry and businesses perspective

From a business perspective, research commercialisation is concerned with managing innovation—using knowledge generated from research, in combination with other resources and capabilities (and particularly management leadership, creativity and talent) to meet customer and client expectations in new ways. Businesses invest in research and development to create new and/or improved products, processes, and service offerings. In knowledge-intensive industry sectors, competitive pressures require a substantial business commitment to research and development.

In application, commercialisation refers to a process of taking a new product from development to market; it generally includes production launch and ramp-up, marketing materials and program development, supply chain development, sales channel development, training development, and service and support development. It relates to achieving a return on investment in time, effort, materials and above all, on the financial resources allocated.

Businesses look to universities and research organisations for new knowledge to complement their own innovation strategies. As shall be discussed later in the report, they do this less by purchasing knowledge products and more through a broad range of interactions and relationships—including reading and review of academic publications, personal contacts, attending professional conferences, recruitment of graduates, contract research and consultancy.

In the emerging commercial and industrial environment, businesses are developing closer relationships with universities and research organisations through cooperative and collaborative research and teaching as a way of accessing knowledge. Arrangements are becoming formalised in jointly owned research institutes and centres.

Public policy perspective

From a public policy perspective, research commercialisation is concerned with adopting, applying, and using new knowledge, particularly knowledge generated from publicly funded research, in the economic processes of production in ways that create wealth. Wealth creation is reflected in increments to GDP per capita and is generally indicated by companies that have been able to increase sales, employment, and exports because of public investments in research.

Private expenditure on research and development is also a major indicator, on the basis that high levels of private expenditure on research and development are associated with high levels of innovative activity (new products, processes, services, and businesses). Public expenditure on research is considered to be a major lever of private expenditure, and has been used as an indicator in a number of Australian Government and state government programs.

Knowledge is also 'commercialised' when taken up by governments and adopted in public programs, and by non-government organisations in areas such as health (for example, new medical and clinical practice), education (new teaching) and the environment (new approaches to natural resource management).

Governments and policy advisers, influenced by new growth theories and perspectives on the new economy, see knowledge as an important factor in production, and a major driver of economic growth (Freeman & Soefe 1997; Nelson 1996; Nelson & Winter 1982). Knowledge is increasingly being seen as a commodity with a value in its own right—and therefore an exchange value. In this way knowledge is able to be incorporated into models of economic growth.

The way knowledge is incorporated into growth models is by measuring inputs—typically expenditure on R&D and human capital. In this economic paradigm, the outputs of knowledge are the knowledge products identified by research organisations. The most tangible and measurable form of knowledge products is intellectual property rights. In other areas of infrastructure investment input and output measures predominate, for example, electricity, gas, roads, bridges.¹

But the way in which knowledge products—at best an intermediate product—are translated into commercial products and services (products with a commercial application and use) is not always clearly understood. Many thousands of individual business decisions may be involved. Moreover, there is a broad range of knowledge products, and a broader range of knowledge services, most of which are difficult to quantify and measure. As will be addressed in Chapter 4, there is a number of separately identifiable, albeit interrelated, research commercialisation processes. This makes the task of measuring impact doubly difficult.

The central argument of this report is that measurement of research commercialisation needs to be related to the processes through which commercialisation occurs.

The linkages between research and innovation

Public policy seeks to promote a strong relationship between research undertaken in universities and publicly funded research organisations and innovation. But while public research is oriented towards scientific discoveries, technological inventions and new explanations of phenomena and behaviour, innovation is first and foremost a business function.

The business and management literature makes it clear that there is no necessary relationship or correlation between an act of invention and discovery on the one hand, and a successful marketplace innovation on the other. The economics of discovery and invention are profoundly different from the economics of innovation (Schrage 2004). The absence of clear linkages between research and innovation has made it relatively easy for companies to offer savings in research and development as part of their cost-cutting strategies.

Although research and innovation are terms commonly used in tandem, the reality is that they are fundamentally different activities. It may take many years, even decades, for discoveries and inventions to be incorporated into innovations: that is, commercially viable processes, products and services customers are prepared to pay for. Economic and industrial history is replete with examples of where discoveries and inventions have been applied in areas that were never imagined by the creators.

¹ As with knowledge, understanding the way in which these outputs create wealth is a complex process. It generally involves economic modelling and estimation techniques such as cost–benefit analysis and discounted cash flows.

There is, however, a widely held view that new knowledge created through investments in scientific research is closely correlated with increases in production of goods and services, productivity and wealth. It is important therefore that linkages between research and innovation be identified, tested and validated. Evidence of linkages between investment in scientific research and economic outcomes is drawn from a number of levels of analysis:

- production-based economic models that link advances in technology and technological progress to economic outcomes; this follows from the knowledge capitalisation argument that investments in knowledge, like investments on other forms of capital, will result in increases in output, employment and incomes
- industry studies based on analysis of labour and multifactor productivity which associate enhanced industry performance with the widespread adoption of new technologies—productivity gains are seen as major drivers of international competitiveness. The Productivity Commission has undertaken a substantial amount of work in this area as have a number of the rural Research and Development Corporations
- business case studies and surveys that associate technological innovation with improved profitability, sales, exports and employment; this approach is commonly adopted in evaluation of research and technology assistance and support programs.

Establishing linkages does not however, establish causality. There are many factors, including management creativity and talent, which impact of the extent to which investments in research and technology will lead to economic and commercial outcomes. It is therefore important to have an understanding of the processes through which knowledge is adopted, applied and used in commercial and industrial situations. It will be argued that these processes differ between scientific disciplines and industries. In order to provide some perspective on these differences, a short overview of public expenditure on research is provided in the following section.

Knowledge of the process for linkages also provides the basis for measurement and performance indicators. However, as will be argued later, the performance indicators are not measures: they are proxies for more robust approaches to measuring, assessing and evaluation performance.

Profile of public expenditure on research

A detailed analysis of public funding of research among industries and research fields, courses and disciplines (RFCD) categories published by the Australian Bureau of Statistics (ABS) is provided at Attachment 5. An overview is provided below.

Public funding for research in universities

The Australian Bureau of Statistics data indicate that, in 2002, \$1008m was made available by governments for research in universities. Half of this (\$507m) was allocated under Australian Government competitive schemes and \$397m under other Australian Government schemes. The states allocated \$104m (Australian Bureau of Statistics 2004b).

Of the total funding provided, \$247m was allocated to research in medical and health services and \$148m to research in the biological sciences. This life science category amounted to 42% of the total. An additional \$99.4m was allocated for research in agricultural, veterinary and environmental sciences and \$148m for research in the natural sciences—mathematics, physics chemistry, and earth sciences. Broad details on the distribution of public funding for research in universities is provided in Table 1.

Table 1: Expenditure on R&D by research fields, course and disciplines classification and source of funds for expenditure in universities, 2002

Research fields, courses and disciplines (RFCD) classification	Australian Government competitive schemes (%)	Other Australian Government (%)	State and local Government (%)	Total publicly funded research (%)
Mathematical sciences	2.0	1.4	1.1	1.7
Physical sciences	4.5	5.2	2.0	4.5
Chemical sciences	4.7	5.1	1.2	4.5
Earth sciences	4.5	3.9	2.2	4.0
Biological sciences	15.7	15.1	8.4	14.7
Information, computing and communication sciences	3.0	3.3	3.5	3.2
Engineering and technology	9.8	9.0	8.6	9.4
Agricultural, veterinary and environmental sciences	10.1	8.7	13.1	9.8
Medical and health sciences	30.9	19.7	37.8	27.2
Education	1.9	4.5	6.4	3.4
Economics	1.4	3.3	1.7	2.2
Commerce, management, tourism and services	1.3	2.1	1.8	1.7
Studies in human society	2.0	4.3	3.7	3.1
Behavioural and cognitive sciences	2.7	3.8	4.0	3.3
Other research fields	5.5	10.5	4.6	7.4
TOTAL	100.0	100.0	100.0	100.0

Source: Australian Bureau of Statistics (2004b)

The relative significance of state government expenditure in health and medical sciences reflects the role of research in public hospitals and affiliated research institutes.

Public funding for research in public research organisations

ABS data indicate that in 2002–03 the Australian Government allocated \$1206m for research in its own research agencies and organisations. State governments allocated \$594m into their own agencies (Australian Bureau of Statistics 2004a).

Of the Australian Government expenditure, \$340m was in the area of engineering and technology, \$163m related to earth sciences (mining and energy), \$155m to information and communication sciences and \$149m to agriculture, veterinary and environmental sciences. Of the state expenditure, \$346m was allocated to agricultural, veterinary, and environmental sciences, \$65m to biological science and \$56m to health and medical research. This distribution, in percentage terms, is illustrated in Table 2.

Table 2: Expenditure on R&D by research fields, course and disciplines classification and source of funds for expenditure in research organisations, 2002–03

Research fields, courses and disciplines (RFCD) classification	Australian Government (%)	State Government (%)
Mathematical sciences	1.8	1.1
Physical sciences	8.5	0.0
Chemical sciences	7.1	1.9
Earth sciences	13.6	5.6
Biological sciences	9.0	10.9
Information, computing and communication sciences	12.8	2.4
Engineering and technology	27.3	3.5
Agricultural, veterinary and environmental sciences	12.3	58.3
Medical and health sciences	1.7	9.4
Economics	3.5	1.0
Law, justice and law enforcement	0.4	1.4
Other research fields	2.0	4.4
TOTAL	100.0	100.0

Source: Australian Bureau of Statistics (2004a)

The growth in commercial activity

Associated with increased expenditure on research has been a substantial increase in university and research organisation 'earned income'. This income is not so much associated with research commercialisation income, but with income used to finance research. This observation is also consistent with data which indicate universities are funding a higher proportion of their research from their own resources (See Attachment 5).

Discussions during this study indicated that there is also a significant transfer of surpluses earned from fee-paying students to university-supported research activities. This transfer is particularly important for universities which do not generate significant funding from the Australian Research Council (ARC) and the National Health and Medical Research Council (NHMRC) competitive grants.

The growth in income earned from commercially oriented activities between 2000 and 2003 is reflected in Table 3, which includes data on university income from government sources and other income categories.

Table 3 indicates that total income in the higher education sector has grown by 32.2% over a three-year period. Australian Government assistance has grown by \$701m, but the size of this contribution in overall income has fallen from 45.2% of university income to 39.9%. Fees and charges, including student fees, have increased by \$1023m or 60% and, excluding HECS, now account for 22.1% of university income, compared with 18.2% three years ago.

Income from royalties, trademarks and licences; that is, income mainly associated with technology transfer, amounted to \$34m in 2003, representing 0.3% of total income. Although revenue from this source had increased from \$14.6m over three years, it still represents a relatively insignificant contribution to university finances. Income from consultancy and contract research, largely reflecting technology relationships, was estimated to be \$637m in 2003—about 5% of income.

Table 3: University income, 2000 and 2003 (summary)

	2000 \$000	Percent of total	2003 \$000	Percent of total	Percent change 2000 to 2003
Australian Government financial assistance	4 218 886	45.2	4 919 513	39.9	16.6
State government financial assistance	143 552	1.5	506 042	4.1	252.5
Higher Education Contribution Scheme (HECS)	1 675 697	18.0	1 917 206	15.5	14.4
Fees and charges (including student fees)	1 697 446	18.2	2 720 720	22.1	60.3
Consultancy and contract research	483 175	5.2	637 500	5.2	31.9
Royalties, trademarks and licences	14 593	0.2	34 872	0.3	139.0
Investment income	320 929	3.4	318 678	2.6	-0.7
Other income	773 390	8.3	1 276 073	10.3	65.0
TOTAL	9 327 667	100.0	12 331 827	100.0	32.2

Source: Australia, Department of Education, Science and Training (2004)

It is not surprising that universities are turning their attention to other, more lucrative ways of generating income and establishing commercial relationships. These include fee-paying students sourced internationally and domestically. They are also working with the private sector to establish innovative ways of securing and financing equipment and facilities for research. Universities are reluctant to commit resources to research commercialisation activities that do not generate returns to their institutions.

To maximise returns from these more commercial relationships, universities are looking to increase income from contract research and consultancy. This is requiring a more proactive approach to building relationships with industry, in a manner similar to professional services organisations. As has been argued above, contract research and consultancy generates income not so much by selling intellectual products through licenses, but by leveraging the knowledge services that derive from the application and use of those products. This combines the explicit (codified) knowledge with the tacit knowledge of scientists and researchers.

Balancing disciplinary and applicable research commitments

Maintaining commitment to disciplinary research, but at the same time supporting applicable research is vital for the success of the system. It is not a question of supporting one or the other. It would be a mistake to base decisions relating to the public funding of research only on assessment of applicability rather than excellence.

Public funding for research provides leverage for other sources of research funding. Australian Government competitive funding schemes provide, on average, just under 15% of the funds for research carried out in universities. This varies considerably across research fields, with the Australian Government providing 21.7% of the funding for agriculture, veterinary and environmental research, and a much lower proportion in the social sciences and humanities. Overall, the public sector funds 29.4% of university research.²

It follows that the outcomes of publicly funded research cannot be looked at in isolation from other sources of funds for research. In particular, publicly funded research outcomes derived from competitive grants and which are reflected in the creation of new disciplinary knowledge, and evidenced in publications and citations, may provide the basis for research outcomes funded from business and general university funding.

2 These data are derived from statistical material presented in Attachment 5.

In terms of assessing the outcomes of research, it is important to look at the whole system and the contribution to creating applicable knowledge outcomes and the transfer of this knowledge through the plurality of mechanisms referred to above. However, the capacity of non-research-intensive universities to leverage public funding for research to create applicable knowledge is constrained. As indicated, these universities rely to a greater extent in re-allocation of surpluses from teaching and learning, particularly fee-paying students, to underwrite their research activities. There are limits to how far this cross-subsidisation can be pushed.

The capacity to attract and retain fee-paying students is closely tied to the reputation of a university as a knowledge-creating institution. This in turn draws on its capacity for research, and the translation of research outcomes into teaching practices. Students like to think that they are accessing the latest and most up-to-date knowledge. They are interested not only in applicable knowledge for vocational skills; they also seek access to theoretical knowledge as a basis for problem-solving. This balance between creating disciplinary knowledge and transfer of applicable knowledge is an issue currently being addressed in management research and teaching, particularly in MBA programs (Andrews & D'Andrea Tyson 2004).

Discussions and consultations for the study also indicated that students are interested in the relationships existing between universities, industry and society.

Commercialisation, external benefits and capacity building

Universities and research organisations often embark on commercially oriented projects with an objective of achieving broader public benefits and building social capital. This is particularly the case in the environmental sciences and in the humanities, arts, and social sciences. The financial driver is to recover costs rather than achieve a return on investment.

Many university outreach and third mission objectives fall into this category. Universities and research organisations provide a leadership role in the creation and diffusion of knowledge which would not, or could not be undertaken by individuals and/or NGOs acting on their own behalf. Austlit, the database for Australian literature, which provides an internet resource for research and teaching of Australian literature, is an important example. Austlit makes its resources available through a subscription service based on annual fees from users.

Universities and research organisations also make arts, cultural, recreational, and sporting facilities available to the broader community at, or significantly below, cost. The older universities have substantial investments in these areas. The facilities and services provided contribute to community wellbeing and quality of life in a variety of ways—and the measurement of the outcomes creates particular challenges in the climate of business-oriented commercialisation measures.

Towards a strategic approach

Commercialisation is no longer seen as a 'one off', or a fortuitous by-product of teaching and research. In the changing funding and demand environment, higher education institutions and research organisations need to generate revenue from commercial (that is, profit-making) activities to fund their core activities. As indicated, the capacity to generate profits relies less on selling intellectual products and more on building relationships based on value and service quality.

As resource pressures become more acute, and expectations from non-government funding grow, commercial relationships will become increasingly important to university strategies. It is becoming clear that success in a full range of commercial relationships and the capacity to generate income through these relationships will be vital for the success and standing of a university in relation to its core missions of teaching and research.

To that end, universities are becoming more businesslike in the way in which they plan, organise, and deliver their knowledge services. They are not necessarily becoming 'businesses' to the extent that they adopt entrepreneurial behaviours of risk-taking (although some have tried), but they manage their commercial

activities on a consistent basis through clearly formulated commercial strategies and management approaches—supported by management systems and procedures relevant to the task.

Commercial management extends beyond the traditional focus of technology transfer offices which have tended to concentrate on contract administration and the legal and compliance aspects of protecting intellectual rights. Commercial management involves assessing the opportunities, the commercial returns, and the risks of alliances, partnership and joint venture projects. *It involves negotiating deals.* In some universities (including Melbourne, Queensland and Sydney), this responsibility is carried out within the offices of deputy vice-chancellors, research and academic. For major deals, vice-chancellors are closely involved.

Under arrangements in most universities, however, relationship-building has been largely left to senior faculty, with technology transfer offices and personnel taking a compliance and support role. Under this system there have been many missed opportunities and a significant leakage of revenue and longer-term returns from universities directly to staff and former staff. The commercialisation of Proteome Systems and Radiata provide contemporary examples where the host University missed opportunities for significant revenue streams (West & Ashiya 2003; Matthews 2003).

To illustrate the emergence of this new approach, several universities have established representative offices in Canberra to build relationships in the government professional services market. The objective is to attract consulting assignments from the large purchasers such as AusAid and Defence, and specialised program areas.

Issues and implications

This chapter has outlined three quite different perspectives on research commercialisation—from the research, business and policy perspectives.

The data reported above and detailed in Attachment 5 indicate that a substantially higher level of public funding for research is allocated to government research organisations than to universities. However, universities receive a much larger proportion of the funds for life sciences research. As will be argued in subsequent chapters, it is public funding of life sciences research—particularly biomedical research—which has received the greatest amount of attention in discussions and debates about research commercialisation. Much of this arises because of the very close link between life sciences research and the pharmaceuticals, medical equipment and devices, and the health services industries.

The commercialisation of biomedical research is associated with a process that gives a great deal of weight to patenting, licensing and the formation of spin-out companies. However, the biomedical approach may be of less relevance to commercialisation in other fields of research and to other industries. In this regard, it is important to note that the available data indicate that public research organisations have a very strong research focus in a number of key areas:

- earth sciences (relevant to the mining and energy industries)
- engineering and technology (relevant to 'old economy' manufacturing)
- information, computing and communications sector (specifically relevant to electronics, communications, computing and multimedia)
- agricultural and veterinary sciences (rural industries).

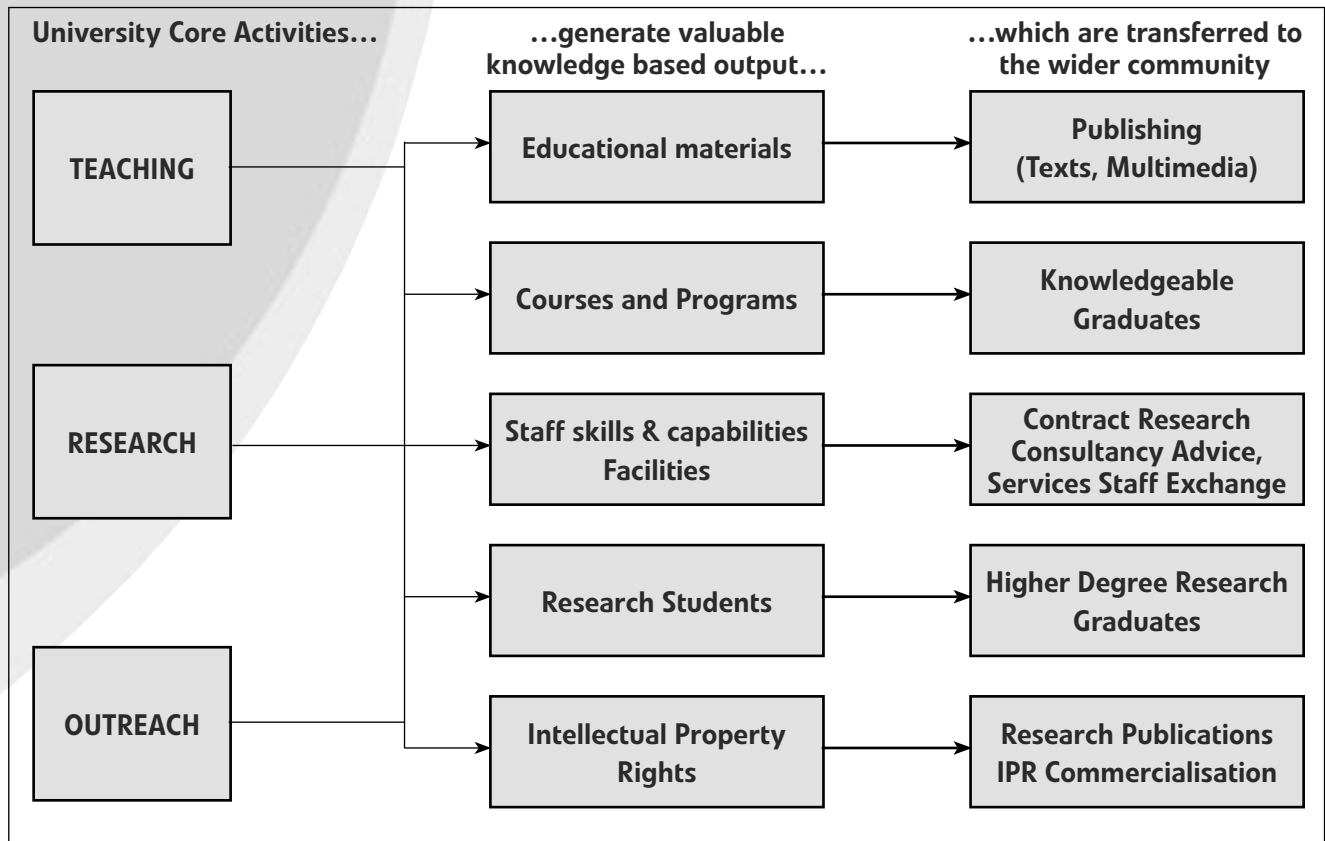
The processes for research commercialisation in these research and industrial areas rely heavily on technology diffusion and high levels of cooperation and collaboration between researchers in public organisations and business.

These preliminary observations provide a basis for a more detailed discussion of research commercialisation processes in subsequent chapters.

Chapter 4: A framework for consideration of research commercialisation processes

Discussions with higher education institutions and research organisations during this study have made it possible to articulate a framework for knowledge transfer which provides a basis for defining research commercialisation processes. This is represented in Figure 1.

Figure 1: Framework for knowledge transfer



The framework identifies the core missions of universities as teaching, research and outreach. These activities are seen to create valued outputs, represented as education materials, courses and programs, skilled staff and facilities, trained research students and intellectual property rights.

Knowledge outputs are taken up in industry and the community through a range of knowledge products and services. These include academic publishing, knowledgeable graduates, contract research and teaching services, research publication and intellectual property rights (IPR) available for commercial use. The features and characteristics of knowledge products and services are outlined in Attachment 1. However, what is of interest in this study are the *processes* by which knowledge is transferred, and subsequently adopted, applied and used in ways that create wealth.

Process as the basis for knowledge transfer

The processes under which knowledge is transferred can be described generically as knowledge diffusion, knowledge production (as discussed above), the development of knowledge relationships, and knowledge engagement. The processes draw on theories and concepts of communicative interaction and modes of discourse and reflect the social as well as the economic basis for knowledge transfer and commercial relationships (Drucker 1988). These processes are outlined below, and form the focus of discussion in Chapters 5 to 9.

The research and analysis undertaken for this study and in related research (Howard 2004a) forms the basis for the definition of four process models relevant to knowledge transfer. These are listed in Table 4.

Table 4: Process models for knowledge transfer

<p><i>A knowledge diffusion model</i>—approaches transfer from the perspective of encouraging broad industry adoption of the results of research; it emphasises communication and adoption of research results.</p>
<p><i>A knowledge production model</i>—sees transfer as the sale of ‘knowledge products’ embedded in intellectual property (IP) and other explicit or codified formats, and manifested in sale and or licensing of intellectual property rights to new businesses (spin-outs) or existing businesses which may be in the public or private sector.</p>
<p><i>A knowledge relationship model</i>—sees transfer as the provision of services to businesses based on a broadly defined intellectual property platform, including trade secrets, know-how and other forms of tacit knowledge; it emphasises collaboration, partnership and joint ventures.</p>
<p><i>An engagement model</i>—sees transfer as a by-product of a convergence of interests between science and society and in particular, the interests of higher education, industry, and government.</p>

These models differ in terms of the way in which they capture and comprehend the relationships between higher education, research organisations, industry, and government. They reflect different approaches to IP management and commercialisation and the delivery of industry, economic, and national benefits. It follows that performance measures and metrics should reflect those differences.

While there is overlap between the models in application, there is also a tendency in discussion and commentary to inadequately differentiate their characteristics, drivers and behaviours, which differ substantially across scientific disciplines and industry. In particular, the knowledge production model, which is associated most closely with the life sciences and biomedical innovation, has limited applicability in most branches of the natural sciences and engineering, and in the social sciences and humanities.

Summary of process attributes

The attributes of these models, and the way in which they impact on measures of commercial outcomes are broadly as follows:

- The knowledge diffusion model has been of major importance for knowledge transfer and innovation in Australian primary industries, through the levy-funded rural research and development corporations, and in mining through industry-funded research. The cooperative research centres (CRCs) have been important enablers in agriculture and mining.
- The knowledge production model has received prominence in the life sciences area and biomedical innovation and has come to be represented as a ‘standard model’ of research commercialisation, but its application outside this area is somewhat limited.
- The relationship model has been particularly important in natural science areas, such as chemistry, physics, certain branches of engineering, economics and finance. The model has a strong cross-disciplinary orientation.
- The engagement model is becoming important in the context of institutional commitments to, and securing the benefits from, knowledge-based economic development.

Features of each model are summarised in Table 5 and in the remainder of this chapter.

Table 5: Models of knowledge transfer and commercial relationships

	Knowledge diffusion	Knowledge production	Knowledge relationships	Knowledge engagement
Model descriptor	Rural R&D model	Life sciences model	Natural sciences/engineering model	Institutional model
Mode of communication discourse	Tell target users about the benefits of adoption	Sell 'knowledge products' to users as rights of access and licenses	Consult—advise and undertake projects on the basis of knowledge platforms	Engage to achieve mutually beneficial outcomes
Assumptions/ presumptions	The research organisation has sufficient information (for example, about technical and market and commercial issues) - It does not want to hear others' opinions, ideas or inputs - It wants to control the message	The research organisation does not have sufficient information about technical and market issues - It wants to understand others' opinions, ideas, or inputs - It wants to involve business and industry in coming up with research content	The research organisation does not have sufficient information about technical and market issues - It wants to understand others' opinions, ideas, or inputs - It wants to involve business and industry in coming up with research content	
Communication style	Informing or explaining: the research organisation wants industry to understand something that the research organisation knows	Persuading or advocating: the research organisation wants a business to do something—acquire or buy a technology	Conferring approach—give and take: the research organisation wants to learn from a business/industry but still control the interaction	Partnership: the research organisation wants to work with industry and government to come up with the content
Target	Industry generally	Businesses, particularly new businesses	Businesses	Businesses and government
Commercialisation path	Encourage, promote widespread adoption of new practices and processes generated through research	Businesses acquire/access IP that they use in new products, processes, services	Professional consulting and project management services provided on the basis of an IP platform	Joint commitment to 'third mission' objectives—e.g. economic and societal development
Research focus	Cooperative	Commercial	Contract, collaborative, joint venture	Partnership
Mode of interaction	Collective base Industry champions and leaders Publications, best practice guides, demonstrations	Market-based Technology transfer offices, venture capitalists, patent lawyers; technology investors	Organisation-based Business development managers, industry sponsored research centres and institutes, project managers	Network-based High-level interactions between leaders in the research community, industry and government
Academic context	Traditional faculty models	Research centres of excellence—virtual relationships. Strong 'silo' basis remains	Tendency to be multidisciplinary	Strong industry and government involvement

Table 5: Models of knowledge transfer and commercial relationships (continued)

	Knowledge diffusion	Knowledge production	Knowledge relationships	Knowledge engagement
Commercialisation objective	Focus is on adoption. Cover costs through industry contributions	Make money from sale of 'knowledge products'—patents, multimedia, spin-outs, fee-paying students	Make money from sale of 'knowledge services'—consulting, contract research, industrial teaching	Business development: mutual long-term benefit; base for creating wealth
National benefit impact	Widespread adoption benefits in industry, resulting in increased output and international competitiveness	New products, services Creation of new jobs, sales, exports, etc	New processes, products Improved business performance—efficiency, effectiveness.	Collective commitment to economic development
IP framework and emphasis	Limited—as a basis for extension and protection against private capture	Proprietary—narrow, codified, as a basis for sale	Broad, tacit as a basis for leverage in business relationships	Leverage for the knowledge economy, placeholder
Industry applications	Agriculture, mining, service industries with collective approach to development	Knowledge-based businesses, particularly life sciences and biomedical; specialised services businesses	Process improvement and product enhancement in engineering and natural science-based manufacture and infrastructure businesses	New industry development and expansion—on basis of regional comparative advantage. Support for local entrepreneurs.
Approach to performance measurement	Industry studies relating to productivity and competitiveness	Business oriented studies relating to increases in sales, exports, performance	Economic studies relating to increments to GDP, sustainability	Regional studies relating to employment, incomes and growth
Output indicators	Publications produced <i>and read</i> Technology diffusion staff activity	Patents licensed—number, revenue received Spin-out companies	Project research and consultancies—number, revenue received	Joint agreements between research organisations, industry and government
Outcome indicators	Evidence of broad <i>industry</i> adoption and change in practices Impact through returns to the industry	Sustained new companies New jobs created Increment to gross domestic product.	Evidence of adoption, application and use in <i>businesses and public programs</i>	Evidence of engaged research organisations. Regional economic indicators—jobs, sales, exports, etc
Third mission interpretation	Outreach, extension, communication	Provide funds to support knowledge product development and sale	Build and support capacity and capability in businesses	Develop a 'social contract' between science and society

The knowledge diffusion model

The knowledge diffusion model is based on the idea that knowledge, once created, should be widely disseminated and action taken to ensure that potential users have the capacity to adopt and use it.

This approach underlies research in commodity-based industries, including agriculture and mining, where strategies are directed towards creating new industrially applicable knowledge and encouraging widespread (collective) adoption through education, extension and training with a view to building productivity and *industry* competitiveness and ensuring sustainability in natural resource use.

The model also reflects a view that the true innovators are the users of knowledge, not the creators.

The knowledge production model

The knowledge production model is based on an assumption that knowledge, in the form of 'intellectual products', has a value in its own right. Universities and research organisations have adopted strategies to sell intellectual products—defined in terms of an intellectual property right—to businesses, mainly through licensing directly or through venture capital investors.

This model has its strongest application in the biomedical area where a proprietorial approach is taken to the creation of intellectual property rights and there is strong interest from venture capital investors, patent lawyers and attorneys and others seeking to capture economic rents from discoveries and inventions.

The knowledge relationship model

The knowledge relationship model is based on the premise that industrially relevant knowledge is created through collaboration and a multidisciplinary approach to research. It also reflects an understanding that value is created not so much through the existence of an intellectual product, but by the way it is used. Thus, more attention is given to combining knowledge with other resources and in providing services based on the *relational value* of an intellectual product.

Engineering, applied science and social science faculties, together with business and law schools, generate substantial income through knowledge relationships. Discoveries and inventions in these areas are incremental and process-oriented, and unlikely to attract the interest of venture capital investors. Much of the intellectual property is in the form of 'know-how', and tacit, related to the knowledge and skills of engineers, scientists and researchers.

A number of universities have established strategic and business development offices with a role to initiate and proactively manage knowledge relationships with industry through collaborative and contract research and associated advisory and teaching services. University-sited industrial research institutes and centres with involvement of research organisations and substantial business investments are becoming important features of campus landscapes.

Industrial research centres and institutes are well established in the higher education system in the United States and becoming increasingly prominent in Britain and Europe. The knowledge relationships which develop have seen the emergence of a 'new breed' of industrial researchers and managers who seek careers outside the peer review system associated with disciplinary research. Industrial research centres and institutes complement rather than replace faculty/ discipline-based research.

The knowledge engagement model

The engagement model is reflected in the ‘third mission’ of universities and research organisations. Engagement extends beyond traditional community service responsibilities into a ‘social contract’ between science and society and an understanding that the once clear lines of demarcation between governments, higher education institutions and industry no longer apply. There is seen to be a convergence of interests, although not necessarily of institutional purposes and practices.

State and regional governments in Canada and the United States have been strong supporters of engagement as an essential element of their economic and industrial development strategies. In Australia, strongest commitments come from Victoria, Queensland and the Australian Capital Territory. In the United Kingdom, the government has provided funding for ‘third stream’ activities for a number of years.

Relationships between knowledge processes and knowledge products

The role and importance of the various categories of knowledge products, as discussed in Attachment 1, and in the research commercialisation processes identified in this chapter, is represented in Table 6. The representation is indicative and intended only to provide a point of reference—and accentuate the properties of the different research commercialisation processes.

Table 6: Research processes and knowledge products

Knowledge product category	Commercialisation process			
	Knowledge diffusion	Knowledge production	Knowledge relationships	Knowledge engagement
Academic publishing	Priority	High	Limited	Limited
Knowledgeable graduates	Graduates important in capacity building and extension activities	Graduates help business in new product and process development	Graduates valued to work on joint projects	Build links between research, businesses and government
Industry-targeted teaching	Industry-targeted teaching an essential component of diffusion	Low	Industry teaching targeted at business needs and qualifications	Particularly important for entrepreneurship
Contract research	Limited	Limited	As basis for building relationships	Assists in building regional capacity
Consultancy	Limited	Limited	As a basis for building relationships	Assists in building regional capacity
Staff interchange and faculty appointments in industry	Valued for diffusion and extension	Limited	Valued as basis for building relationships	Priority
Scholarly research publication	To provide academic credit to researchers	To build and maintain disciplinary reputations	Limited	Limited
Creation of intellectual property rights	To ensure open access to technologies	As a basis for generating revenue	IP as a platform for contract and consultancy	Limited
Formation of spin-out companies	To facilitate diffusion and distribution of knowledge within industry	As a basis for commercialisation of research	Companies as a vehicle for capturing revenues from IP licensing, contract research and consultancy	Limited. Focus on support for established industries

This framework provides a reference point for further discussion and analysis in later chapters.

Chapter 5: Knowledge diffusion processes

Knowledge *diffusion* refers to the creation of *awareness* of and interest in emerging technologies, with a view to promoting adoption, application and use in commercial, industrial, social and environmental contexts.

The main focus of diffusion is on making technology available for adoption through communication, capacity building and institutional strengthening. It has a long history and track record in primary production and mining. Governments also pursue diffusion initiatives in relation to providing information about technologies relevant to manufacturing, particularly in regard to process improvement.

Context: the idea of the public domain

One of the driving forces for the development of legal frameworks for 'intellectual products' has been the idea that knowledge leads to social and economic benefits when it is widely shared. The greatest prospects for sharing arise when knowledge enters what is often referred to as the 'public domain'. However, the idea of sharing runs counter to mercantilist and protectionist beliefs that publication of knowledge about useful technologies would undermine the national economy (Tuomi 2004).

Supporters of the public domain argument point out that the actual expression of knowledge only occurs by making it available to others. This communicative feature of knowledge has led to multiple ways to externalise and articulate knowledge in the form of languages, conceptual systems, text and technical designs, and in intellectual property. When expressions of knowledge become artefacts, such as in documents, they become mobile and accessible—to the point that the original creator may lose control over them and the capacity to generate income from their use.

It can be argued that royalties from copyrighted material and patents provide compensation for loss of this control, as well as contributing to offsetting the cost of investments involved in creating the knowledge. Where those investments are publicly funded, the returns to community are reflected in increased industry productivity and performance and follow-on wealth generated by the industry for the economy.

Knowledge artefacts are useless without users who make them meaningful. Without creative audiences for example, artists and artworks could not exist. As Drucker argues, it is the receiver who communicates, not the sender: a message has not been communicated until it has been received and acted upon in some way (Drucker 1993). Thus, it has been pointed out that:

Innovators can only do their work by relying on the innovative capabilities of potential users. Sometimes they do this naively and fail miserably. The heroic models of innovation sometimes make the creative role of users difficult to see, as they more or less by definition, allocate all creativity to the creator. (Tuomi 2004)

Knowledge diffusion processes recognise that knowledge creation is also a deeply social and cultural phenomenon. Individuals learn by becoming engaged in socially embedded practices where cultural and historical stocks of knowledge provide the basis for the emergence of new knowledge. Innovation essentially involves using existing technologies in new and creative combinations to make products and services that customers want and will pay for.

The important public mission of universities, research organisations and researchers, and the fact that so much of the research conducted is supported by public funds, suggests that their licensing policies and strategies should favour the active communication and broad dissemination of the results of research. In this context intellectual property protection provides a platform for knowledge diffusion.

On the basis of recent research and evidence, it has been argued that universities should pursue non-exclusive licensing agreements for the adoption of the results of publicly funded research, wherever possible, on the presumption that this enables broad dissemination (Mowery et al. 2004). That is:

... exclusivity should be employed in licensing agreements only when it is clear that the technology would not be commercialised without an exclusive agreement. Non-exclusive licensing agreements need not result in the sacrifice by universities of significant financial returns. ... some of the most significant sources of licensing revenues for licensors during the 1980s and 1990s were licensed on a non exclusive basis. (Mowery et al. 2004)

Promotion and support for adoption has been a major feature of programs and initiatives that provide public funds for industrial research. It has been particularly important for primary industries, including agriculture and mining, where government departments and agencies have provided support and invested in promoting adoption through extension, education and information initiatives. State agriculture and mines departments, rural research and development corporations, the former Bureau of Mineral Resources and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) all have had a focus on dissemination of information and knowledge as a means for *industry* to improve economic performance, raise productivity and increase international competitiveness.

Industry competitiveness and national wealth will be enhanced, it is argued, if all producers adopt and apply new technologies. In addition to supporting the creation of new knowledge, this requires public agencies to make complementary investments in knowledge diffusion activities. This involves investments in capacity building and extends beyond publishing the results of research on the internet and preparing glossy booklets and brochures.

Social capital, relational capital, and trust as the basis for knowledge diffusion

Social capital is a form of collective knowledge reflecting shared understandings, values and behaviours. It is seen as providing a bridge or a connection between individuals who are intent on achieving their private purposes to enable them to achieve the broader purposes of a community, organisation or region. High levels of trust, robust personal networks, and a sense of equitable participation are all evidence of strong social capital. Social capital supports cooperation, commitment, access to knowledge and talent and coherent actions and strategies (Cohen & Prusak 2001).

Most knowledge transfer starts with personal contact and interaction. It is also recognised that trust and the formation of trust-based relationships are the basis of knowledge transfer and business relationships (Maister, Green & Galford 2000). Trust recognises the tacit and implicit aspects of knowledge that are as important—and often more so—than codified and explicit forms of knowledge.

Research in the United States and by the World Bank has highlighted the role played by social capital in creating and binding networks and leveraging investment in human capital and physical capital (for example, research facilities). Researchers and policy-makers are exploring the social capital concept because it helps to explain the pervasive trend towards greater informal interorganisational linkages. This investment in social capital is viewed as a major driver of industrial resurgence in the United States (Fountain 1998; Howard & Matthews 1999).

The social capital concept has been criticised, however, as it can give rise to conformity and uniformity, thereby working against innovation. A more contemporary concept of *creative* capital has been adopted to explain innovation associated with diversity, innovation and economic growth built around *weak* ties, relationships, and embedded trust (Florida 2002). Florida's perspectives and analysis have been quite influential in regional economic development policies and strategies.

Technology diffusion, knowledge networks and technology clusters

Whether it is social capital or creative capital, networks among researchers are recognised as a critical driver for the sharing of knowledge, creativity, and discovery. The experience of Silicon Valley has been written up extensively as a model for 'cluster' based economic development (Saxenian 1996).

Economists have sought to explain the economic and industrial impacts of cluster development (Enright, Hagstrom & Solvell 1999; Porter 1998, 1999) and the implications for government policy and business strategy. However, Silicon Valley had some unique features based on personal relationships and a willingness to share and discuss concepts and ideas among peers in business and research organisations and venture investors.

The Silicon Valley experience has been difficult to replicate. Very few cluster-based initiatives have developed the international and global focus that Silicon Valley was able to engender (Bresnahan & Gambardarella 2004). Nonetheless, governments throughout the world have sought to initiate and implement policies and strategies based on the Silicon Valley experience, particularly in terms of employment effects. An important aspect of these policies and strategies has been the promotion and facilitation of co-creation and sharing of knowledge among businesses and between businesses and research organisations.

The common theme in the literature on clusters is the importance of *leadership* in promoting and stimulating cluster development, growth and sustainability. That leadership may come from the community in the form of civic entrepreneurship (Henton, Melville & Walesh 1997), universities and research organisations (Walshok 1995; Walshok et al. 2002), government (United Kingdom, Department of Trade and Industry 2003; National Governors Association 2002), and/or industry associations (Humphreys 2004).

The role of industry associations in cluster-based industry development in terms of technology diffusion is becoming particularly important. As governments have worked towards creating better linkages between their investments in public research, workforce improvements and economic and industry development, new kinds of industry associations have started to emerge around the rapidly growing technology sectors of information technology, biotechnology, environment and medical devices.³

These newer industry associations are more focused on having strong and active science and technology programs, creating partnerships with government to address gaps and issues, and ensuring a strong higher education and research infrastructure. For governments, these newer associations have become important allies and supporters of research and technology programs and of higher education investments to address issues such as the need for expanded graduate programs, targeted technician programs with the technical and further education (TAFE) sector, and expanded ways for university faculty and students to connect with industry (Plosila 2004).

Many Australian industry associations still retain a traditional advocacy focus—concerned with matters associated with the business climate, employment and industrial relations, workers compensation, tariffs and trade, and business regulation. While these issues are important, the reality is that the agenda of science and technology-based innovation is a key driver for improved productivity, profitability and international competitiveness. Changing this culture is a major challenge for Australian industry.

³ The strongest associations in this area are Ausbiotech, the Australian Computer Society, the Australian Electrical and Electronics Manufacturing Association, the Australian Industry Group and Australian Business Limited.

The elements of knowledge diffusion strategies and programs

From a policy and research funding perspective, there are four main elements of knowledge diffusion strategies. These are broadly as follows:

- communication: creation of awareness of the benefits of adopting new business practices, processes and procedures and seeking behavioural change
- capacity building: building the knowledge, skills, and capabilities of organisations and businesses to adopt, apply and use new technologies, through training, education and other forms of learning experiences
- introduction of standards relating to process and product quality and performance: science-based standards provide industry performance benchmarks and create a target for process and product improvement and for enhancing client and customer confidence regarding product safety, integrity and health⁴
- support for commercialisation of new technologies: where a new business model is seen as the most appropriate method to promote adoption of the uses of a technology.

These pathways also provide the basis for developing measures to assess performance. Some comments follow.

Communication

Communication of research results to industry is an important role for government departments and agencies and industry associations as a basis for improving industry productivity, enhancing industry sustainability, and increasing international competitiveness. The approach has been a key element in the strategies of public support for rural industry research, as well as in a number of other commodity-based industries, such as mining and energy.

Communication of the results of research has also been an important element of public support for the emerging new economy industries based on information and communication technologies (ICT) and biotechnology. This is reflected in public support for the formation of internet-enabled knowledge exchanges and technology showcases. The Australian Research Council has supported projects to improve communication about the results of research.

In addition to internet-based initiatives, support for communication covers public support for conferences, seminars and workshops; for example, the Department of Education, Science and Training supports the Commercialisation Forum and Fair of Ideas. There is also a specialist R&D media. Universities and research organisations, together with industry associations, also commit to technology diffusion through dissemination of survey results in relation to best practice and case studies.

Preparation of communication strategies remains a challenge, however, as the distinction between publication, publicity and promotion, on the one hand, and communication on the other, is not always appreciated. Communication has not occurred until messages have been received, understood and acted upon. As already noted above, it is the *receiver* who communicates, not the sender (Drucker 1988). This requires, in turn, building the capacity within industry to receive, adopt, apply and use the results of research.

Capacity building

Capacity building has been a feature of rural research and development for a long time, with primary producers involved in field trials and the development of 'demonstration' farms and plantation operations. More recently, greater commitments have been made to *action research*, which involves producers in the research and development projects at deeper levels, starting with the actual conceptualisation of the project.

4 Hazard analysis and critical control point procedures are now widely adopted in the food processing industry.

Agricultural research institutes, supported by rural Research and Development Corporation (RDC) project funding, have assisted groups of producers to undertake their own research programs. For example, Australian Pork Limited works with top producers who contribute significantly in kind to the R&D and, given the nature of the industry, are the key agents of change (Centre for International Economics 2003).

As well as direct involvement in R&D, the RDCs develop tools and packages for industry, and support public and private extension agents to improve delivery of information to promote adoption. Some RDCs provide training for these 'agents of change', and a few even fund the agents themselves; for example, Horticulture Australia Limited's industry development officers and Cotton RDC's support for extension officers (Centre for International Economics 2003).

Improved standards and conditions

Introduction of standards in the form of quality systems and accreditation has been an important diffusion process in primary production and food processing industries. Initiatives have included Cattlecare, Flockcare, Graincare and Pork Quality systems.

Adoption can be mandated by government regulation and industry standards, as well as by voluntary certification schemes and even indirect regulation. Examples include the Australian Pork Industry Quality Program and standards relating to beef quality and certification.

Commercialisation

As discussed earlier, a commercialisation pathway involves the creation of corporate entities with a charter to manufacture and distribute knowledge products to the industry. This will be followed if it can lead to broad industry adoption.

Examples include biotechnology-enabled devices for testing and monitoring, and software products and services.

Research organisations have adopted strategies of seeking out small innovative companies through which to adopt and develop new technologies. It is a practice that has been adopted by the Defence Science and Technology Organisation, CSIRO and Meat and Livestock Australia.

Other strategies

Government, industry, universities and research organisations have put in place a number of actions and initiatives to support research commercialisation through diffusion processes. These include:

- science and technology business incubators
- support for creation and maintenance of research 'clusters'
- alumni networks
- university business forums and councils
- informal networks and 'networking events'.

Management of technology diffusion: the rural research and development model of technology transfer

The following information is drawn from information that is publicly available about the approach to R&D management adopted by the RDCs and industry-owned companies.

The Australian RDC model is seen as world's best practice for supporting R&D and disseminating the results. The key elements of the model are:

- an independent board charged with taking a strategic approach to rural R&D
- a rational and integrated approach to R&D priority-setting
- strong involvement of industry throughout the whole process
- the broad scope of rural research activities for funding
- a strong focus on outcomes
- a dual accountability to both industry and the Australian Parliament.

There are 12 RDCs and industry-owned companies. The strength of the model lies in the industry leadership which has been created through a collective commitment to research and development and the adoption of research results.

Strategic plans are prepared by each RDC which set out objectives and priorities for a five-year period, and outline the strategies which will be adopted to meet those objectives. Plans are prepared, following consultation with research providers, industry and government. Government provides the RDCs with regular statements outlining its priorities for rural R&D (see below for more detail).

RDCs are funded on the basis of the Australian Government matching dollar for dollar industry R&D levies, up to a maximum of 0.5% of the industry's gross value of production. The government's matching contribution is intended to provide an incentive for industry to increase its R&D funding and to become more involved in R&D priority-setting and the adoption of outcomes. It also recognises that activities funded by the RDC generate a mix of public and private benefits.

In 2002–03 industry contributed \$233 million in R&D levies and the Australian Government provided \$195 million in matching and appropriation funds. Total RDC expenditure for that year was over \$454 million. The allocation of funds for research is shown in Table 7.

Table 7: Allocation of RDC investments among research purposes

Investment area	Proportion of funding (%)
Promoting industry competitiveness	25
Sustainability R&D	24
Processing	21
Distribution, storage and transport R&D	3
Market-oriented R&D	8
Commercialisation and technology transfer activities	7
Human resource development	5
Other—includes data collection and funding of post-graduate scholarships	6
	100

Source: Australia, Department of Agriculture, Fisheries and Forestry

The broad spread of RDC investments flows from their commitment to a whole-of-industry approach. In the dairy, grains, horticulture, meat and wool industries, individual primary producers pay the R&D levy, yet are prepared to approve R&D investments in off-farm, downstream activities. In effect the producers pay the R&D levy, but downstream industries are the main beneficiaries. Producers receive indirect benefits through increased demand for their products. RDC investments are spread across a range of institutions, as shown in Table 8.

Table 8: Allocation of RDC investments to research organisations

Investment area	Proportion of funding (%)
CSIRO	19
State government	35
Universities	18
Private sector	18
other	11
	100

Source: Australia, Department of Agriculture, Fisheries and Forestry

The information which has been provided does not address output, outcome and impact. Measurement of performance of investments in rural R&D is currently being addressed by the RDCs. Aspects of measuring performance are outlined below.

Performance measures

Performance measures fall into a number of categories. These are input measures, output measures and outcome and impact measures.

Input measures

The allocation of funds for investment set out above provides information on the relative priorities of the corporations.

Output measures

The outputs of technology diffusion investments relate to:

- communication of the results of research, through a range of communication strategies, as a basis for improvements in production techniques and management practices⁵
- capacity-building activities, including education, extension and training
- standards relating to process and product safety, integrity and quality
- commercialisation of discoveries and inventions with broad industry application and where complementary investments may be required to bring the discovery to market.

The extent to which initiatives have been successful is approached on the basis of program evaluation studies and reports. Increasingly, evaluation requirements are built into program design and undertaken on a periodic basis. Results of evaluations may, or may not, be made public.

Outcome and impact measures

The outcomes and impacts of commercialisation processes relating to technology diffusion include:

- increased or enhanced industry competitiveness
- increased or enhanced productivity, reflected in labour productivity or multifactor productivity.

⁵ Research reports are the most common research 'output', but publication of a report does not amount to communication unless the information in it is used.

These outcomes are assessed through industry studies in the manner undertaken by the Productivity Commission or in response to specific project briefs.

A critical challenge in industry studies is to establish causality between expenditure on public research and industry.

Performance indicators

Output-related performance indicators relevant to technology diffusion relate to:

- communication activity, reflected in numbers of publications, brochures, information bulletins, newsletter, internet pages; these indicate the scope of communication activity, but do not assess awareness and changed behaviour
- education, extension and training activity, including training courses, extension activities
- implementation and updating of standards and the 'sign on' to standards reflected in registration for quality programs
- creation of intellectual property that can be commercialised (brought to market) in the form of a marketable product licensed to an existing company on the basis of a start-up company; the viability of the start-up is highly contingent on purchases of products and services by the producers and users who largely funded its creation.

Outcome-related indicators are often tied to changes and improvements in overall industry performance data and industry benchmarks. Industry data on production, sales, and employment are readily available.

Chapter 6: Knowledge production: the standard model of research commercialisation

In this chapter a ‘standard model’ of a research commercialisation process is described. It is a model reflected in public policy and supported by key players in the scientific community, the venture capital sector and among patent attorneys and lawyers. However, it is only a partial representation of the way in which knowledge generated from publicly research funded is transferred to industry and the community.

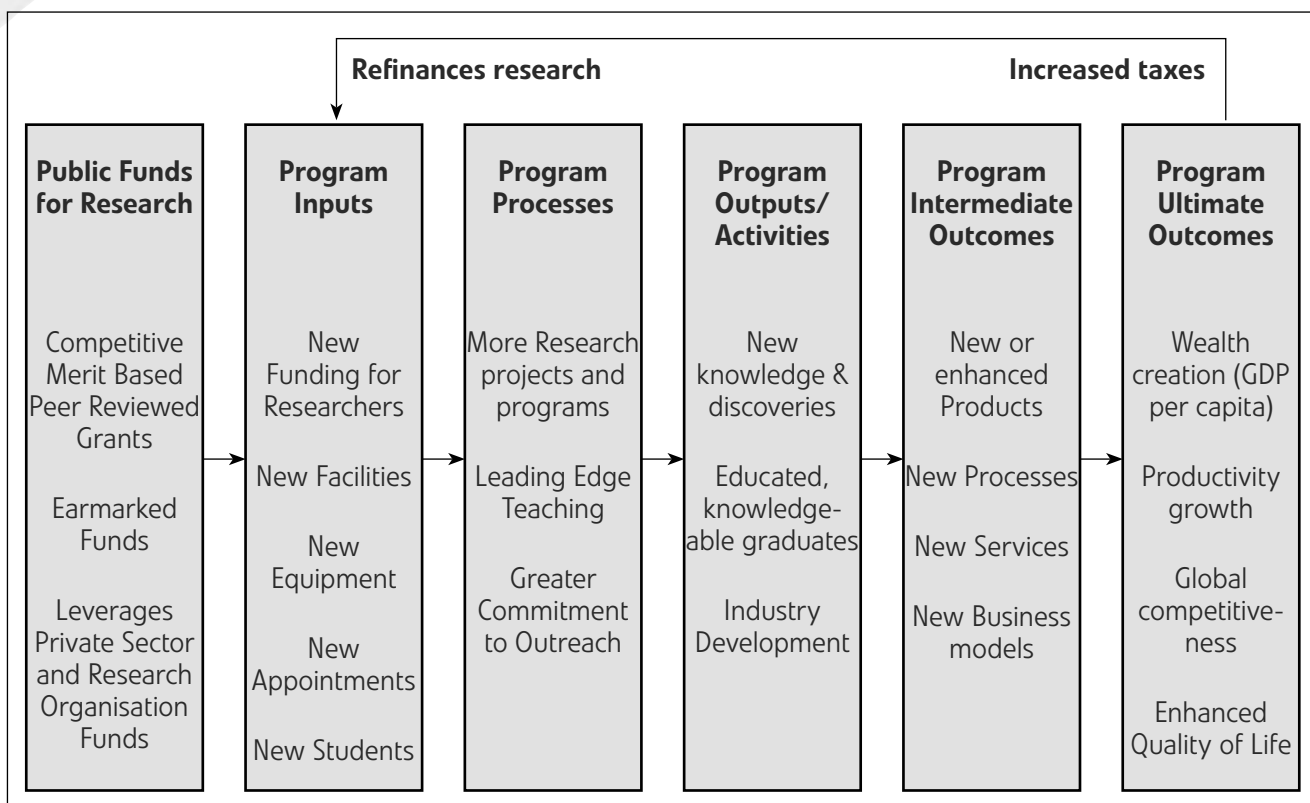
Context: The standard model as a ‘virtuous cycle’

Public funding for research is generally seen to increase the creation of new knowledge. In the model of the research university, research funding is linked with education and research training. Public funding is also intended to leverage funds in universities, from the private sector and philanthropic sources, and from state governments—generally on a matching basis.

Funding is generally administered at ‘arms length’ from political processes through independent bodies such as the statutory Australian Research Council, the National Health and Medical Research Council, and the Cooperative Research Centres Committee. Funding supports the salaries of researchers as well as the acquisition of equipment and access to facilities. Some funding is provided specifically for construction and/or acquisition of physical facilities and equipment.

The joint production of new knowledge and education increases the supply of scientists, engineers, and technologists who can convert research findings into marketable products and services. In some instances, it will lead to the creation of new businesses. The elements of the process are illustrated in Figure 2.

Figure 2: Publicly funded research: a virtuous cycle



Through this process, publicly funded research assists universities to acquire the resources (people, facilities, knowledge) necessary to enter new technological areas, and catalyse new forms of relationship with the private sector. Through the marketing and sales of new products and services, and the formation of new businesses, a more robust economy is created, which in turn generates more revenues from taxation, which can be returned to further research funding. Venture capital investment, as an asset class created for the commercialisation of intellectual products, provides resources for bringing new products and services to market.

In addition, the process of competitive funding is seen to encourage and reward research excellence. It is also seen to narrow the differentials among research institutions, as more universities and research organisations lift their standards as a way of getting access to competitive grants.

Basic research as a driver of industrial innovation

There is a presumption in the model—drawn in large part from studies, observations and assertions relating to the features of the ‘new economy’—that public funding for basic research is the major driver of industrial innovation. That is, innovation occurs as a result of shifts in *theoretical and scientific* knowledge created through curiosity-driven discovery research. This perspective is closely associated with the knowledge capitalisation argument outlined in Chapter 2.

Examples most often relate to the biomedical/life sciences area, particularly drug discovery in the pharmaceuticals industry, where scientific findings are linked directly to a new product, process, or procedure for an uncertain, untested, but potentially highly profitable market. Discovery research, using techniques of molecular biology, for example, has been very important in this process. Similarly, advances in materials science have been important in driving applications of nanotechnology—but commercial application of many discoveries is subject to high risks and may take many years for potential to be realised.

An important issue is, however, the extent to which experience in the biomedical area can be extended into other areas of scientific research. From the biomedical perspective, advances in theoretical and scientific knowledge are able to ‘push’ the innovation process into new product and market opportunities. Technology investors, such as venture capitalists specialising in this area, perform a critical role in this process by taking discoveries forward into the next research stage. Technology investors insist, however, in having secure and unencumbered patent protection as a basis for their investments. Secure patent rights also allow researchers to continue with their research.

Thus, science-based innovation is associated with a growing trend in universities and public research organisations towards establishing ownership of new discoveries and inventions through the creation of intellectual property rights, particularly in the form of patents. Patenting—and associated commercial opportunities for universities, research organisations, and researchers through the sale and licensing of patent rights—has become a major focus of the standard model of research commercialisation.

Science-based innovation is also becoming important in an increasing number of industry sectors in the so-called ‘old economy’ industries of mining, agriculture and factory-based manufacturing. Food processing for example is seeing significant opportunities for the application of science-based innovations.

While the timeframe for publicly funded scientific research to be realised through products and services is long, funds are not just handed over to promising projects: an important part of the strategy has been to invest in, and support, promising *individuals* employed in *discipline*-based departments, faculties and centres of excellence. That is:

Starting a project that requires considerable time often seems risky, *but the payoff from successes justifies backing researchers who have vision*. It is often not clear which aspect of an early-stage research project will be the most important; fundamental research produces a range of ideas, and later developers select from among them as needs emerge. Sometimes the utility of ideas is evident

well after they have been generated. For example, some early work in artificial intelligence has achieved unanticipated applicability in computer games, some of which are now being investigated for decision support and other professional uses as well as recreation.
(National Academy of Sciences 2003)

This observation also points to the need for patience on the part of funding agencies and research organisations in seeking returns from basic research.

The continuing relevance of technology-based innovation

In many industries, however, innovation continues to be based on shifts in *technical* knowledge; that is, applications or engineering-based innovation, such as in information and communications technologies, plastics, chemicals, materials, and automobiles. In these industries the need, and the opportunity, for ongoing product development is the main driver of innovation. Product development is driven by competitive, commercial and market considerations. In these industries, there is a demand for relevant and *applicable* knowledge, and particularly knowledge that transcends scientific disciplines and research fields.⁶

Technology-based innovation processes emerge from basic research and new knowledge into technologies to create new and/or enhanced products, processes, and service offerings. The creativity, imagination, and resourcefulness of educated and skilled graduate engineers and technologists are critical attributes in this area of innovation. Businesses have repeatedly pointed to the important role of the higher education system in producing graduates with relevant theoretical knowledge *and* capacities for applying that knowledge in industrial and commercial contexts.

Product lifecycles, competition, and cost pressures limit the opportunity for companies—large and small—to train people who are knowledgeable in scientific theory in the practical application of knowledge in product development and business. This issue applies as much in the social sciences as it does in the natural sciences and engineering. Businesses expect newly minted graduates to be ready for work and in a position to create value. This is also part of the reason why companies are now looking outside their business boundaries for innovation.

Nonetheless, product-driven innovation relies on a base of continual generation of new knowledge through scientific discovery. But it may take many years for new discoveries to become attached to a commercial application. For these reasons, businesses outside the biomedical area see discoveries and inventions generated through university research as being far too premature for adoption and use in a commercial setting (Howard 2004a).

The standard model of research commercialisation has a specific application in science-based innovation, particularly in the biomedical area. Patents and the creation of spin-out companies are a key indicator of performance for science-based innovation. In technology-based innovation, the standard model is relevant to the extent that it can stimulate the creation of *applicable* knowledge and generate a supply of knowledgeable and skilled personnel. However, there are few accepted measures that specifically address these outcomes.

In addition, there are some more specific limitations of the standard model concept which are addressed in the next chapter. Before doing so, the measures and metrics relating to the impact of publicly funded research, which are built around the standard model will be identified and discussed.

6 Applicable knowledge is created through interactive rather than linear processes. This is addressed below.

Measures of knowledge production performance

Framework

As the knowledge production model is based on a linear flow (production function), there is a presumption that expenditure inputs will, almost by definition, lead to desirable outcomes and results; that is, inputs finance processes, which in turn, generate outputs which lead to outcomes and impacts. Perceived shortcomings in achieving overall innovation performance are generally represented as being due to insufficient inputs, as well as to bottlenecks and gaps in the production process.⁷

In this production-oriented framework, the providers of funds want to be assured that, if more inputs are provided, there will be commensurate increases in outputs and impacts. There is also an interest in assessing the performance of the process, so that problems can be identified and ironed out on the basis that such action will contribute to improved performance. This means mapping the process and making assumptions about the linkages and interrelationships between the various elements.

There is an overwhelming perception among researchers and industry that more resources for research is a good thing. Less attention is focused on how well these resources are allocated—in terms of efficiency, effectiveness and appropriateness. However, the production model provides a basis for examining these issues.

A representation of the process, together with commonly defined measures and methods for collecting information relating to measures, is provided in Figure 3.

Figure 3: Publicly funded research: measures and methods

Program Inputs	Program Processes	Program Outputs/ Activities	Program Intermediate Outcomes	Program Ultimate Outcomes
<p>Measures</p> <p>Budget Appropriations, trends</p> <p>Leverage of State and Industry Funds</p> <p>World class facilities established/ maintained</p>	<p>Measures</p> <p>Recruitment of world class faculty</p> <p>Attraction of top students</p> <p>Industry/ Government commitment - eg joint facilities</p>	<p>Measures</p> <p>Patents, cited publications</p> <p>Graduates entering industry/creating new businesses</p> <p>Contract research/ consulting</p>	<p>Measures</p> <p>Stream of new products to market</p> <p>Investment increase</p> <p>Jobs increase</p> <p>Sales/profits increase</p>	<p>Measures</p> <p>Increment to GDP</p> <p>Increment to labour productivity</p> <p>Increment to MFP</p> <p>Increment to trade</p>
<p>Methods</p> <p>Reports from funding agencies</p>	<p>Methods</p> <p>Reports from institutions</p> <p>Scholarships available and awarded</p>	<p>Methods</p> <p>Administrative process data</p> <p>Special reports</p> <p>Graduate follow-up</p>	<p>Methods</p> <p>Business/ industry Surveys</p> <p>Relationship to baseline data</p>	<p>Methods</p> <p>Econometric Studies</p> <p>Industry Studies</p> <p>Case Studies</p>

⁷ A common criticism from technology investors and their advisers is that scientists and researchers are not sufficiently commercial in their orientation. This of course raises ethical and probity issues as to whether individual scientists and researchers *should* be commercially oriented—as distinct from being commercially aware and cognisant of commercial potential and reality.

The nature of the measures is discussed in more detail in the following paragraphs.

Input measures

Typically, R&D effort is publicised and promoted in terms of inputs. On the basis of official statistics, stakeholders draw attention to the level of expenditure on research and development and make comparisons with expenditure in other countries.

Inputs refer to the resources being allocated and available for research. They cover:

- funding allocations: and leverage of funding from other sources
- taxation deductions and concessions
- physical capital measures: facilities and equipment acquired
- human capital measures: research personnel recruited and appointed
- social capital measures: teams, collaborations and networks established
- structural capital measures: management capacities, capabilities and performance.

Public policy is also focused on the extent to which public funds 'leverage' or bring forward, funds from other sources. Leverage is often seen as a major performance measure.

Process measures

Process measures assess the way that production is planned, organised and managed to create the outputs at given levels of resources. Measures can be a direct by-product of the 'production' process, but do not measure the attributes of the final product per se. In the science and technology areas, key process measures include:

- recruitment and retention of world-class researchers
- provision of world-class facilities and equipment
- attraction and retention of top students
- ongoing industry and government commitment and support for research.

Measurements of process can be derived from regular reports from institutions and from administrative data held by managers of programs designed to improve process performance, such as scholarships to attract students and incentives to recruit faculty.

Output measures

In a knowledge production context, output measures typically relate to:

- quantity: conformance to intended/planned outputs, that is, how much is provided (numbers of patents, publications etc.)
- timeliness: conformance to scheduled completion dates, that is, how long it has taken
- quality: conformance to use requirements/specifications, that is, quality of patents, publications as assessed through peer review and place of publication, citations etc.)
- customer and client satisfaction: conformance to expectations, such as relevance and use in industrial contexts.

Output indicators should reflect the critical characteristics of the output of an activity that meets an end-user need. Users include a range of stakeholders including the relevant minister, the government, businesses, and the economy. Indicators should provide information on the final product as it is received—as distinct from the process used to achieve the output.

A matrix of output measures is provided in Table 9. The material included as descriptors is indicative only.

Table 9: Output indicators in knowledge production

	Quantity	Timeliness	Quality	Client/stakeholder satisfaction
Funded projects	Number	Number awarded per year	Research methodologies and techniques	User satisfaction regarding the applicability and utility of outputs
Publications (refereed)	Number	Number per year	Number appearing in prestigious journals	Ease of access to published material and capacity to apply it in a commercial context
Patents registered	Number	Time between initial disclosure and filing	Security of the patent	Exclusivity; requirements for complementary IP
Prototype products	Number	Time taken to develop a prototype for demonstration and inspection	Capacity to work in ways envisaged and intended	Marketability—capacity to generate benchmark return on investment
Prototype processes	Number	Time taken to demonstrate credibility and integrity of new and/or improved processes	Capacity to deliver demonstrable improvements in process performance	Implementability—capacity for sustained improvement and achieve return on investment.

Outcome measures

Outcome or impact measures in relation to knowledge production are generally taken to include the following:

- new/improved products, processes and services that have been brought to market
- increases in investment in plant, equipment and production facilities
- new business creation and growth in established businesses
- increases in employment
- increased sales
- spill-over effects to other businesses.

Outcomes can be measured by reference to administrative data, data provided by funded recipients and through regular reporting. Client satisfaction data, collected through market research survey techniques are the most appropriate means for collecting client satisfaction data. However, such data do not measure impact or results from an overall, economy-wide perspective.

Impact measures

Impact measures describe the direct results of publicly funded research in creating wealth—generally reflected as an increment to GDP per capita. There are additional measures relating to social and environmental outcomes. Policy-makers also have an interest in the employment-generating effects.

The task of establishing and assessing economic impact involves economic modelling and estimation through econometric studies. Research organisations and institutes are able to establish and demonstrate impressive economic benefits flowing from publicly funded research. Econometric growth models have been used widely in endeavouring to demonstrate the economic benefits of public funding channelled through CRCs (Howard 2003).

Case study methods are also widely used to demonstrate benefits of publicly funded research. There have been numerous case studies of a small number of businesses which have been created on the basis of research outcomes—including Cochlear, Radiata, Resmed, and the Photonics CRC Group of companies (at the time of the technology boom). The economic performance of these companies has been used to extrapolate the economic benefits of research with some rather impressive results (Allen Consulting Group 2003).

Performance indicators

Due to the time involved and the expense of commissioning economic analyses and case studies, proxy indicators of performance are selected and used as a basis for regular reporting. On the output side, commonly used indicators include:

- research outcomes published
- technology licences, patents, invention disclosures awarded
- spin-out companies created
- venture capital investment attracted.

These indicators, which refer to the creation of knowledge products, are linked to outcomes on the basis of expected or anticipated causality. Like all indicators used in an industrial and commercial context, they are, at best, proxies and less than perfect in defining final results. However *changes and movements in indicators* over time can inform policy-makers about the direction of impact and performance.

The outcome indicators most often used in relation to knowledge production processes relate to sales (as evidence of increased productive activity), employment, exports and 'complementary' investments.

Chapter 7: The knowledge production model in an industrial and commercial context

This chapter provides some additional discussion and analysis on the generality of the knowledge production model to the commercialisation process. This follows from the importance placed on the model in arguing for additional public funding for basic research. However, it is important to see the limitations of the model in application, and to ensure that other commercialisation processes are also supported and encouraged.

The knowledge production model is based on a 'production function' or linear flow for the creation and application of knowledge. It reflects a view that the main outputs of the process are knowledge products, predominantly intellectual property rights. However, few businesses base their knowledge acquisition strategies on the purchase or licensing of intellectual property.

The knowledge production model has also created a number of systemic pressures in the university system and in research organisations which impact on the capacity of these organisations to participate in the other knowledge commercialisation processes. It is also argued that the generality of the knowledge production process is very much overstated.

It is therefore necessary to look to other forms of knowledge products and services and the way in which they are created, marketed, and sold in a research commercialisation context. From the background developed in this chapter, these processes will be examined in the remainder of this report.

Context: changing strategies for investment in industrial research

The knowledge production model reflects a traditional, 'linear flow' model of research, with scientists coming up with interesting ideas and novel concepts and passing them over to production and marketing managers. There is a view that there are also a large number of interesting ideas in universities which could be passed to corporations in this way. However, there are substantial difficulties in taking those ideas to the next step through adaptation, scale-up, production and, most importantly, addressing an end-user need.

Industrial research is increasingly being approached on the basis of a capital expenditure/investment appraisal decision, and on a project-by-project basis, using a business management model. Internal research divisions now charge other divisions for results produced for their (the latter's) use. These research divisions are also being 'market tested' against independent research laboratories, including publicly funded research organisations and universities. As a result, universities and research organisations have substantially increased their commitment to project-oriented research.

In a number of industries, research and development capability is no longer regarded as a critical strategic asset and a barrier to competitive entry. Large industrial corporations which have traditionally undertaken most of their research, including basic research in house, are facing newer companies which do little or no basic research on their own, but obtain access to relevant and applicable knowledge and capability through acquisition of technologies developed in start-up companies (Chesbrough 2003b). Some of these start-ups are 'spun out' of universities and research organisations.

As a response, established corporations have been cutting back on their long-term in-house research capability. The market testing of research projects has also influenced this trend. These developments have increased the importance of the role played by universities and research organisations with close industry involvement as they build up the 'R&D corporate knowledge' of a sector. But the response involves much more than extending the activities of faculty: it involves creating new structures and organisational frameworks in the form of multidisciplinary research institutes and centres.

Many established companies have also found that much of their basic research is not useful to them. They have exited or abandoned projects, only to have them taken up by start-ups and turned into valuable companies. Companies are now developing policies and strategies to license or 'spin out' technologies (and business units) not regarded as relevant to their core business and value propositions.

The result of these trends is that industrial structures are moving from vertical to horizontal forms of integration mediated through robust alliances, partnerships and contractual arrangements through the value chain.

Corporate knowledge acquisition strategies

Most of the discussion about commercialisation relates to explicit and codified forms of knowledge—also referred to as *know what*. This is knowledge that can be valued (albeit imprecisely) and traded through market-based relationships between universities, research organisations and industry. But there is a substantial amount of knowledge generated through research and embedded in the minds of researchers and subsequently in the minds of their students, as *know-how*. In this mode, researchers and students bring a capacity to resolve problems and develop opportunities.

Know-how is applied in a range of situations and circumstances, including contract research and consultancy, professional education, and industrial teaching. It is also communicated through a range of mechanisms, including interdisciplinary research institutes, industry-sponsored chairs, jointly owned facilities, and informal contacts between industry, universities and research organisations. Know-how can be a much more important and significant way of transferring knowledge from a university or research organisation into society than technology licensing (Agarwal & Henderson 2002).

In the United Kingdom, research indicates that businesses seek relationships with universities for five main reasons (Gristock & Senker 2000):

- as a training pool for highly skilled recruits
- for keeping up to date with the latest research
- for providing them with advice and information
- for opening up access for pools of specialist advice
- for their ability to generate good public relations.

In most industries, ideas for new products have come from inside a company. However, ideas are often set in motion by stimuli from outside, including the science and engineering research base. In addition, university staff are often called upon to check and validate internal ideas and concepts. Academic engineers have an important role in the construction industry, for example.

Industry scientists, researchers and managers scan published papers to find out about new developments, techniques and contacts. They follow this up by approaching people directly within the research community. These contacts contribute to the development of tacit knowledge, including underlying knowledge of methods, designs and techniques and why they work in certain ways. Knowing what is going on is often more important than knowing about the results of research projects (Howard, Johnston & Fowler 2001).

Such personal contacts facilitate the transfer of scientific knowledge that is not communicated in research papers, books and other publications. Industrial researchers also maintain dialogue with academic colleagues to discover what is in the research pipeline. These contacts work across all scientific disciplines, from the life and natural sciences to the social sciences (for example, economics and finance) and the humanities. Formal mechanisms are seen as just the tip of an iceberg in the totality of relationships between universities, research organisations and business (Feller 2004; Gristock & Senker 2000).

The knowledge flows occurring through informal arrangements might be less measurable and observable than large, formal, and expensive public programs, but the benefit to industry of informal linkages bears little

relationship to the cost of the transaction. It is becoming recognised, for example, that patents and licenses and the creation of spin-off companies is by no means the major indicator of successful technology transfer and wealth creation.

Businesses entering into new or unfamiliar areas of science and technology tend to obtain both formal and tacit knowledge from external sources. This includes employing researchers with relevant knowledge and qualifications, engaging consultants, and by interacting with people on a less formal basis. Companies seek to learn about what is involved in a new line of research before making a large resource commitment.

Systemic pressures created by application of the standard model

Public funding of research rarely funds the total cost of research. Research at scientific and technological frontiers, particularly in the areas of biotechnology and more recently nanotechnology, requires purchases of complementary and expensive capital-intensive inputs, including laboratories, machines, equipment, and buildings. Approximately 40% of publicly funded research in Australia is directed towards the health/biomedical area.

Some public research funding requires a matching contribution from industry or other sources (such as philanthropic foundations) on the basis that funds provide 'leverage' into other funding sources. In reality, the greatest source of leverage, particularly in the biomedical area, is the internal funds of a university, represented as 'cash' or 'in kind' contributions.

The Australian Government also provides support for higher education institutions to meet overhead costs associated with research projects supported by the Australian Research Council, the National Health and Medical Research Council and other national competitive research granting agencies under the Research Infrastructure Block Grants (RIBG) program. The amount of funding is set at 20 cents for each dollar of Australian competitive research grant income earned by universities and medical research institutes.

The RIBG program tends to favour those universities that have a strong track record in securing competitive research grants. These grants are based on research excellence assessed through peer review processes, and thus tend to support disciplinary research oriented towards curiosity and discovery. Accordingly, grants find their way to faculties and departments (academic silos) rather than multi- and cross-disciplinary research institutes and centres.

The Victorian and Queensland Governments provide support for physical research facilities (buildings, laboratories, equipment), but in an expectation that the facilities will generate industrial and economic outcomes, particularly employment. However, the type of research that is expected to be undertaken in state government-funded facilities is not always of the type undertaken by people who attract competitive research grants. Thus, physical capital is made available, but often without the researchers to staff it. This places even greater pressure on universities.

The Australian Government does provide funding to cover overhead and other costs associated with scientific research, such as maintenance, materials and support staff. But the nature of health and biomedical research is such that these costs are quite substantial by comparison with many other research fields and disciplines. Internal cross-subsidisation, particularly from profitable business and engineering schools which have large full-fee paying student enrolments, is widely practised in universities with a strong biomedical research focus.

Some argue that the level of cross-subsidisation within universities is becoming unsustainable, as academics and fee-paying students look closely at the quality of the teaching service being provided in return for the income generated. It follows that the biomedical area is under the greatest pressure—internally as well as externally—to generate income from the sale of their research outputs. It therefore comes as little surprise that technology transfer offices are strongest in universities with substantial research funding for biomedical research—over half of university patenting occurs in the health/bioscience area.

The peer review and funding process also generates competition among institutions for faculty and students, which in turn drives up the costs of undertaking leading-edge research. The cost of attracting and retaining world-class faculty is high. Federation Fellowships have addressed this in part, as have some state government initiatives (for example, Smart State Fellowships in Queensland). Many universities offer supplementary scholarships and stipends for research students.

Competitive, merit-based peer review in new and emerging areas of science and technology requires a pre-existing capability. This in turn requires substantial up-front investments to stay at the cutting edge. Only the well-endowed universities are in a position to finance these investments. Increasingly, they are doing this on a strategic basis. For example, the University of Queensland has focused specifically on the area of molecular biology.

Thus, universities and now state governments (Queensland and Victoria in particular) have provided substantial funding in advance of Australian Government funding to enter the emerging fields of science and technology. They are providing a form of 'venture capital' to participate in the next generation of science and technology (Feller 2004). This pattern is well established in the United States and Canada. Thus, in order for the nation to benefit from industrial and economic outcomes generated through publicly funded research, universities and state governments must invest up-front to create the research capability.

Universities and state governments which cannot provide the support necessary to maintain competitive higher education systems are likely to fall behind in developing nationally competitive knowledge-based economies. Given the importance of major research universities in shaping the geopolitical contours of the research system, the standard model, particularly as it applies to biomedical research, serves to perpetuate and exacerbate disparities in state and institutional competitiveness for national and industrial research funding (Feller 2004).

The result of these trends is that public funding for research is flowing to a relatively small number of 'research intensive' universities. Moreover, universities are beginning to differentiate on the basis of their research capabilities and the relative strength of those capabilities in relation to the other dimensions of their core missions—those relating to teaching and outreach.

Other limitations of the standard model

On the basis of recent analysis and reviews in the United States, it has been observed that the general applicability of the standard knowledge production model of commercialisation may have been exaggerated (Lester 2003; Mowery et al. 2004). The following realities are often overlooked:

- University patenting and licensing, though rapidly increasing, remains a very small contributor to the overall stock of patents.
- University licensing income is a very small fraction of income from sponsored research (between 1% and 2% for Australian universities in 2000).
- Only a very small fraction of university patents make money.
- Patenting is a relatively minor pathway for the flow of knowledge from universities to the private sector, outside the biomedical and ICT sectors.
- Few members of faculty are involved in patenting activity.
- Although firms are increasingly relying on external sources of knowledge for their innovations, they are considerably more likely to view customers and suppliers as direct sources of ideas rather than universities and research organisations.
- For many firms, the principal obstacle to innovation is not access to new technology, but access to people with the necessary skills and who can apply technologies in a business and commercial context.

- Relationships between universities, research organisations, and businesses are highly interactive and rely to a significant extent on personal associations and contacts between senior faculty and business leaders.
- There are many complex steps required to move technologies developed in a research environment into commercially oriented product development cycles.
- In many areas the research work of universities competes with, rather than complements, the research work of industry.

These observations have been reinforced during the consultations, interviews and analysis undertaken for this study and in previous studies for the Australian Research Council (Howard, Johnston & Fowler 2001) and the Department of Communications, Information Technology and the Arts (Howard 2004c).

Most technology-based companies grow slowly, building up management capacity, sales and marketing skills and trust-based relationships with suppliers, distributors and customers through the value chain. Sales in these companies grow and retained earnings are reinvested. Over time they become sustainable and do not attract the attention or interest of venture capital investors (Bhidé 2000). Many company founders, wishing to retain ownership of their companies, eschew the overtures of venture capital investors. For a business wishing to grow over the longer term, venture capital is very expensive money (Zider 1998).

Issues and implications

There has been a tendency among science and technology business advisers, venture capital investors and a range of policy advocates to think about research commercialisation in a model shaped by the experience of the biomedical sector. To that end, measures of commercialisation success have tended to focus on patenting, licensing and new business creation. These are the performance indicators associated with technology transfer office benchmarking surveys and studies.

Other sectors contain mechanisms for integration and knowledge transfer that are completely different from biomedical innovations. Thus, it is difficult to generalise from the experience with biotechnology and bio-medicine to other sectors of industry or disciplines of science. Biotechnology is a specific and unique mode of interrelationship between the research community and industry (Leydesdorff 2003).

It has been argued, rather forcefully, in a study of university–industry technology transfer in the framework of the United States Bayh–Dole Act that:

... a single minded focus on patenting and licensing as the only important or effective channel for technology transfer is unrealistic and may produce policies that limit the effectiveness of other channels that are more important for knowledge transfer and exchange. (Mowery, et al. 2004)

Chapter 8: Knowledge relationships: collaborative processes

An important aspect of research commercialisation occurs through the collaborative and cooperative relationships between businesses and research organisations.

Knowledge-based collaborative relationships provide capabilities and capacities to enhance the innovation potential of businesses. Public funding in this area is directed towards building those research capacities and strengthening research partnerships between businesses, universities and research organisations.

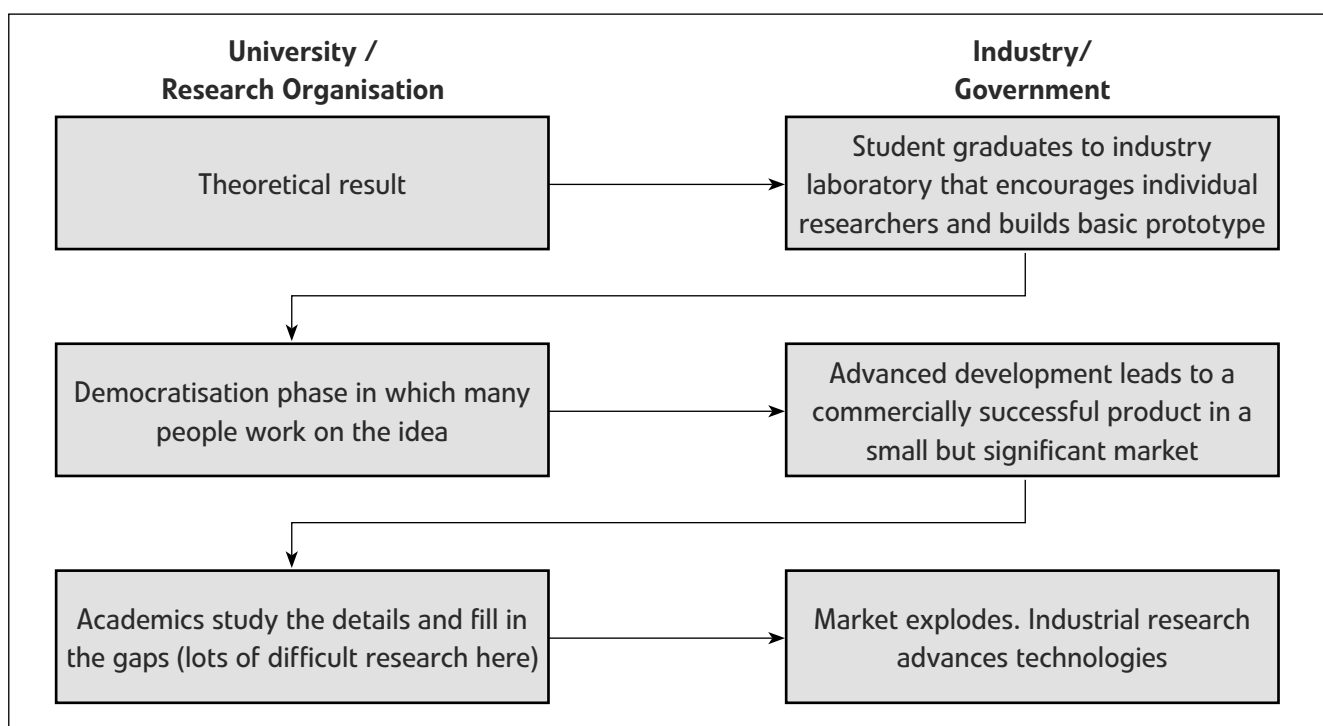
Capacity building occurs through infrastructure-related investments in physical capital (buildings, equipment, and laboratories), human capital (scientists and researchers) and structural capital (management and organisational infrastructure).

Context: the distributed and interactive nature of knowledge creation

Knowledge creation is being seen as an increasingly socially distributed process. There has been an expansion of the number of 'sites' where recognisably competent research is undertaken, including think tanks, philanthropically supported research institutes and consulting organisations. The research universities are no longer seen as a monopoly supplier of knowledge. They are becoming specialised and niche players (Gibbons et al. 1994).

Contrary to the underlying premise of the standard model of a knowledge flow from research funding through to industrial and economic outcomes, the reality is that research commercialisation and knowledge transfer is a highly interactive process involving research organisations and industry. In ICT and engineering, for example, there is an interactive relationship between research, teaching and application. The closeness of these interactions has been the foundation of success of 'industry clusters' reported in the science and technology management literature. The process is represented in Figure 4.

Figure 4: Knowledge transfer in ICT, engineering



Source: Tennenhouse, cited in National Research Council (2003)

The success of the framework is highly contingent on the personal interactions between people in research organisations and business. In the 'democratisation' stage, a research community is enlarged into a community with a critical mass of researchers exchanging ideas, building prototypes and teaching others. Innovation occurs through sharing knowledge and development of communities of practice.

Categorisation of collaborative relationships

In a report for the Australian Research Council, *Mapping the nature and extent of business–university interactions in Australia* (Howard & Matthews 2001) several categories of business relationship were identified. These covered:

- gifts and bequests: donations from alumni and businesses relating to objectives of philanthropy and corporate social responsibility
- corporate sponsorship: industry-funded chairs, scholarships and events
- contract research and consultancy: project-based and fee-for-service research related to specific problems and opportunities
- cooperative and collaborative research: research undertaken on the basis of university–business joint venture and alliance arrangements
- commercial partnerships: joint development of buildings and other physical assets intended to generate income and return on funds
- competitive interactions: situations where universities compete in a contested market for research, teaching and training services.

It was argued in that report that these relationships were planned, organised and delivered through a range of institutional and structural arrangements. The efficiency and effectiveness of those relationships was highly contingent on the way in which those relationships were organised and managed.

Collaborative knowledge relationships, and the organisational and management arrangements supporting them, deliver a range of knowledge products and services, but the relative emphasis differs from the outputs of the knowledge production process, where there is a focus on the creation and marketing of intellectual property.

Aspects of knowledge-based relationships between universities, research organisations and businesses are addressed below.

Contract research, teaching and consultancy

The features of contract research, contract teaching and consultancy are described in Attachment 1.

Contract research for industry, based on addressing specific problems and issues is becoming an increasingly important aspect of university research profiles, particularly those which do not receive a significant amount of funding from the competitive peer-reviewed funding processes. Similarly, contracted teaching services, based on addressing specific business requirements and reflected in corporate MBAs and other business-specific certifications are assuming major importance.

A recent report from the National Academy of Engineering in the United States describes a pattern for transferring the results of academic research in the financial services sector, which relies extensively on the consulting contribution of academic researchers (National Academy of Engineering 2003):

- Academic researchers publish a series of papers on a topic in the field of financial economics; these papers set the stage for a few innovative firms to test products based on the idea.
- Faculty members become consultants to these firms.
- In some cases, junior and senior researchers resign from academia to work on these projects full time.

- If the product proves to be effective, the financial industry invests in further development; at this point, many firms attempt to duplicate the product or service.
- Controversies about protection of intellectual property via trademarks, copywriting, trade secrets, and patents are addressed by the courts as they arise.

A significant proportion of the activities in the financial sector would not have been possible without fundamental mathematical tools developed and adapted by academic researchers. These tools and techniques enable the industry to price an almost unlimited variety of financial instruments. Markets as diverse as options, futures, other derivatives, securitisation, and re-insurance could not exist without these tools (National Academy of Engineering 2003).

Similarly, in the transport and logistics industry, consulting engagements for universities are also seen as an important means for moving research results into the field. The National Academy notes:

Although the relationship between consulting and technology transfer is not well documented, faculty consulting provides an obvious mechanism for generating new practices with industry. It also provides faculty with much needed exposure to industry problems, which has enormous benefits in shifting research from interesting but theoretical subjects to useful and applicable subjects. In logistics, academic consulting has often been a precursor, as well as a complement, to academically oriented software start-up companies. (National Academy of Engineering 2003)

Further material on knowledge transfer in financial services and other sectors is included in Attachment 4.

Trends in the consulting services sector

Within the consulting sector there has been a growth in demand for 'fact-based consulting' where firms are developing research capabilities to collect and analyse information in order to create theories and principles capable of being applied from client to client, from industry to industry, and in more fundamental research projects (Czerniawska 2002). This approach necessarily involves developing intellectual property, only a portion of which belongs to individual clients. Universities and research organisations are taking a major role in this emerging market segment and clients are looking to consulting firms for their research capacity.

There is still a demand for process-based consultancy built around practical experience rather than theory-based perceptions, understandings and knowledge. However, practice-based consultancy is moving to a closer involvement in clients' businesses and the distinction between practice- and theory-based consultancies is beginning to dissolve. Be that as it may, practice-based consultancy is not a business with which universities and research organisations would necessarily want to be involved.

Thus, the evolution and segmentation of the consulting industry between research-based and practice-based components creates opportunities for universities and research organisations to contribute to the development and application of theory-based knowledge. To do this, however, requires a commitment of management and organisation to assembling capability currently provided on an ad hoc and reactive basis.

Universities are currently reviewing and strengthening their policies and procedures relating to consulting and 'outside academic work' based on both a business development strategy and on a compliance and control requirement.

The role of new technology-based firms (NTBFs)

The creation of new companies by graduating students and academic staff, based on research results and consulting and an understanding of commercial opportunities, is an important mechanism for commercialising academic research results and increasing their impact on industry. These companies are usually formed independently of a university or research organisation and the involvement of technology transfer offices.

In the past five years there have been numerous technology-based companies created to develop and market products and services in the field of ICT or other products and services based on an ICT platform. Once a new company is created, graduate students are often hired to pursue further development of software products. ARC Linkage Grants are often sought to support this research. Grants under the Commercialising Emerging Technologies (COMET) program have also been awarded to many companies in this category.

Considering the success of many of these companies, the industry impact of knowledge diffused on this way is likely to be substantial. In many cases, larger companies eventually acquire the start-up companies, thus providing more resources for continued product development and more extensive marketing (National Academy of Engineering 2003).

There are substantial opportunities for building collaborative research relationships for companies formed in this way. They require, however, a business-oriented approach to the use of resources, the management of intellectual property and expectation of commercial returns (Howard 2004c).

Building relationships through collaborative research

Collaborative research can be of a general or strategic nature. Industry and commercial partners not only contribute to the research activity through funding, but also through participating in the research and/or providing access to specialised facilities.

Businesses are increasingly looking to universities and research organisations to undertake science-based industrial research on a collaborative basis. In the present business environment, the technological and market forces that drive companies to develop external technology linkages include:

- proliferation of technological content of products and services
- requirement to shorten development and lead times
- increasing interest and mutual understanding between business, government, academia
- growing experience in joint R&D work.

Relationships often develop beyond formal contract arrangements, as businesses want to get to know the scientists and researchers to learn how their technology works, what the technology can accomplish, and what types of products and services it might yield. In these circumstances, relationships move beyond mere contracts and consultancies to sustained collaborative relationships. Businesses and investors who leverage university research into commercial products may plough money back in the form of further R&D funding for research centres.

Opportunities and expectations in relation to cooperative and collaborative research have been factors stimulating the growth of research-intensive universities. But their continued expansion requires more rather than less university support, as well as business commitment and public funding to build capability as a precursor for effective contributions to industrial research, and achieving economic outcomes. There exists a major challenge in supporting research centres funded with public funds to undertake disciplinary research through the peer review system (research excellence) on the one hand, and the need for research centres to undertake interdisciplinary applicable research relevant to business and industry (research relevance) on the other.

Building capacity and capability for cooperative and collaborative research includes not only physical facilities and resources, but also support for recruitment of key researchers and managers capable of working at the interface between the cultures of the research community and industry. Many Australian universities are beginning to commit substantial levels of resources to interdisciplinary research centres, with substantial industry and state government commitment. This follows a pattern being developed in North America with state and provincial governments making substantial commitments to build up research infrastructure.

The role of industry research centres and institutes in industrial innovation

As argued earlier, knowledge applicable to industrial problems and opportunities is typically cross-disciplinary in nature. Innovation most often occurs at the interface of disciplines—as well as between the research community and industry. For example, physicists and mathematicians pioneered developments in biochemistry as a result of curiosity about the logic and complexity of nature. Sometimes this results in new disciplines which gain academic respectability, such as biotechnology.

Jointly owned and funded industrial research centres have been developed to facilitate ways whereby businesses can tap into the knowledge base of universities and individual researchers. Governments may provide support for capacity and capability building through funding for creation of physical infrastructure and support for human resources. Policies and strategies to this end have been adopted by the Australian Government and the Victorian and Queensland Governments.

University research centres are generally regarded as flexible, comprehensive research and education organisations, offering a research climate that focuses on product development, design testing, as well as the traditional basic research discovery activities. They are also seen as focusing on interdisciplinary research, knowledge transfer, and technical assistance to industry. They are expected to bridge the gap between academic applied research and the more narrowly focused technology activities which, it is hoped, will lead to economic development in their own states and the global economy (Tash 2002).

Research centres are usually more involved in knowledge transfer. They have become an important resource for finding employment for non-tenured scientists and post-doctoral scientists. They also encourage scientists to become more involved in cutting edge technologies and interdisciplinary research. There is advantage for students in participating in hands-on research and for later careers in industry.

In the United States it has been predicted that university research centres (URCs) will have an increasingly significant impact on university operations (Tash 2002). Envisaged trends are:

- greater research centre influence: on university-wide policies and curricula revisions to match societal needs and government policies and regulations
- university adaptations: administration will offer increased support and attention to centres, as national rankings of research universities become increasingly dependent on research centre funding
- economic development: there will be increased pressure to strengthen regional economies and global markets; industry funding is expected to double from 10% to 20%
- a larger share of universities' R&D: at least 50%—up from 33% in 2001, much of it based on fixed-price contracts
- centre durability: more permanent, sustained funding from government, universities and industry
- faculty involvement increasing: close to 80% of the science and engineering faculty will be involved in URC research; faculty joining centres to increase publications and have access to more costly but essential equipment; faculty merit raises and tenure linked to URC funding
- student involvement: at least 80% of graduate science and engineering students involved and close to 50% of undergraduate science and engineering majors
- greater interdisciplinary focus, leading to less of a single-discipline dominance.

These trends are only emerging in the Australian context as funding for research is still heavily oriented towards academic peer review, and the funding from industry for research centres is still relatively small. But given the structure of the Australian economy, it might well be that the opportunities for growth in industry research centres will arise more in the services industries (including finance, construction, health and transport) rather than in manufacturing.

Challenges for the management of industry research centres

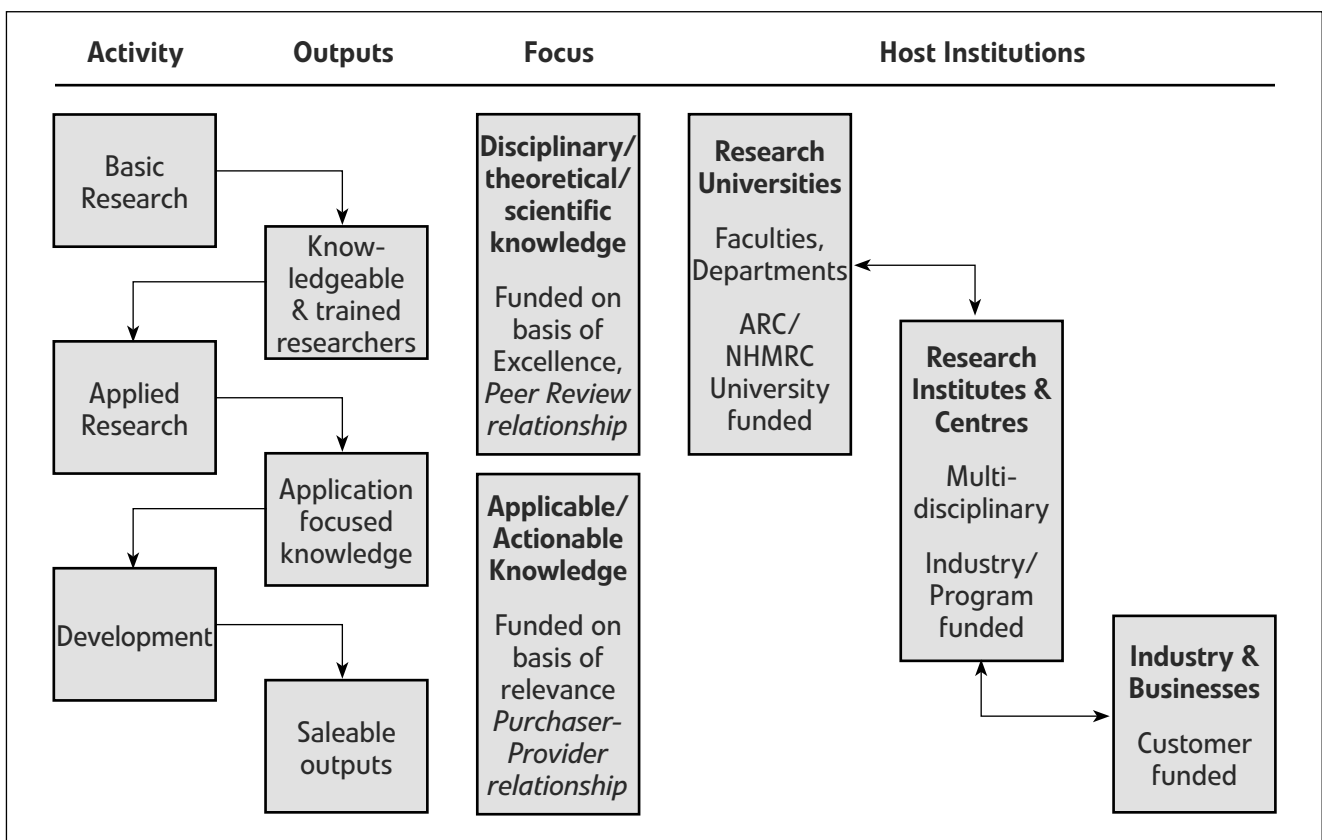
Industry-supported research institutes and centres sit at the interface between discipline-based faculties and business. Many staff are part-time or seconded from their host organisations. Quite often, career academics have little interest in working in research centres and institutes because of the constraints on academic careers imposed by undertaking industry applicable and relevant research. The Australian science and innovation system has not yet worked out a way of effectively funding long-term applicable research undertaken in research centres and institutes.

Academic researchers have advocated the establishment of research institutes and centres as virtual organisations and communities, drawing on popular management writings (Lipnack & Stamps 1997; Savage 1996). The image of virtual centres allows academics to provide fractional commitments, without the discipline of strategic direction and management oversight. However, virtual centres are bound to fail, if only for the reason that virtuality often defies the basic and fundamental principles of leadership and management.⁸

Cooperative research centres and centres for excellence that span a number of diverse locations have been very difficult to manage due to the divided commitments of researchers to their host faculties and research programs and the mission of the CRC (Howard 2003). However, they have also provided a vehicle for channelling another source of research funding into ongoing faculty research interests and programs.

Collaboration, creativity and innovation are stimulated when people work in very close proximity. This builds the social capital essential in building distinctive capability (Cohen & Prusak 2001; Fountain 1998). The institutional placement of research institutes and centres between research universities and business is represented in Figure 5.

Figure 5: Research institutes and centres: between disciplinary and applicable research



⁸ These are: every organisation needs a structure of some form or another so that work is coordinated in order to achieve results; and someone has to be in charge, particularly in times of pressure and crisis (Drucker 1999).

The emergence and effective performance of cross-disciplinary and interdisciplinary science has required the development of a new type of industrial research manager capable of working at the interface between disciplines and institutions. This interface is reflected in an integrated organisation established as a partnership, joint venture and alliance. Success or otherwise in interdisciplinary entities depends heavily on the way in which they are led and managed.

It is of interest that the CSIRO is taking on more of the characteristics of a university research centre/institute along the lines outlined in this section. On the one hand, it is focusing much more on private sector partnerships and collaborations, while on the other, it is getting closer to the university setting by co-location on university campuses and joint investment with universities and state governments in the development and operation of research facilities. This development is also relevant to the engagement process discussed in Chapter 9.

The role of patenting and technology licensing in collaborative research

It has been argued that patent protection and licensing is strong and economically significant in biomedical research, and the dominance of licensing revenues by biomedical inventions reflects this. But in many manufacturing, mining and services industries a commercial device may require access to numerous patents, and the average value of a patent is much lower. Where patent licenses are much less valuable, industrial firms often collaborate with academic researchers with little expectation of obtaining rights to key patents.

Insistence by university administrators on extensive and detailed agreements covering intellectual property may serve as a source of friction rather than as a lubricant for research collaborations (Mowery et al. 2004). This has been recognised as a problem, for example, in innovation in the Australian food industry. Mowery et al. observe:

It is important for university research administrators to adjust their intellectual property policies to accommodate these intersectoral differences, rather than conceptualising all research collaboration as resembling those common in biomedical research. ... this recognition requires the pursuit of a broader and more flexible set of objectives through patenting and licensing policies, rather than focusing on licensing revenues. (Mowery et al. 2004)

Intellectual property lawyers and contract administrators have been active in promoting policies for universities and research centres and institutes to develop collaborative agreements around ownership and access to intellectual property. However, industry representatives have commented that one of the greatest barriers to effective collaboration is the approach taken to intellectual property management within research centres.

Performance measures

Measures of performance for knowledge relationships should relate to the purposes of supporting knowledge relationships, particularly in relation to cooperative and collaborative research. A number of criteria are relevant and important:

- strengthening capacity for innovation
- attracting and retaining highly skilled research personnel
- strengthening research training for researchers
- promoting networking and collaboration among researchers with a multidisciplinary orientation
- ensuring optimal use of the infrastructure.

These criteria are used widely in the evaluations of publicly funded research centres (Begin-Heick 2003). Issues associated with each of these criteria are addressed below.

Strengthening capacity for innovation

Research capacity and capability developed in research centres and institutes provide a basis for innovation. In turn, this is dependent on the quality and quantity of research infrastructure and on the provision of funds to support the research enabled by the infrastructure.

The capacity for innovation is impacted to a very significant extent by the cooperative and collaborative arrangements that have been established and lead to the creation of industrially relevant and applicable knowledge.

Attracting and retaining highly skilled research personnel

The capacity to innovate rests largely on the availability of highly skilled and creative research leaders. Competition for the researchers with these attributes is international and intense. Without quality infrastructure, it is very difficult to attract these researchers.

Research leaders attract other researchers and students and build social capital in a community of practice. They are also skilled in building industry partnerships and effective working relationships with government. However, they require world-class facilities and equipment with which to operate.

Strengthening training for researchers

Research facilities and newly created institutes and centres of excellence can give confidence to trainees that they will receive an educational experience comparable with the best in the world. In this way investments in research infrastructure increase the size and quality of the pool of trained and qualified people for working on resolving problems and opportunities in an industrial context through the application of scientific knowledge.

Industry in this context not only means agriculture, mining and manufacturing, but also health and a range of public sector-oriented services.

An impact and outcome assessment framework should identify the numbers of people involved in research training—and the addition to the pool of trainees enabled by the facility.

Promoting networking and collaboration

Research institutes and centres of excellence provide opportunities for researchers to work together. Collaborations are increasingly necessary to achieve results in a timely and creative manner.

As indicated earlier, advances in research and industrial application occur at the interface of disciplines. Publicly funded research should aim to foster such interactions to enable large projects to get underway which would otherwise have been difficult to achieve.

The impact and outcome assessment framework should identify the way in which researchers have built collaborations and the number and scope of multidisciplinary projects.

Ensuring optimal use of resources

There are risks that the optimal use of research infrastructure can be limited by the availability of funds for operation and maintenance. The recruitment and retention of skilled personnel for operating and maintaining facilities is limited by the capacity to offer adequate salaries and suitable career paths, particularly in competition with other sectors.

The impact and outcome assessment framework should collect information on optimal use as a basis for assessing needs and requirements for support services.

Performance indicators

The performance indicators relevant to university, research organisation and industry collaboration are identified below.

Process and output indicators

Process and output indicators include:

- number, location and fields of research of *permanent* joint university, research organisation and business-owned and operated industrial research centres and institutes
- staff and students working full time in industrial research centres and institutes
- investments by businesses in the establishment and operating of research centres
- research contracts with businesses, including number, value, research field (including multidisciplinary research) and industry segment
- industry-oriented consulting, advisory and opinion services—number, value, industry segment
- invention disclosures, patent applications, licenses executed and spin-off companies created from joint university, research organisation and industry research centres and institutes
- industry-oriented education programs, teaching contracts, training contracts
- publication activity.

These indicators draw on recent work undertaken by the British Higher Education Funding Council and other funding councils in Scotland and Wales and reflected in the Higher Education: Business Interaction Survey 2001–02. The survey is significant in that it concentrates on relationship processes as distinct from the knowledge production-oriented studies in the tradition of the Association of University Technology Managers (AUTM) surveys.

Outcome and impact indicators

Outcome and impact indicators include:

- contribution of centres to industrial innovation, reflected in commercially viable new processes, products, services and business models (new companies)
- ongoing viability and sustainability of research centres and institutes
- global networks and reputation of centres and institutes in terms of their capacity to attract industrial research and co-location of corporate research facilities.

Information relating to these indicators would require collection through survey and evaluation processes and procedures.

Chapter 9: Engagement processes

Engagement is a process of communicative interaction between universities, business and government. This interaction derives from the need in both government and industry to address complex problems, 'the provenance of which is often far removed from the world occupied by academics' (Gibbons 2003).

Engagement has come into prominence in the context of growing attention to the *third mission or third stream* activities of universities. These activities seek to generate, apply and use knowledge and other university capabilities outside academic environments; they are concerned with interactions between universities and the rest of society (Molas-Gallart et al. 2002).

Context: the idea of engagement

Many have argued that the separation between the major institutions of society have begun to break down. Michael Gibbons, from the Association of Commonwealth Universities, has put it in the following terms:

The once clear lines of demarcation between government, industry and the universities and the technology of industry, between basic research, applied research and product development, between careers in academe and those in industry seem no longer to apply. Instead there is a movement across established categories, greater permeability of institutional boundaries, greater blurring of professional identities, and greater diversity of career patterns. In sum, the major institutions of society have been transgressed as institutions have crossed onto one another's terrain. In this, science has been both invading (the outcome of one way communication with society), but also invaded by countless demands from society. (Gibbons 2003)

This change, it is argued, has occurred because institutional leaders, industrial managers and people generally understand the importance of science and they respond to the growing complexity of the contemporary world by drawing on the research capabilities of universities into their interests and concerns. Scientists are now seen to be more actively engaged in more open and complex systems of knowledge production (Gibbons 2003).

Engagement is a characteristic of a university's policy and practice. It is not an 'add on' to the functions of teaching and research, but is reflected in the responsibilities given to senior staff, rewards and incentive mechanisms, career structure and promotion criteria, the learning experience of students and the number, nature and sustainability of relationships with organisations external to it. It is also a two-way orientation, with institutions outside higher education committed to engagement with universities in a similar way (Coldsteam 2003).

To meet such demands requires a university to be fully engaged with its community—not tacitly but explicitly, and not only in research partnerships, but in ways which profoundly influence both teaching and research, as well as reaching out to meet society's intellectual, social and cultural needs. It has been argued that universities are being increasingly linked to *place*—that is, their local and regional economies.

Up until recently, financial support for universities had been seen as an Australian Government responsibility—within a framework of state government statutory, regulatory and management oversight. Recognising the importance of higher education to technology, innovation and Australia's future, the Minister for Education, Science and Training has recently released an issues paper which addresses the benefits and the risks of transferring legislative responsibility for higher education to the Commonwealth (Australia, Minister for Education, Science and Training 2004).

This growing national concern with the contribution of higher education to innovation and economic performance is also occurring at a time when some (but by no means all) state and territory governments are becoming interested in the contribution of higher education to state and regional economic and societal development. It follows that national, state and regional issues will have to be carefully balanced, with some

higher education institutions having a national focus, while others will develop strong state and regional ties. Institutional differentiation enabled by industrialisation and deregulation of the higher education sector will enable universities to develop their own distinctive capabilities and competencies in responding industrial and societal opportunities and needs (Howard 2004a).

The scope for moving towards higher levels of engagement will be limited if higher education moves too far away from the core values of scholarships and excellence in teaching and research. Reaching the ideal involves building *institutions of engagement* which work at the interface, not only between scientific disciplines but also between universities and society. Building these institutions is not a trivial issue (Howard 2004a; Johnston & Howard 2003).

Engagement, the third mission, and community outreach

In Great Britain, the government is committed to capturing the economic potential of universities and has launched a series of programs designed to increase third mission activities. A particular emphasis is on regional economic development (Molas-Gallart et al. 2002). However, third mission activities extend beyond research and its commercialisation to all forms of engagement which link universities to society and the economy. That is:

The commercialisation of the Intellectual Property (IP) owned by universities is an important component of Third Stream activities, but only one amongst many other functions that link universities and society. Furthermore, the generation of revenues from commercialising IP cannot be considered to be the main driver for universities to engage in such activities. The Russell Group of universities are involved in commercialisation primarily as a means to create public value, and only secondarily as a means to raise funds. (Molas-Gallart et al. 2002).

The level of commitment to the engagement ideal varies considerably among universities in Australia. Generally, the concept of 'outreach' is embraced, but this is often reflected in opportunistic links with industry (for example, to extract additional funds for researcher-oriented research), continuing education and community service programs. Only a few have fully embraced engagement as a 'third mission'. A profile of Australian university third mission statements is contained in Attachment 3.

An Australian Universities Community Engagement Alliance has been established with representatives from 28 universities who are considered to be practicing, researching or have interests in community engagement. The alliance has a broad community and regional development focus, rather than one specifically concerned with the commercialisation of research. The Department of Transport and Regional Services has sponsored research in this area (Garlick & Pryor 2000).

In Garlick and Pryor's book, *Compendium of good practice university—regional development engagement initiatives* (2000), several categories of engagement are identified and discussed: sustainable development; cultural development; industry; economic development; health; student access; social development. Commercialisation is not covered as a topic.

Over the last ten years or so, there have been several major initiatives, whereby research organisations, business and government have financed, constructed and operated research facilities and equipment. These facilities are generally intended to further interdisciplinary research and have an outcome relating to creation of applicable knowledge. CSIRO is currently acting on a recent report advocating a closer relationship between the organisation and universities, including construction of facilities on university campuses (Australia, Department of Education, Science and Training 2004a).

State governments are supporting university and industry proposals for the construction of facilities under programs such as the Science and Technology Initiative (STI) in Victoria (Victoria, Department of Innovation, Industry and Regional Development 2004) and the Smart State Research Facilities Fund (SSRFF) strategy in Queensland (Queensland, Department of Innovation and Information Economy 2004).

Public policy support for third mission activities

Notwithstanding the pressures and expectations of government, industry and the community for a greater role for universities in society, there are no public programs in Australia that specifically provide support for these activities. During discussions and consultations for this study, vice-chancellors and senior officers commented that, as much as they would like to support more engagement activity, they were constrained due to limited resources.

At this stage in the Australian context, public policy support for engagement is heavily oriented towards support for technology transfer in the 'standard model' of knowledge production. There is a focus on the activities of technology transfer offices rather than the broader knowledge creation and transfer activities of universities.

In Great Britain, support is provided under the Higher Education Innovation Fund for engagement activities with a commercial orientation. The program builds on the Higher Education Reach-out to Business and the Community Initiative. This funding has been referred to as 'third steam' funding. It is, however, based on a narrower concept of engagement than that described above.

Extract from Higher Education Innovation Fund 2: Invitation to Apply for Funds, 2003

HEIF 2 will provide greater flexibility to back a range of effective proposals from the higher education sector. These include adding to venture funds for early seed corn finance, and boosting the scale and range of other knowledge transfer and entrepreneurial education activities. HEIF funding is not restricted to science or technology related knowledge transfer.

In the nature of the knowledge base in HEIs, most proposals may be related to science, including social science, and technology, but it will be important for HEIs to develop bids based on their strengths and the opportunities that these strengths present. Clearly these strengths could include the arts and humanities, and the creative industries. It is likely that the range of proposals submitted will reflect the following major themes:

- work to promote enterprise in HEIs and to promote networking between the HEI, business and other communities who use the outputs of knowledge generation;
- the infrastructure and capability to transfer knowledge from HEIs into business and the community—including through applied research, technology and knowledge development, expertise in continuing professional development, and consultancy, linking with the full range of business;
- the commercialisation of research outputs through licensing of intellectual property to existing businesses and through the formation of new companies to spin out such knowledge, supported by seed corn funding;
- work to improve the social and public services infrastructure, for example helping to improve local health services or transport infrastructure;
- acquiring new knowledge or technology and the generation of solutions to real world problems, the provision of training in the application of these technologies, and the transfer of knowledge through communities of practice—working networks of practitioners, researchers and others;
- establishing a centre specialising in the teaching and practice of commercialisation and entrepreneurialism;
- the development of commercial enterprises to pursue the broad range of knowledge transfer activities described here.

The maximum payment for any single non-collaborative bid is £2.4m with collaborative bids supported up to £3.25m. A total of £187m is available over the years 2004–05 and 2005–06. A key aim of the current program is to develop the capability of less research-intensive departments to broaden knowledge transfer activity. Sixty-three per cent of the funding is for this latter activity (Funding Stream B). The focus of the Higher Education Innovation Fund initiative is *knowledge transfer* rather than technology transfer.

The guidelines indicate that higher education institutions need to demonstrate that they have a 'clear institution-wide strategy for the successful exploitation of their research activities and/or their wider third stream activities'. They are also required to identify how their approach to managing knowledge and expertise more generally will 'enhance the potential for successful transfer and application of this in the rest of the economy'.

Universities in the United Kingdom are in the process of making submissions to increase the level of third stream funding. There is strong support for similar initiatives in Australia. In the Australian federal context however, where outreach activities deliver substantial benefits to state and regional economies, it might be expected that state governments would support outreach and third stream activities. In several states, governments provide support for research infrastructure and the development of research capability. This includes the Victorian STI Initiative and the Queensland Smart State strategy. These initiatives reflect a renewed interest in knowledge, or more specifically, science and technology-based economic development

Third mission and knowledge-based economic development

Over the past five years there has been a renewed interest in science and technology-based economic development. This interest differs from the underlying premises of the knowledge production and relationships models discussed earlier.

In North America, it has been suggested that the interest of policy-makers, industry and academic leaders in science and technology-based development follows a number of themes (Plosila 2004). These themes, summarised below, are highly visible in an Australian context, although the level of leadership and commitment varies between states, territories, and regions:

- State and regional governments are increasingly interested in creating industry clusters around complementary industry segments, and critical masses of talent, technology and capital for sustaining and improving their economies; technology is a major focus of these cluster efforts because of its importance to global competitiveness, particularly in advanced manufacturing, information technologies or biosciences.
- States and regions, business foundations and higher education coalitions are increasingly driving technology-based visions, strategies and action plans—much more than was apparent before 2000.
- Higher education leaders have a growing interest in contributing to economic development in a much broader fashion than their traditional focus on research. These contributions include building talent through curriculum, customised training, and lifelong learning, technical assistance and problem solving, and regional and state leadership roles for higher education in economic development.
- State premiers and ministers have sought to better position their economies around technology and knowledge sectors, and have shown a willingness to commit to sizeable investments in spite of severe fiscal constraints—but the time delay between investments and economic impact is likely to be a decade or more.

Building stronger connections to higher education institutions has become an important aspect of economic development in North America and Europe. In Australia, the Queensland, Victorian, and the Australian Capital Territory governments have made substantial commitments in infrastructure investments. Programs and incentives are now offered involving universities in areas such as sponsored research, access to equipment and facilities, lifelong learning and customised job training, technical assistance expertise and problem-solving and entrepreneurial assistance and support.

An important focus of science and technology-based development concerns support for infrastructure, particularly physical infrastructure. However, there has been a discernible shift in state economic development practice over the last five years, from an almost exclusive real estate focus (technology parks to develop surplus land) towards an integrated set of technology infrastructure investments, including incubators, accelerators and research parks. Funding has moved from single tenant arrangements to facilities to support multiple tenants and to reflect the needs of many technology firms with an interest in developing a product, not owning a building (Plosila 2004).

It has been argued that many of the technology parks developed before 1990 reflect a real estate and location history and have limited ties to their adjacent university and/or research organisation. This was a major criticism of the Australian Technology Park in Sydney. More recently, however, technology parks recognise their close connection to a university, research organisation or medical centre, and are developing affiliation agreements and other mechanisms for stronger partnerships (Plosila 2004).

The older universities in Australia are major owners of land and are seeking to put this to productive and creative use through the construction of buildings to accommodate and house facilities, research staff and students. Many of these initiatives have been built around science parks and technology precincts. Property and facilities management strategies that build bridges between research, teaching, and business are becoming more central to the core missions of universities.

Many of the parks and precincts have been developed with public funding and corporate support. Significant examples include:

- Australian Technology Park: the site of ATP Innovations (an incubator program) and many research centres and ICT small-to-medium enterprises (SMEs)
- Adelaide Technology Park at Mawson Lakes: operated by the University of South Australia, the location of several ICT related CRCs, SMEs and larger technology companies
- Brisbane Technology Park: the base for Queensland Manufacturing Institute (QMI) facilities. These facilities are now owned and operated by a private company
- Macquarie Research Park: developed in partnership with Boulderstone Hornibrook, with tenants including Siemens, Dow Corning, Becton Deckenson (biotech), Goodman Fielder, Nortel, and Radiata.

Australian Technology Park

Since 2000, Australian Technology Park (ATP) has made its mark as one of Australia's most significant technology precincts. ATP is a unique place focused on supporting the growth and commercialisation of Australian technology businesses

Built and established in and around the heritage listed Eveleigh Railway Workshops, ATP is home to over 1,000 people working across approximately 100 organisations. It offers an environment for information exchange, collaboration and networking opportunities second to none.

ATP specialises in the development of technologies in the fields of information and communication, biomedical sciences, education and photonics. Our community comprises one-person start-ups and small-to-medium businesses through to cooperative research centres and multinational organisations. We share a common commitment to enabling technological innovation that will benefit individuals, communities, Australia and the world.

The ATP community works with all levels of the education sector to develop new interfaces between industry and education. There are seven premier Australian universities with a presence at ATP, as well as a number of other leading education institutions including TAFE NSW. Supporting these intellectual resources is high-level data connectivity and transmission, as well as a supercomputing centre facilitating high-end analysis of R&D data.

Source: ATP Innovations

Measures and metrics

Measures of engagement will be reflected in the impact of science and technology policies and strategies in promoting regional economic development. Key measures and indicators should relate to interactions of people and institutions and include:

- co-location of research facilities and businesses, particularly on or adjacent to university campuses and adjacent to science and technology parks and precincts
- clustering activity and performance
- university and research organisation support for new businesses and entrepreneurship
- community access to and use of higher education/research organisation facilities and services.

Measures and indicators are discussed further in Chapter 10.

Chapter 10: From public research to economic benefits: a framework of measures and metrics

The final item in the study brief required suggestions for methodologically robust and cost-effective strategies to:

- Develop a rich understanding of how publicly funded research leads to economic benefits, and
- Chart progress in commercialisation success across sectors of the economy.

The first sections of the chapter provide a framework for identifying and defining economic benefits. This framework has underpinned much of the discussion in earlier chapters on the focus of the different commercialisation processes. This is followed by a categorisation of the methods and measures widely used to assess program performance and how they can be adopted and applied in assessing the commercial outcomes and impacts of publicly funded research and development.

This is followed by a discussion of performance indicators, noting that performance indicators only *indicate* performance and cannot substitute for regular and comprehensive performance assessments. Indicators also need to be constantly assessed in terms of the extent to which they drive performance improvement or skew behaviour to meeting the logic of the measures, rather than the logic of the policy and program.

Forms of economic benefit

In a study prepared by the Science Policy Research Unit (SPRU) for the United Kingdom Treasury, the following forms of economic benefit were identified as flowing from basic research (Martin & Salter 1996):

- a source of new information and knowledge
- creation of new instrumentation and methodologies
- development of skills by those engaged in basic research (particularly graduate students)
- gaining access to networks of experts and information
- people trained in basic research who are good at solving complex technological problems
- creation of spin-off companies.

These economic benefits reflect the *outputs of basic research* and have a strong supply-side orientation; that is, they reflect the perspectives of the creators of knowledge. A more detailed discussion of the scope of research outputs is included in Attachment 1.

The presumption in much of the economic benefit discussion and debate is that more public funding for research will create more knowledge products and services which will, through a commercialisation process, lead to an economic outcome. That outcome will be reflected in increased national production (GDP), national income, employment and wealth. Four processes have been identified, described and assessed in earlier chapters.

The way in which these research outputs are reflected in the economic *outcomes* and *impacts* delivered through the commercialisation processes raises a different set of issues in relation to the way in which the results of publicly funded research are identified, assessed and measured. Some of these issues have been touched upon in earlier chapters. They are given in more detail in the following section.

Assessing and measuring economic benefits

From discussions, consultations and review of the literature on research commercialisation, the economic benefits of publicly funded research are assessed at four broad levels:

- the level of the *economy*: covering contributions to wealth, reflected in indicators such as national production (output), investment, and the contribution to research to economic performance
- the level of the *industry*: relating to factors such as industry productivity and enhanced industry competitiveness
- the level of the *enterprise*: relating to specific commercial outcomes, such as profitability, viability and sustainability
- the level of the *region*: relating to regional performance through clustering of activities—interest in networks and networking.

All of the classifications and typologies involve measurement issues. These issues are described briefly below.

Economy-level assessment

Assessments of benefits at the level of the economy focus on the ‘public good’ characteristics of research funding. The essence of a pure public good is non-exclusivity and non-rivalry. That is, by making the results of research publicly available, it is not possible to exclude anyone from using it, and one person’s use does not affect the ability of others to use it. This provides the framework for public policy that emphasises non-exclusive licensing of intellectual property rights and wide dissemination of the results.

As indicated in Chapter 2, there is a widely held view that knowledge is a form of capital that can be identified, owned, exchanged and invested to generate an economic return. Publicly funded research stimulates technological change, which in turn contributes to ongoing economic growth. There is an assumption that knowledge created through publicly funded research will be available to all enterprises to develop new products and processes, thus increasing the total level of national output.

Assessments of the impact of knowledge on the economy rely heavily on endogenous growth theory. Endogenous growth economists believe that growth in national output is linked to a faster pace of innovation and extra investment in human capital. They stress the need for government and private sector institutions and markets which nurture innovation, and provide incentives for individuals to be inventive.

Endogenous growth theory predicts positive externalities and spill-over effects from a high valued-added knowledge economy which is able to develop and maintain a competitive advantage in growth industries in the global economy. The main points of the endogenous growth theory are:

- The rate of technological progress cannot be taken as a given: appropriate government policies can permanently raise a country’s growth rate, particularly if they lead to a higher level of competition in markets and a higher rate of innovation.
- Higher levels of capital investment have the potential to increase returns.
- Private investment in R&D is the central source of technical progress; public funding can leverage private investment through collaborative processes.
- Protection of property rights and patents can provide a major incentive to engage in R&D.
- Investment in human capital (education and training of the workforce) is an essential ingredient of growth.

Demonstrating national economic benefits through modern growth theory relies on sophisticated econometric modelling and statistical techniques. The approach has the benefit of providing aggregate data and demonstrating economy-wide effects, in the form of social rates of return from research. These techniques are often used to justify investing public funds in research, including CRCs.

Due to difficulties in tracing the way in which knowledge generated from research finds its way into application, it is not possible to determine what a particular research program or technology contributes to the outcomes attributed to research investments. Nonetheless, economic studies are valuable for monitoring trends and for comparisons among jurisdictions.

Industry-level assessment

At the level of the industry, publicly funded research provides a *collective* benefit, available to all producers for the purposes of improving industry performance. Improved industry performance will, in turn, deliver broader national benefits. Recognising this provides a rationale for joint government– industry funding of research, as in the levy-funded rural research and development framework (Australia, Department of Agriculture, Fisheries and Forestry 2001). It also provides a rationale for government support for industry structural adjustment programs and research components of Action Agenda initiatives (Australia, Department of Agriculture, Fisheries and Forestry 2002; Australia, Department of Industry, Science and Resources 1999).

Industry studies are generally based on neoclassical growth models which assume:

- The productive capacity of the economy can be characterised by constant returns to scale production functions.
- Firms are essentially price takers in a competitive market place; individual firms have no influence over market prices and have no market power.
- Technological change is exogenous (independent of the actions of consumers and producers).

The implications of the neoclassical growth model are that sustained increases in per capita incomes can only be delivered through increases in total factor productivity. The model underlies the strategies for providing assistance to and assessment of performance in commodity-based industries, such as mining, agriculture and certain manufacturing and services industries. The objective of such interventions is to raise industry performance and enhance international competitiveness.

Assessments of performance are generally focused on industry *productivity* improvement and measures associated with increased exports. For example, the National Food Industry Strategy is expected to result in a substantial increase in Australia's share of world trade in processed food (Australia, Department of Agriculture, Fisheries and Forestry 2002).

The Bureau of Industry Economics, the Industries Assistance Commission, and now the Productivity Commission have undertaken assessment of industry-level performance, from the perspective of industry economics, regularly and systematically over many years. Studies are also undertaken from a strategic management perspective by analysts and consultants using the 'five forces' Porter-type analyses of industry competitiveness (Porter 1980, 1990).

Industry adoption of the results of research is a key performance indicator in that it indicates the extent to which producers are taking up new methods, processes, standards and techniques.

Enterprise-level assessment

At the level of the enterprise, publicly funded research can provide a *private* benefit to owners and managers through *exclusive* access to the results of research. The rationale is that individual businesses are more likely to adopt the results of research if granted exclusive intellectual property rights: exclusivity, it is argued, provides the basis for securing additional investments from venture capital and other technology investors for more research and development and complementary investments in production, marketing, sales and distribution.

At this level of analysis, and reflected in the resource-based view of the firm, it is assumed that businesses are different and that they can compete on the basis of their core competencies and distinctive capabilities. These relate to ownership and/or access to strategic assets (including knowledge), their internal and external networks of people and contacts, their leadership and creativity, and their capacity for innovation. Making the results of publicly funded research, in the form of new discoveries and technologies, available to every business in an industry will not necessarily bestow competitive advantage.

Where the results of publicly funded research are made available for private benefit, the creators of knowledge seek to recover the costs of research through licensing fees and downstream royalties. However, the process of assessing the value of intellectual property is fraught with difficulty.

From a policy perspective, making research results available to businesses specifically, rather than to industry generally, could result in more national wealth through business-related investments that will increase sales, production, employment and exports. The venture capital industry is a strong advocate of this perspective.

Assessment of performance relies on periodic returns and surveys of companies that have had access to publicly funded research results, and case studies of successful companies. The focus of measures is on sales, employment, investment and exports. The emphasis and interest is on *profitability* and *business sustainability*, rather than on productivity improvements.

Regional-level assessment

At the level of the region, publicly funded research delivers a combination of public, collective and private benefits. The focus is determined in large part by the regional development and engagement strategies followed by research organisations, government, industry associations and businesses working in engagement-type relationships and processes.

As Pages, Freedman & Von Bargen (2003) found, regional policies and strategies are heavily focused on:

- transferring knowledge and ideas into commercial application
- building a base for successful new firms
- supporting active and aspiring entrepreneurs
- building local support systems
- business training and mentoring
- enabling regional networks
- encouraging and supporting business start-ups and firm growth.

These policies and strategies are heavily focused on building entrepreneurship as a base for delivering economic benefits to a region. Universities and research organisations are regarded as having a key role in this process through the transfer of knowledge and ideas, and taking a leadership role in the engagement process. The number of courses and programs teaching entrepreneurship has increased substantially in recent years. There has been an associated interest in social capital and social entrepreneurship (Pages, Freedman & Von Bargen 2003).

The focus of this engagement approach is on community and social benefits as well as financial. It reflects an understanding of the linkages between entrepreneurship and a community's social and economic health, and to creativity—a key driver of innovation. Measures and metrics associated with creativity and entrepreneurship have been addressed extensively in Richard Florida's *The rise of the creative class* and other works (Florida 2002, 2003).

In the following section, a more detailed discussion of measures and metrics is provided.

Performance methods and measures

A wide and extensive range of measures is available for assessing the performance of public programs. Current debate about measures relates not so much to the relative merits of different techniques, but to the appropriateness of measures to the evaluation questions, the cost and administrative feasibility of the approach, and ensuring a mix and balance between methodological paradigms (Ruegg & Feller 2003).

Framework

Methodological approaches for measuring the economic benefits of publicly funded research were canvassed extensively by the Science Policy Research Unit for the United Kingdom Treasury in 1996 (Martin & Salter 1996). A more comprehensive assessment was provided in the work of Ruegg and Feller for the National Institute of Standards and Technology in 2003 in relation to the Advanced Technology Program. The Ruegg and Feller framework for identifying and selecting performance methods and measures is reproduced in Table 10.

All of the methods and measures have been used to varying degrees in the assessment of publicly funded research programs in the Australian context. Some methods are more useful for assessing early stage research programs, while others are better suited for later stage, closer to market programs.

Ruegg and Feller argue that the more a research program's scope spans from research to commercialisation, the more methods evaluators can use to capture the full range of impacts. Thus, 'a far sighted strategy' would be to approach performance assessment that lets early evaluations focus on collecting survey information for participants' immediate use, with the idea that these data can be used as baseline information for subsequent evaluations. Multiple methods and approaches could capture the full range of impacts and identify and validate relationships and impacts not foreshadowed in the initial design.

Table 10: Overview of performance measurement and assessment methods

Method	Brief description	Example of use
Analytical/ conceptual modelling of underlying theory	Investigating underlying concepts and developing models to advance understanding of some aspect of a program, project or phenomenon	To describe conceptually the paths through which spill-over effects will be generated
Survey	Asking multiple parties a uniform set of questions about activities, plans, relationships, value, or other topics, which can be statistically analysed	To find out how many companies have licensed their newly developed technology to others
Case study— descriptive	Investigating in depth a program or project, a technology, or a facility, describing and explaining how and why developments of interest have occurred	To recount how a particular joint venture was formed, how its participants shared research tasks, and why collaboration was successful or unsuccessful
Case study— economic simulation	Adding to a descriptive case study, quantification of economic effects, such as through cost–benefit analysis	To estimate whether, and by how much, benefits of a project exceed costs
Econometric and statistical analysis	Using tools of statistics, mathematical economics, and econometrics to analyse functional relationships between economic and social phenomena and to forecast economic events	To determine how public funding affects private funding of research

Table 10: Overview of performance measurement and assessment methods (continued)

Method	Brief description	Example of use
Sociometric and social network analysis	Identifying and studying the structure of relationships by direct observation, survey, and statistical analysis of secondary databases to increase understanding of social/organisational behaviour and related economic outcomes	To learn how projects can be structured to increase the diffusion of resulting knowledge
Bibliometrics—counts	Tracking the quantity of research outputs	To find how many publications per research dollar a program generated
Bibliometrics—citations	Assessing the frequency with which others cite publications or patents and noting who is doing the citing	To learn the extent and pattern of dissemination of a project's publications and patents
Bibliometrics—content analysis	Extracting content information from text, using techniques such as co-word analysis, database tomography, textual data mining, supplemented by visualisation techniques	To identify a project's contribution, and the timing of that contribution, to the evolution of the technology
Historical tracing	Tracing forward from research to a future outcome or backward from an outcome to precursor contributing developments	To identify apparent linkages between a public research project and something of significance that happens later
Expert judgement	Using informed judgements to make assessments	To hypothesise the most likely first use of a new technology

Adapted from Ruegg & Feller (2003)

Another approach involves assessing performance in relation to principles and criteria. The following sections elaborate on this and the Ruegg and Feller analytical methods.

Analytical and conceptual methods for modelling and informing underlying program theory

It has been recognised for some time in the corporate world that all organisations incorporate a set of assumptions which shape behaviour, dictate decisions about what to do and what not to do, and define what is thought to be meaningful results (Drucker 1995). These assumptions constitute what is known as *the theory of the business*. A valid theory is clear, consistent and powerful and has three parts:

- assumptions about the environment: society and its structure, the market, the customer and technology, what the organisation is paid to do
- assumptions about the specific mission of the organisation: these need to change with the times, what the organisation considers to be meaningful results
- assumptions about the core competencies needed to accomplish the organisation's mission: what the organisation must excel at to maintain leadership.

A theory of the business must be known and understood throughout the organisation and has to be tested constantly. It is a hypothesis about contexts and issues in a constant state of flux. To establish, maintain and restore a theory requires constant review, re-appraisal and action. Business policies, programs, projects and practices are in a constant state of evolution, responding to opportunities, pressures and constraints.

Public sector programs, including research funding programs, also reflect theories in the form of underlying concepts, beliefs and actions. Programs supporting research are typically based on a set of hypothesised and documented relationships that link activities to objectives. Some of these are explicit and are set out in policy documents and program statements; others are implicit, involving widely shared acceptance and assumptions about stylised facts and causal linkages. These explicit and implicit relationships constitute a program's theory (Ruegg & Feller 2003).

A program theory is a testable assertion whereby certain activities and sub-objectives will bring about specified results. In practice, programs are often established on partly formed theories, incomplete documentation and/or fragile empirical grounds. There are often assumptions about associations between program interventions and outcomes, implying direct and linear relationships. However, causality may be more complex and there may be intermediate steps. It is therefore important that the underlying 'program theory' be regularly tested, validated and updated. This is a central task of program evaluation and performance review.

Many recent reviews and evaluations of performance in the science and technology area have devoted a considerable amount of time to understanding and articulating program theory (Howard 2002a, 2002b, 2002c). Analytical and conceptual methodology centres on the purpose of an intervention, and results in conclusions and judgements relating to:

- *merit constructions* which concern the *intrinsic* quality of what is being evaluated, irrespective of the setting in which it may find applications: for example, was the program or initiative within the program a good way to address the problem/s that had been identified?
- *worth constructions* which concern the *extrinsic* usefulness or applicability of what is being evaluated in concrete local, regional, national or international settings: for example, was the program or initiative worth doing, having regard to the results achieved—intended as well as unintended?

This distinction between merit and worth is of particular importance in relation to research-oriented programs. Research can be excellent in its own terms (that is, push the frontier of knowledge) but may not be worth doing from a public policy or application perspective. The advance in knowledge may only benefit the researcher(s) and not the wider community.

Although shortcomings in the capacity of potential users to appraise the value of knowledge created through research, as well as other impediments to uptake, need to be considered, the potential exists for merit and worth to be unaligned in a research environment. This points to a need for clear lines of communication between research providers and research users, and an understanding of the processes of 'knowledge created in application' (Gibbons et al. 1994).

Survey methods

Surveys generate a range of descriptive statistics and describe programs in terms of frequencies, percentages, means, medians, and significance of sample data. Results are typically presented in terms of aggregates to protect confidentiality of response using graphs and tables.

Survey methodologies, based on market research approaches, have become quite important for assessing outcomes of a range of government programs. Such a methodology was used in the evaluation of the CRC Programme (Howard 2003) as a way of quantifying a range of outcome metrics. The approach was supported by an extensive process of consultation to provide context to the survey results and to provide a basis for further conclusions and recommendations.

Survey methodologies are used extensively in industry to gauge impact and outcome of various business activities. In many sectors, surveys are conducted by industry associations and reported publicly. They are, however, expensive and require strong support from participating businesses and downstream users. The AUTM-type survey of research outcomes falls into this category (Australian Research Council, Commonwealth Scientific and Industrial Research Organisation & National Health and Medical Research Council 2002). The recently completed *National survey of research commercialisation* was also a very resource-intensive process for participating institutions (Australia, Department of Education, Science and Training 2004).

It is important to look at the way in which this type of approach can be developed to enable the reporting of national benefits across a broad range of programs supporting research. It may be useful to extend the scope of the survey to research users, as well as research providers.

Case study—descriptive

Descriptive case studies are in-depth investigations relating to a program, project, or facility designed to examine 'what happened': the context, to explore how and why, and consider what might have happened otherwise. Case studies are particularly helpful in eliciting interesting general propositions and identifying key relationships and variables (Ruegg & Feller 2003).

Case study methodologies have become recognised as a legitimate approach to policy research, analysis and advice and the identification of benefits. They look for *generative mechanisms* which can, with sufficient evidence, be formulated as rules. That is, studies are undertaken and solved, investigators reflect on the lessons learnt, look for relevance of lessons in the next case, reflect again, and so on. The greater the number of cases, the greater is the potential for generalisation. The outcome of the process is a series of guiding principles which can be generalised to explain and predict new or similar experiences.

It is important that the impact and influence of the guiding principles developed through case studies be corroborated through other methodologies. As indicated, survey methodologies seek to produce statistically valid research results and present them as validating a causal relationship, or model.

Case studies have been widely used in assessing performance of research funding programs. They have a particular application in assessing impacts at the business or enterprise level. However, studies that simply report 'good news' stories are of little value in systematically identifying the benefits of research. Case studies need to be objective, rigorous, and credible, based on a research methodology.

Case study—economic estimation

Economic case studies combine descriptive case histories with quantification and distribution of benefits and costs. Descriptive analysis is a critical precursor to quantification, as it defines the data to be captured and collected, the analytic techniques, and sets out the assumptions to be made where data are not available. Similarly, too much data (particularly administrative data) can distort and skew analysis and interpretation. Just because data are available, does not mean that they are useful for evaluation (Howard 1987).

As economic case study analysis requires data to be presented in financial terms, it is more relevant to applied research and technology development than to basic research, where the ultimate impacts and effects are many years away and difficult or impossible to capture. However, even with later stage projects, there may be difficulties if results and outcomes are some distance from the market. The further upstream from the market in which a program is positioned, the more complicated the task of estimating downstream benefits and apportioning costs and disentangling the contributions by various parties to the eventual technology (Ruegg & Feller 2003).

These techniques used in economic case studies include public sector cost–benefit analysis, discounted cash flows, options valuation, and modern portfolio theory.

Case studies are often extrapolated to the economy-wide and sector levels. They can show impressive results in terms of the social rate of return on investment. However, all suffer from serious methodological and conceptual weaknesses, as well as problems relating to data availability, timeliness, accuracy, relevance, and the level of aggregation. There are also some limiting assumptions and complexities, including:

- the relationship between spending on public research and the much larger investments required in development, production, marketing and distribution
- the complex interactions and relationships between research and technology, relationships which differ substantially across fields and sectors.

Economic studies are of particular relevance to the assessment of impacts at the industry level. Methodologies used by the Productivity Commission in exercising its responsibilities in relation to industry assistance form the basis of analysis in its reports in areas such as motor vehicle manufacturing, information and communications technology, and textiles.

Economic and statistical analysis

Economists interested in the relationship between research and economic outcomes have attempted to measure public benefits through economic and econometric modelling techniques. The techniques involve:

- hypothesising relationships that derive from, or correspond to, theoretical or programmatic concepts
- selecting and constructing measures for dependent and independent variables corresponding to the key concepts and relationships proposed in the theory
- using and interpreting appropriate statistical tests.

Rarely, however, are there data available to match the theoretical propositions. While theory suggests the data to be sought, data availability suggests new theoretical questions and stimulates the development of new statistical methods. Examination of theories in the light of data leads to their review and revision and new interpretations—as well as questions about overall quality of the data (Ruegg & Feller 2003).

The availability of accurate, relevant, and timely data for performance review is a major issue in the evaluation of science and technology programs.

Econometric methods involve the use of a number of techniques:

- regression and correlation analysis, for example, to examine linkages between levels of patenting and levels of research funding
- production function analysis: the mathematical expression of the relationship between inputs and outputs, and used extensively in industry studies
- macro-economic modelling, for example, economic forecasting based on input-output tables and structural equations that explain various economic relationships to analyse national effects of increases in R&D spending and technological change.

Econometric and statistical models add substantially to analytic capability and can produce quantitative results with detailed parameters and can demonstrate cause–effect relationships. However, not all effects can be captured in economic modelling. This is a major problem in an environment of changing technical knowledge and economic and social relationships. The selection and application of models requires continual review, and validation of policy and program theories discussed on page 81.

Sociometric and social network analysis

The relationship model presupposes that economic behaviour is embedded in networks of social ties which have a profound impact on economic outcomes. There is a growing appreciation on the part of economists of the significance of social networks and the economic impacts of research and technology development investments.

Methodologies, such as sociometrics and social network analysis, are being used to assess the spheres of influence of scientists, researchers, and innovators in order to identify the effect of informal associations, collaborations, and spill-overs in the development and diffusion of knowledge.

Social network analysis brings into focus a dimension of economic impact that tends to be overlooked in traditional economic analysis. That is, if social networks are important for spill-over effects, then it is important to understand how they work and to assess their performance. The methods for collection of relevant information rely on survey, interview, and analysis of administrative databases.

Research and analysis relating to cluster development and performance relies on social network analysis.

Bibliometrics

Publications and patents are the major outputs of research programs in the natural and life sciences. Large databases have been created to capture these outputs and support the bibliometric method of evaluation and performance measurement.

Bibliometrics encompasses:

- tracking the quantity of publications and patents
- analysing citations of publications and patents
- extracting content information from documents.

Bibliometric methodology is also used to assess the quantity, quality, significance, dissemination and intellectual linkages of research, as well as to measure the progress, dynamics, and evolution of scientific disciplines (Ruegg & Feller 2003).

Bibliometric methods are widely applicable in the assessment of program performance *where there is an emphasis on publishing and patenting*. The approach is straightforward and a diverse audience can understand the results. The data are readily available from existing databases and the evaluation processes are not a burden for researchers.

Bibliometric approaches treat publications and patents as program outputs and therefore ignore other outputs and long-term outcomes. Moreover, numbers of publications, patents, and citations indicate quantity, not quality or application and use. As argued earlier, propensities to patent differ across research and technical fields and disciplines which do not relate to science and research productivity differences (Ruegg & Feller 2003). From a communication perspective, patenting and publication do not amount to dissemination and diffusion of research results, although these processes can *enable* it.

There are other problems with using bibliometric methods:

- Mature technology areas tend to exhibit more citations than emerging technology areas.
- Works of poor quality may be heavily cited.
- Self-citation and colleague citation can artificially inflate citation rates.
- Many citations are provided by patent examiners.
- Citing organisations may not have significant intellectual linkages.
- Databases may be inconsistent and incomplete.

The contribution of bibliometric methods is that counts, and ratios of counts to research inputs, provide *indicators* of research performance. But indicators are not measures: they provide a starting point for formulation of questions and more robust and searching methods for assessing performance in the manner referred to earlier.

Historical tracing

Historical tracing, or historiography, is similar to case study method, but it involves in-depth investigation in a story-telling framework. The method traces a series of interrelated developments chronologically, leading from research to ultimate outcomes, or from outcomes back to the conditions that gave rise to them.

The approach produces interesting and credible studies and provides evidence of linkages from early inputs and ideas to outputs and results. It informs process dynamics. However, the methodology is complex and it is often difficult to know the significance of particular events.

Historical studies were used as supporting material in the Science and Innovation Mapping Project (Australia, Science and Innovation Mapping Taskforce 2003).

Expert judgement

Academic and industry experts are often called upon to give opinions and advice about the quality and effectiveness of a research program. Expert opinion and advice is a *judgement*-based process, drawing on accumulated knowledge and experience. Experts provide judgements quite often on a collective or group basis after receiving written and sometimes verbally presented evidence and making direct observations.

Procedures for the granting of research funds generally involve expert panels and committees, supported by staff to assemble data, prepare briefs and report decisions. Judgements are expressed in the form of narratives, quality ratings or as numerical scores in relation to specified criteria.

Expert review methods include:

- peer review: used to make judgements about the value of publications, the standing of institutions and the allocation of funds to individuals, organisations, programs and projects
- relevance review: used to assess whether an agency's programs are relevant to its mission and purpose
- benchmarking: used to evaluate the standing of an organisation, program, or facility relative to another.

Expert judgement can be a relatively fast, straightforward and widely accepted approach to performance assessment. It provides the opportunity for exchange of ideas, which can lead to new perspectives. However, the quality and accuracy of expert judgement as applied to research impact assessment is relatively unknown. Expert judgement needs to be supported by other review methods and supporting studies, particularly when assessing expert phenomena.

The main challenges are to identify qualified and experienced reviewers, free of bias and conflicts of interest (real or apparent) and to calibrate reviewer ratings to ensure consistent judgements according to desired criteria (Ruegg & Feller 2003).

Expert judgement is used widely in reviewing the performance of the CRC programme—with expert panels appointed to undertake second and fifth year reviews of CRC performance. This responsibility is now assigned to the boards of centres.

Principles and criteria-based approaches

A recent New Zealand report, *National benefit and its application to publicly funded research, science and technology investments* (Morten 2002), suggests that assessments of national benefit by public research funding agencies tend to be undertaken through the application of 'principles'. These are often built around criteria such as:

- Returns must ultimately be realisable—that is, there should be a value to a potential user and there must be a strong probability of producing an eventual return.
- National benefit means benefit to the country making the investment.
- The extent and application of social, cultural and environmental returns must be taken into account.
- Displacement of private sector effort should be avoided.
- The incremental value that the additional public sector investment brings about should be recognised.

In Australia, the Industry Research and Development Board has published a set of 'national benefit principles' which might be seen as a typology of benefits (Australia, Industry Research and Development Board 2000). The principles are used by AusIndustry in assessing grants in relation to its suite of programs and are used by the Australian Research Council in relation to Linkage grants.

More recently, the Australian Government has identified a set of National Research Priorities which specify benefits that research activity is expected to generate. These priorities are supplemented by priorities for research funded by the RDCs. Through the articulation of priorities, a basis is provided for the specification of principles which will, in turn, become the basis for assessment of funding applications. That is, grant applicants will frame funding requests in accordance with the 'principles' set out in application guidelines.

Very rarely, however, are projects reviewed in relation to the extent to which they have actually *achieved* the original objectives of the research. The RDCs have developed methodologies which report return on investment from their research. However, grants for basic research are rarely assessed in relation to what they set out to achieve. Reporting frameworks generally do not require it (Howard Partners, Ernst & Young & ACIIC 2001).

Indicators of performance

In review and evaluations of granting programs, proxy measures are often developed to enable identification of economic benefit. In the context of the earlier discussion of performance measurement, a number of indicators have been identified. These indicators are generally related to outputs rather than outcomes.

The usefulness of indicators lies in the *link* they provide between outputs and outcomes. As suggested above, assessment of impact relies on research-oriented studies and evaluations undertaken periodically. Indicators provide proxies and interim pointers to how a program is going.

Performance indicators therefore cannot be expected to perform the same function as performance measures.

A typology of indicator categories relating to the knowledge processes covered in this report is provided in Table 11. These categories can be measured through numerical counts, ratios to research income or expenditure and movement over time. A full list of possibilities would cover many pages: the purpose here is to define indicator categories. Their definition, usefulness and application will vary across institutions.

Table 11: Summary of output indicators

Process	Output indicator categories
Knowledge diffusion	Communication activities
	Capacity-building activities
	Extension and education activities
	Standard-setting activities
Knowledge production	Academic publication activities
	Patenting and licensing activities
	Income streams
	Spin-off company formation activities
Knowledge relationships	Contract research and consultancy activities
	Income streams
	Staff and students working on interchange with industry
	Industry research managers and staff with sessional and adjunct appointments in universities
	University-appointed 'visitors' from industry
Knowledge engagement	Participation in non-academic community and economic activities
	Scale and scope of jointly owned and operated technology infrastructure—technology and research parks, buildings, equipment, instruments etc.
	University-organised events for community and regional economic benefit (workshops, seminars etc.)
	Community and business use of university facilities for non-academic purposes (e.g. libraries, cultural centres, sportsgrounds)

The output indicator framework should be kept simple and manageable. It is important to avoid the inclination to assemble data generated through administrative processes and regard this as performance information. The value of performance indicators lies in their limited number and their relevance to performance assessment.

Many public programs suffer from the availability of too many performance indicators. The result is that, due to the complexity and ambiguity of reporting and presentation few, if any, are used by policy-makers and managers. When the relationship of indicators to expected program outcomes is not clear, commitment to indicators may drive inappropriate performance.

For example, it is relatively easy to increase the numbers of invention disclosures or spin-out companies, but such increases may have little relationship to the creation of wealth from research activity. However, invention disclosures and spin-outs in the area of microbiology may point to substantial downstream economic benefits.

Summary framework

The performance measurement framework that has been outlined in this chapter can be summarised in Table 12.

Table 12: Summary of research commercialisation measures

	Knowledge diffusion	Knowledge production	Knowledge relationships	Knowledge engagement
Focus of measures	Broad adoption by industry of the results of research	Creation and/or expansion of new businesses	Building of capacity and capability for industrial research and innovation	Knowledge-based economic development
Key aspects of process	Broad dissemination of the results of research leading to widespread industry adoption	Creation of knowledge products that can be adopted, applied and used in industrial and commercial contexts	Industry–research collaboration that results in	Industry–research–government partnership in economic development
Reflected in	Evidence of: <ul style="list-style-type: none"> workable communication strategies capacity building education production and marketing standards 	Discoveries and inventions adopted and applied in business contexts Graduates who work in industry	Higher levels of cooperation and collaboration Joint ventures, partnerships and alliances Number, scale, and scope of industrial research centres and institutes	Clusters, social capital, creative capital Joint government, industry, research organisation facilities, instruments and equipment
Typical output measures	Communication activities Training and extension workloads Standards developed, disseminated and adopted	Intellectual ‘products’ created and sold—patents and patents registered and licensed to industry	Numbers of collaborations; contributions to process and product improvements e.g. discoveries and technologies adopted in product development	Regional output measures
Outcome measures	Industry competitiveness and value added	Business growth and sustainability	Contribution to national output	Regional development and sustainability
Main focus of measures	Industry studies	Business-focused case studies	Economic studies	Regional studies

The relevance and applicability of the performance measurement and assessment methods and techniques to each of the knowledge commercialisation processes is summarised in Table 13. For example:

- Analytical and conceptual modelling is relevant to all commercialisation processes; it is important to understand the underlying program theory as a basis for assessment, validation and possible change.
- Survey methods are particularly relevant to knowledge production and knowledge relationships, involving interviews and consultations with companies to assess change in business performance and with research organisations and businesses to assess collaboration.
- Descriptive case studies are also used widely in assessing performance in knowledge production and knowledge relationships; information about performance is sought from business owners and managers.
- Economic case studies are used widely in assessing performance in knowledge diffusion, insofar as research and its diffusion leads to productivity improvements and improvements in competitiveness; industry data can be used in these approaches.
- Statistical analysis and econometric modelling are used widely in assessment of research relating to knowledge diffusion and knowledge relationships; national economic statistics can be used in these approaches.
- Sociometric analysis is used in assessing performance in diffusion, relationships and engagement; it identifies personal contacts and interactions.
- Bibliometric counts and citation analysis are used widely in the knowledge production process; bibliometric approaches provide proxy indicators of output.

It is emphasised that the assignment of performance measurement and assessment approaches to commercialisation processes is illustrative only. It serves, however to demonstrate the diversity of approaches and the way in which they have a different level of applicability across each of the processes. Moreover, different measurement and assessment approaches will have differing applicability between disciplines and industries—depending on the predominance of the commercialisation process.

Table 13: Application of measures to knowledge commercialisation processes

Method	Knowledge diffusion	Knowledge production	Knowledge relationships	Knowledge engagement
Main focus of measures	Industry studies	Business studies	Economic studies	Regional studies
Analytical/conceptual modelling of underlying theory	√	√	√	√
Survey		√	√	
Case study—descriptive		√	√	
Case study—economic simulation	√			
Econometric and statistical analysis	√		√	
Sociometric and social network analysis	√		√	√
Bibliometrics—counts		√		
Bibliometrics—citations		√		
Bibliometrics—content analysis		√		
Historical tracing	√		√	√
Expert judgement		√	√	

Attachment 1: The scope and scale of knowledge products and services

In this attachment, a typology of knowledge products and services is identified to represent the outputs that are subsumed in knowledge transfer processes. The typology is used in the analysis of knowledge transfer processes in the main body of the report.

Academic publishing

This category includes the production, marketing, distribution, and sale of books, papers, electronic and other copyrighted material through academic presses and/or commercial publishers established for this purpose. It covers a broader purpose than publication of the results of scientific research in peer-reviewed journals and monographs, in that it includes literary works and relates to the community services mission for universities. This is the main focus of Australian university presses.

From the seventeenth century, and the invention of the printing press, academics sought to share their knowledge and discovery with peers, partly as a contribution to the 'public good', or the 'knowledge commons' through publication in books and scientific journals published by their professional societies. Universities established academic presses to meet the objectives of sharing knowledge and discovery with peers and students and inviting debate and discourse.⁹

Thus, academic publishing represents the most traditional way in which the outputs of a university are captured. It is also the primary measure of research quality undertaken through peer review and disclosure of theory, method, findings and conclusions. However, universities and authors earned little, and generally expected little, in the way of income from this process. But over the last 150 years, most academic publishing, especially its prestigious titles, has moved from learned member-based societies and academic presses to commercial ownership.

Coinciding with the expansion of university research the volume of academic publishing has increased, almost exponentially, to keep pace with academic output. Paradoxically, the returns have not been captured by the academics, but by commercial publishers.¹⁰ This arises as a result of the contemporary features and peculiarities of academic publishing:

- The creator of content (the academic or researcher) gives away their intellectual property (copyright) to the publisher as a condition of publication. They rarely receive payment from the publisher (few academic titles earn royalties).
- As employers of the authors, universities and research institutions still pay for the production of the content.
- The incentive to publish (the reward) for the academic is the prospect of career advancement.
- The labour which gives the product value in the marketplace—peer review and editing—is also provided free by scholars, since this activity also advances careers.

9 Cambridge University Press has been operating continuously as a printer and publisher since the first book was published in 1584. It is an integral part of the university and has charitable objectives of advancing knowledge, education, learning and research. The press has extended the research and teaching activities of the university by making available worldwide through its printing and publishing a remarkable range of academic and educational books, journals, examination papers and Bibles. It currently has 24 000 authors in 108 countries, including 8000 in the USA and over 1300 in Australia. Similarly, Oxford University Press is a department of the University of Oxford and has the purpose of 'furthering the University's objective of excellence in research, scholarship and education by publishing worldwide'.

10 If a university owns the press, then profits are returned to the university. But apart from the global university presses such as Cambridge, Oxford and Harvard, academic publishing is highly concentrated in public companies. These include Addison Wesley, McGraw Hill, Pearson, Sage, Routledge and Wiley. Academic publishing by universities in Australia operates mainly as a service to academics in the domestic market rather than as a substantial business. Academic presses are associated with the University of Melbourne, RMIT, Southern Cross University, University of Queensland, the University of New South Wales and the University of Western Australia.

- The profitable market for the product (the journal) is not the end user (or reader/author) but collectively, the higher education and research sector (the employers of the authors) through their libraries and the students who pay exceptionally high prices for journals and textbooks (Council of Australian University Librarians 2002).

This pattern of commercialisation of copyrighted materials is being paralleled in the commercialisation of intellectual property reflected in patents. It is the intermediary, usually a venture capital investor, who is motivated to capture the profits from patented discoveries and inventions. The critical issue in this area is the *value added provided* by the entrepreneur and the level of economic rent that is considered to be intellectually and socially acceptable and that would cover the cost and reward the risk that is being taken.

A substantial amount of material which reflects the results of research is published in reports, papers, books and through multimedia systems that do not pass through the academic peer review system. Where universities, research organisations, and governments wish to communicate knowledge created through research to a wider constituency than other researchers, characteristics such as readability, attention, and capacity to create are of major concern. This form of publication forms an important aspect of communication strategies associated with research that is associated with a knowledge diffusion process.

Knowledgeable graduates

The strongest contribution of university-based research to industrial innovation is its role as a training ground for future entrants into the industrial workforce. The integration of research and education creates an outward flow of human resources from a university, which results in an educated workforce as well as new spin-out companies and start-ups. A US study notes that 'a rising tide of entrepreneurship in universities is making it possible for some research-trained students to participate in commercially relevant activity while still at university (Grossman, Morgan & Reid 2000).

The study finds that demand for research-trained graduates is particularly high in the medical devices and equipment and network systems and communications industries. In financial services and transport, distribution and logistics, demand for graduates with research training is concentrated in a small number of leading companies, and the consulting and software companies that serve the industries. Start-ups are a strong force attracting graduates in the five sectors studied (Grossman, Morgan & Reid 2000).

The model of the American research university is seen to be unique in the degree to which it integrates research with education. Not only do graduating students serve to staff industry, but they also are the most effective vehicle for technology transfer. Federal support for university research drives this process. In top university computer science programs, over half of all graduate students receive financial support from the federal government, mostly in the form of research studentships (National Research Council 2003).

Knowledge is also transferred when researchers in university employment leave and work in research positions in companies or establish their own technology-based businesses. Students, following completion of graduate and postgraduate studies, often establish their own businesses to convert knowledge into commercial application. Sometimes these businesses retain close contacts with faculty.

Proteome Systems Limited

Proteome Systems commenced operations in January 1999. The company was founded by Professor Keith Williams and a core team of internationally recognized scientists from the Macquarie University Centre for Analytical Biotechnology who pioneered the field of proteomics over the previous decade.

During the 1990s, the scientific founders of the company made an important contribution to defining the revolution in proteomics including coining the word 'Proteome' in 1994; establishing the world's first government-funded proteomics facility (APAF) at Macquarie University under the Australian Major National Research Facilities Program in 1995; co-authoring the first text on proteomics in 1997; and developing commercial proteomics technologies.

The founding scientists' vision was to use their multidisciplinary knowledge and experience to build a proteomics company, headquartered in Australia. Their goal was to take advantage of the emerging global market opportunity for new tools and integrated solutions for proteomics research. The founding scientists believe that proteomics will provide researchers with valuable new insights into understanding biological complexity and ultimately have the potential to accelerate the development of new diagnostics and drugs.

Recent studies have found that academically generated knowledge flows to industry mainly through the educated graduates and postgraduates recruited or engaged by businesses (as contractors/consultants) and through a company's reading of academic literature (Gristock & Senker 2000).

Industry-targeted teaching

Professional education

This category covers the preparation, marketing and sale of courses and programs to meet a specific user need for professional recognition and career advancement. Many courses and programs in technological sciences and engineering require accreditation from professional bodies for graduates to be able to practise in the nominated professions. A major focus is on management education.

Recently, business schools have been offering corporate MBAs, tailored specifically to the requirements of a large business or corporation. Student work can be undertaken and recognised as part of a work-related assignment. Many universities also offer courses and programs tailored specifically to small ICT business owners and managers through business schools and faculties of management.

Deakin University has grown to become Australia's leading provider of education and training for organisations, working in partnership with government, major corporations and professional associations—such as IBM, Coca-Cola, Amatil, Coles Myer, General Motors-Holden, Ford, Qantas and CPA Australia. The university recently entered into an agreement with Coles Myer.

Coles Myer and Deakin University launch new institute for the future

1 October 2003

Coles Myer (CML) today launched a unique education and development centre for its 165,000 staff.

CML Chief Executive Officer John Fletcher said Coles Myer had formed a partnership with Deakin University to create the Coles Myer Institute.

The Institute will provide a wide range of development opportunities for employees throughout Coles Myer's eight major retail brands and support functions, ranging from customer service training at store entry level right through to MBA programs.

Mr Fletcher said that developing employees' skills was critical to Coles Myer's success.

'If we are to succeed in our goal of being Australia's number one retailer in all of our brands we will have to have the best people, with the best skills, no matter what their role is in our organisation,' he said.

Mr Fletcher said that the Coles Myer Institute was a company-wide extension of the successful Coles Institute which offered training and development opportunities within Coles Supermarkets, also through a partnership with Deakin University's corporate training arm, DeakinPrime.

'We're on a journey of change at Coles Myer and a critical success factor will be developing our people into a team best equipped to provide customers with the best service and best value every day.

'The Coles Myer Institute is a great example of how a successful program in one of our brands has been developed and broadened to benefit the whole of our organisation,' Mr Fletcher said.

'I'm also pleased that our alliance with Deakin has developed and deepened and I look forward to this next phase of our relationship,' he said.

The Vice-Chancellor of Deakin University, Professor Sally Walker, said that the agreement between Coles Myer and Deakin presented a clear and positive message to corporate communities.

'Deakin aims to be Australia's most progressive university; this is a strategic direction that sees Deakin making education available, not just on-campus and off-campus, but also in the workplace.

'The corporate sector is fiercely competitive. To survive in today's environment, employers must ensure that their employees are given every opportunity to keep pace with innovative practice and technology and to remain in tune with global developments in their particular areas. DeakinPrime, Deakin University's corporate training arm, facilitates these arrangements.

'We are delighted to build on Deakin's partnership with Coles Supermarkets which has seen hundreds of Coles employees gain credentials that they may not otherwise have had the opportunity of attaining.

'Deakin is committed to lifelong learning and to access and equity; what better way to demonstrate this than in the stores, offices and boardrooms of one of Australia's largest companies and to make this available to employees working throughout Australia—from the biggest city to the smallest country town.'

Education and training contracts

Over the last several years government departments and agencies have approached universities and other training organisations to provide education and training services on the basis of service contracts based on partnership principles.

The Defence Materiel Organisation (DMO), for example, is currently seeking proposals to establish a strategic partnership with universities and/or other training providers to develop and implement a new approach to the delivery of the organisation's education and training.

AusAid awards contracts to universities for the provision of training courses and capacity-building programs as part of its international aid and development programs. The amounts involved are quite considerable.

Contract research

Universities generate a substantial amount of income from research provided under contract with business and government organisations. This ranges from the use of testing and modelling equipment to complete research projects undertaken over many years. In this way contract research is becoming an increasingly important form of knowledge transfer.

Universities regard any activity as research when it is characterised by originality. Contract research therefore differs from consultancy in that it should have investigation as a primary objective and have the potential to produce results that are 'sufficiently general for humanity's stock of knowledge (theoretical and/or practical) to be recognisably increased' (Business Liaison Office, University of Sydney 2003).

Contract research is undertaken by universities for external clients to study an issue or problem and will produce a deliverable report addressing outcomes. Clients usually expect to have an exclusive license to, and may request ownership of, the intellectual property directly arising from the research. The ownership arrangements are generally negotiated between the parties.

Universities generally manage contract research activities through their technology transfer offices. These offices must manage any ethical dilemmas that arise when universities accept funding on a project basis for what are, in effect, 'discovery research' activities, such as in clinical testing of biotechnology-based drugs.

Consultancy

University leaders see consultancy as providing an important way of leveraging their knowledge base to assist and benefit industry, as well as generating a significant stream of commercial income.

Scope of consultancy

Consultancy services cover a range of activities:

- commissioned research: investigation and analysis of specific problems and opportunities, requiring the application of specialist knowledge and formulation of recommendations for action
- management consultancy: covering the provision of objective and independent advice to assist managers in the pursuit of their purposes and objectives
- testing services: services involving testing, measurement and trialling (data collected from humans)
- expert witness services: expert testimony by university staff in legal undertakings
- provision of professional services to private patients and clients in medicine, law, architecture etc.
- lectures, broadcasts or performances given under the auspices of another organisation.

The essence of consultancy is fee for service. Generally, fees are calculated on the basis of time expended together with an amount to cover costs incurred and a contribution to overheads and corporate related costs.

Some aspects of consultancy are addressed below.

Academics acting in a private capacity

University staff undertake a range of consultancy and other activities in a private capacity. The arrangement is between a staff member and external party and is entirely independent of the university. Universities generally allow staff to undertake such activities for around a day a week. The activities must not involve the use of the university's name or its resources. Staff engaged in private consultancies are not covered by the university's insurance policies. Approvals are generally required to undertake private outside earning work.

The university approach is fundamentally different from approaches in the business and commercial environment, where discovery of staff performing work independently and without the imprimatur of their employer would constitute grounds for dismissal. At the same time, however, professional services firms encourage senior staff to undertake a range of pro bono work. This work is, however, recorded and costed and reflected in financial reports and statement as a donation.

The extent of an effective university subsidy to the private consulting academic has attracted the interest of commercial providers and government in relation to competitive neutrality. In 2002 the New South Wales Auditor General expressed an opinion that:

... while all universities have developed policies to manage paid outside work and to protect IP rights, many of those policies are outdated and require urgent review. Many of them do not adequately protect the universities or provide adequate compensation for the use of their resources or their name. There also seems to be a lack of clarity for accountability to monitor and enforce the policy.
(New South Wales Audit Office 2002)

Many academic staff generate substantial revenue from outside earnings in a private capacity. Some universities are concerned about the extent of academic private earnings and the impact on time available for university research, teaching, and outreach commitments. This is quite apart from the leakage of potential revenue. However, they are reluctant to clamp down on these practices because of the risk of driving them underground.

Professional (university) consultancy

Professional consultancy involves the commitment and utilisation of the resources of the university or research organisation. There is often some debate about whether a project should be handled as a consultancy or as a research project. The distinction sometimes is drawn in relation to ownership of intellectual property arising from the work. This has implications for calculation of payments from the Australian Government under the Institutional Grants Scheme (IGS). A university only receives credit towards the IGS for consultancies, where the work is not defined as 'research'. Private outside earnings by academics do not count towards the IGS. Similarly, a business does not receive a tax concession for research regarded as a consultancy.

The following types of activities are not generally regarded as research and fall within the consultancy category:

- preparation of teaching materials designed primarily for the use of internal or external students, such as course notes, texts, or audio-visual aids
- literary and artistic creative work
- technical indexes, bibliographies, compilations or data information
- standard and routine testing
- routine computer programming, systems work or software maintenance.

Nonetheless, the capacity to perform consultancy work is inevitably informed by, and reflected in, knowledge generated through research. Some activities will also be incorporated in subsequent research work. In schools and research centres built around the disciplines of economics, finance, industrial psychology, public policy, and management, consulting is a very important form of knowledge transfer.

Many public higher education institutions have established private subsidiary companies to undertake research and consultancy projects and deliver education and training programs on a fee-for-service basis. These businesses are, in effect, part of the professional services sector offering services to business, and often compete with private sector providers.

Higher education institutions encourage senior academics to undertake advisory and consulting services as a means of supplementing academic salaries and bringing prestige to the institution. Most universities have policies and guidelines that seek to ensure that such activities do not conflict with the interests of university.

Guidelines also generally define rights and obligations of staff and the university, and detail procedures intended to protect both the university and staff from legal liability and other risks.

Many businesses and government agencies believe that university-based consultancy will yield objective and independent analysis and results. Nonetheless, the cultures of academic research and commercially oriented advice differ in relation to process, client relationships, and outcomes. Over-commitment among academics to consultancy can compromise teaching, particularly where junior faculty are assigned to teaching responsibilities, while senior faculty are committed to consulting.

Issues in university management of academic advisory and consultancy services

Few universities market and manage their consultancy services well. However, the provision of advisory and consultancy services by academic staff effectively places a university in a position as a 'professional services' provider. As well as opportunities, this carries obligations and risks:

- obligations to the organisations and people who pay for services in terms of quality, timeliness, and cost (value for money), and the overall relationship with the university
- obligations to staff to ensure that they have opportunities they wish to pursue, as well as being protected from disadvantageous terms and conditions imposed in commercially oriented negotiations
- obligations to students to ensure teaching and learning resources are not being diverted
- obligations to external funding bodies to ensure that public research funding is being directed to discovery and curiosity-driven research
- obligations to university corporate management and stakeholders, in terms of recovery of costs, management of risk and liability, and provision of indemnity.

As a matter of principle, all project research, consultancy, and paid expert advisory services involving the work of academic staff who are full-time employees of the university should be managed through the university. As this principle applies to the creation of intellectual property products generated through research, there is no valid reason why knowledge services provided through consultancy should not also be regarded as university-owned and provided services.

There are substantial opportunities to leverage the knowledge base of the university through more effective marketing, delivery and management of project research, advisory and consultancy services. Project research, advisory and consultancy services already generate substantial revenue; there is potential to substantially increase this, particularly in expert opinion and research-based consultancy.

Most universities levy an overhead recovery charge in relation to advisory services and consultancy contracts identified and negotiated by staff; some academic staff question why they should pay this, and see it as a 'tax' to be avoided; others are happy to have the university look after accounting, management, and insurance costs and recover the costs of using university facilities and services. The charge is rarely seen as contributing to marketing and creating further business opportunities.

Some universities deduct outside earnings from advisory and consultancy services from salaries. This practice is, of course, adopted in commercially oriented professional services firms. However, it is resented by academic staff who see consulting as a way of supplementing their incomes. The opposite argument is that if academic staff want to be consultants they should be exposed to the market risks that commercially oriented consultants encounter.

Many full-time academic staff have interests in consultancy companies and service businesses. This has been an important form of knowledge transfer in areas such as finance, economics, transport and logistics and management. Often students work in these companies to undertake their research (a United States model, particularly in the ICT area). However, the arrangements may run counter to perceptions of scholastic independence and competitive neutrality principles.

The capacities and capabilities of universities vis-a-vis advisory and consultancy services should be effectively planned, marketed, and managed—as well as controlled. The extent of centralisation and devolution is an issue; professional services organisations *distribute* these functions between ‘corporate’ and ‘business units’.

From a management perspective, it is difficult to ‘tack’ these responsibilities onto existing faculty/departmental structures. Universities that are doing well in these areas work through designated research centres and institutes.

University performance in consultancy should be clearly acknowledged as knowledge transfer and covered in measures of performance.

Staff interchange and faculty appointments in industry

Policies and programs have encouraged interactions between researchers in universities, research organisations and industry. The ARC Linkage program is specifically targeted at joint research projects. More limited, however, is the free flow of people between appointments in universities, research organisations and industry. The criteria for academic appointment prevent many from being eligible for senior faculty appointments. Nonetheless, people from industry are particularly important to ensure the success of industrially oriented and supported research centres and institutes.

The Massachusetts Institute of Technology (MIT) has history of senior faculty leaving to direct industrial research centres while retaining university linkages. There are a number of people who work in government and industry who retain academic titles and professorial appointments aimed at preserving linkages with universities.

Many senior faculty hold appointments in large corporations and make a contribution in the form of new perspectives and ideas. They are also associated with formation of science and technology-based start-up companies and quite often this gives investors a form of assurance through the credibility associated with the presence of eminent scientists on newly formed company boards.

Research publication

Publication in peer-reviewed learned journals and respected academic presses enhances the reputation and standing of the authors. Career advancement for academics is still dependent upon publication, peer review and securing of research grants. However, publication is also important to industrial users of knowledge since it enables them to keep abreast of the field and, potentially, adopt and apply research findings in their own research programs and product development strategies.

It cannot be assumed, however, that creation of peer-reviewed academic content automatically enters the public domain through publication.¹¹ As indicated, that domain has, to a large extent been captured by global publishing houses. On the other hand, some academic authors have been quite successful in commercial publication in their own right, earning substantial individual royalties from publications, particularly textbooks.¹²

With the growth in the potential applicability of scientific research in the production of marketable products, the orientation of research agendas and the influence of those agendas on publication of the findings of research is becoming a matter of concern. There are suggestions that commercial pressures have distorted research programs and reports. Such a process creates greatest risks—for the integrity and scholastic standing of the university itself (Bok 2003).

11 There is, of course, a vast amount of material that enters the public domain via the internet that is not subject to quality checks.

12 Success in publishing, particularly in a popular market, is often frowned upon by academic peers and not seen as serious university-based research academic output.

Creation of intellectual property rights

Notwithstanding the range of knowledge products and services referred to above, commercialisation is most often associated with the identification and subsequent definition of a knowledge product in the form of an intellectual property right (IPR) through registration of a patent, copyright or design, and the generation of revenue from their licensing and sale.

However, universities and research organisations register IPRs for a variety of reasons, only one of which is to generate revenue. Moreover, intellectual property may also be marketed and licensed without registering a patent—for example, licenses to use copyrighted material, such as multimedia licenses. Moreover, there are situations and circumstances where it might be commercially prudent *not* to register an intellectual property right.

Definitions and concepts

Broadly defined, the term ‘intellectual property’ covers ideas, inventions, discoveries, symbols, images, expressive works (verbal, visual, musical, theatrical)—or any potentially valuable human product that has an existence separable from a unique physical embodiment—and whether or not the product has been ‘propertised’ (brought under a legal regime of property rights (Landes 2003).

In practice, and in a university setting, intellectual property most frequently refers to patentable inventions and copyrightable works created by faculty and staff in the course of their research or scholarly activities. It also covers trade secrets and know-how that can be codified, for example, in manuals and handbooks. The University of Sydney *Business Liaison Office manual*, for example, defines intellectual property as covering:

... all copyright and neighbouring rights, all rights in relation to inventions (including patent rights), plant varieties, registered and unregistered trademarks (including service marks), registered designs, confidential information (including trade secrets and know-how), circuit layouts, and all other rights resulting from intellectual activity in the industrial, scientific, literary or artistic fields.

In addition to specific documentation, IP is also covered by covenants and non-disclosure clauses in employment and contract arrangements. For many corporations, know-how might be the most valuable form of intellectual property.

Why universities and research organisations create IP

Universities and research organisations have developed and implemented intellectual property protection policies and strategies for a number of reasons. The University of Sydney *Business Liaison Office manual* (2003) cites three main reasons for patenting inventions:

- The university has a commitment to ensure that the results of its research are disseminated to the benefit of the community and to Australia at large, and accepts the National Guidelines on IP Management. Often the only way in which this can be done is to give a company, through a licensing agreement, a monopoly or partial monopoly to exploit the intellectual property. This enables the company to justify the investment required to commercialise the invention.
- Demonstration of appropriate IP management by the university encourages an understanding of the quality and relevance of university research and encourages commercial relationships and opportunities for additional research support and collaborations.
- The inventor(s), the university and the department in which the work leading to the invention was done may all gain significant income from the commercialisation of a patent.

The focus on dissemination in the guidelines is clear, as is the leverage that IP provides in commercial relationships and the possibility of generating some revenue. But apart from a recognition of the limited returns to a university or research organisation from technology licensing, the prospects of revenue generation still attracts the attention of public-policy advisers, venture capital investors, IP lawyers and patent attorneys who see opportunities to generate very substantial returns if a 'blockbuster' patent is discovered.

The IP policies and strategies adopted by universities and research organisations will have a major influence on the way in which a university will interact with industry. There are various formal mechanisms for this interaction, including technology transfer offices and research offices (sometimes combined), stand-alone major research facilities, faculty business units, commercially oriented research and testing laboratories, university-owned consulting companies, and industry- and government-funded and specifically designated research centres.

Although technology transfer offices facilitate IP protection activities, the drive and motivation for patenting often comes from faculty; that is, the people who make the discoveries and create the inventions which embody IP rights. This motivation is, of course, underscored by university policies that vest (at least in the first instance) the ownership of IP with the university. While policies can be communicated to staff, no one can force a scientist or researcher to make a disclosure. There are other forces at work that need to be considered.

Formation of spin-out companies

The emergence of science-based innovation, particularly in the biomedical area, has involved the development of the 'spin out' company as a preferred commercialisation route. This flows directly from the exceptionally high risk of commercialising science-based discoveries and inventions—but with the prospect of very high returns as a result of monopoly profits deriving from a business based on secure and protected intellectual property assets. A relatively new asset class—venture capital—has emerged to fund the growth of these companies.

Following experience in the United States, some universities seek to derive more income from equity injection and subsequent sale or listing rather than direct licensing of the technology to the new company. These arrangements involve a high level of collaboration between universities, business, venture capitalists and other financial intermediaries. Some companies established to develop technologies in this way have received assistance under government technology assistance programs (for example, R&D Start). Investment decisions by venture capital fund managers are often conditional on a technology development grant being received.

The spin-out route is most likely when:

- The innovation (that is, commercial application) arises directly from basic research.
- It is a 'disruptive technology', that is, the technology is not yet being applied in industry.
- There is no readily identifiable receptor.
- There are opportunities for integration with established companies should the technology be of commercial value, for example, a biotechnology start-up with the potential for downstream take-up by a pharmaceutical company.

In all reality, these situations are quite rare.

Large firms often prefer to invest in or purchase spin-out companies rather than develop an emerging technology internally. They may take a minority position in a start-up to gain access to the new technology it creates. This is a popular strategy for big pharmaceutical firms lacking a biotechnology development capability, but with necessary marketing, manufacturing and financing skills. Companies also support a 'portfolio' of start-ups and exercise options for acquisition at an appropriate time. This avoids the larger risks in people, finance and technology.

The prospect of obtaining funding through venture capital has also been a major source of stimulation for the formation of spin-out companies. Success stories and promotion by the venture capital sector have had a significant effect on shaping popular beliefs and the direction of formal research in relation to new business ventures. But venture capital-backed firms tend to be concentrated in only a few high-technology fields such as ICT-enabled devices (including biomedical devices). They are also geographically concentrated—notably in California and Massachusetts. However, it is relatively easy to document their strategies and performance (Bhide 2000).

Spin-outs require investment much greater than the initial public investment in the research: they require the commitment of very skilled people apart from the researchers, notably marketers and entrepreneurial managers who are skilled and experienced in building research-based companies. These skills are in very short supply and difficult to access.

One of the major challenges in the Australian context is finding venture capital investors who can also bring the knowledge, skills and experience to develop and nurture a company from the earliest stages to a situation where it will be attractive to follow-on investors.

Income generated from knowledge products and services

Published data provides information in relation to commercial (earned) income under a number of categories:

- income from teaching: much of it is earned on the basis of active and strategic marketing of courses and programs in a highly competitive market for overseas students and for corporate education programs
- income from consultancy and contract research
- income from royalties, trademarks and licenses: this includes license income generated from intellectual property that may not be subject to formal IPR protection.

The performance of universities in generating commercial income is provided in Table 14.

It is notable that:

- In 2003, Australian universities generated \$637.5 in contract research and consultancy income—compared with \$34.9m from licences and royalties (Australia, Department of Education, Science and Training 2004). This represents an increase of 36% since 2000.
- Income from student fees and charges amounted to 16% of total income.
- Income from contract research and consultancy amounted to 5% of total income.
- Income from royalties, trademarks and licenses amounted to 0.2% of total income.
- Overall, income from knowledge products and services amounted to 27.5% of total university income.

These proportions differ quite substantially between universities and groups of universities. However, the significance of income from student fees and charges and contract research and consultancy suggests where universities are likely to allocate their resources for generating and sustaining commercial income. The limited prospects for increasing revenue from trademarks, royalties, and licenses will be addressed later in the report.

Table 14: University income from knowledge products and services, 2003

	Student fees and charges	Other fees and charges	Consultancy and contract research	Royalties, trademarks and licences	Total knowledge income	Percentage of total income	Total income
Major research universities							
Australian National University	34 696	711	35 416	-	70 823	13.5	523 571
Monash University	164 656	30 165	30 250	2 688	227 759	29.5	771 957
The University of Melbourne	164 697	84 647	25 347	4 954	279 645	30.3	922 585
The University of New South Wales	148 723	60 779	37 986	-	247 488	33.5	739 291
The University of Queensland	83 755	27 569	121 505	7 267	240 096	32.8	732 266
The University of Sydney	137 441	29 685	66 415	3 658	237 199	27.1	874 814
The University of Western Australia	37 399	12 031	62 085	-	111 515	26.5	420 922
University of Adelaide	36 085	2 874	21 837	343	61 139	16.8	363 429
	807 452	248 461	400 841	18 910	1 475 664	27.6	5 348 835
Innovative research universities							
Flinders University of South Australia	17 940	6 239	7 641	148	31 968	17.0	187 749
Griffith University	76 796	17 295	4 832	34	98 957	27.5	359 755
La Trobe University	39 740	10 949	20 417	-	71 106	21.7	327 593
Macquarie University	91 858	27 361	6 067	282	125 568	41.0	306 192
Murdoch University	22 201	7 228	18 942	-	48 371	29.9	161 876
The University of Newcastle	30 089	14 243	22 390	-	66 722	24.7	270 426
	278 624	83 315	80 289	464	442 692	27.4	1 613 591
Technology network universities							
Curtin University of Technology	104 716	14 995	9 305	-	129 016	32.9	392 479
Queensland University of Technology	80 107	6 365	9 457	796	96 725	23.6	409 778
RMIT University	147 592	14 678	17 742	-	180 012	35.0	514 906
University of Technology, Sydney	81 860	4 245	5 760	58	91 923	29.5	311 131
University of South Australia	55 524	7 690	15 589	712	79 515	25.8	307 606
	469 799	47 973	57 853	1 566	577 191	29.8	1 935 900

Table 14: University income from knowledge products and services, 2003 (continued)

	Student fees and charges	Other fees and charges	Consultancy and contract research	Royalties, trademarks and licences	Total knowledge income	Percentage of total income	Total income
New generation universities							
Australian Catholic University	10 627	3 682	208	1 450	15 967	14.8	107 558
Central Queensland University	84 239	10 646	374	11	95 270	46.6	204 649
Edith Cowan University	33 861	8 377	1 532	4 252	48 022	23.6	203 096
Southern Cross University	12 492	2 235	3 364	40	18 131	19.6	92 285
University of Ballarat	7 686	20 875	4 170	-	32 731	30.5	107 231
University of Canberra	18 653	6 098	5 027	-	29 778	26.0	114 673
University of Western Sydney	44 565	3 980	9 744	-	58 289	18.7	311 140
Victoria University of Technology	41 555	30 726	7 500	26	79 807	27.0	295 779
	253 678	86 619	31 919	5 779	377 995	26.3	1 436 411
Regional universities							
Charles Darwin University	4 683	2 079	3 708	-	10 470	7.3	143 377
Charles Sturt University	26 653	16 667	1 330	8	44 658	21.9	203 640
Deakin University	65 963	36 284	11 037	6 896	120 180	34.1	351 920
James Cook University	15 689	12 586	12 376	508	41 159	21.5	191 842
Swinburne University of Technology	55 531	24 255	11 056	101	90 943	35.9	253 251
The University of New England	13 425	17 738	4 095	650	35 908	21.9	163 643
University of Southern Queensland	22 018	4 442	1 336	-	27 796	23.2	119 991
University of Tasmania	18 410	9 079	5 688	(22)	33 155	15.5	213 255
University of the Sunshine Coast	4 538	583	631	12	5 764	14.5	39 825
University of Wollongong	51 922	24 891	13 732	-	90 545	38.1	237 619
	278 832	148 604	64 989	8 153	500 578	26.1	1 918 363
Other							
Australian Maritime College	1 599	1 908	1 339	-	4 846	22.3	21 742
Batchelor Institute of Indigenous Tertiary Education	-	563	-	-	563	1.7	32 714
The University of Notre Dame Australia	12 099	1 194	270	-	13 563	55.9	24 270
All institutions	2 102 083	618 637	637 500	34 872	3 393 092	27.5	12 331 827

Source: Australia, Department of Education, Science and Training (2004)

Data from other sources indicate that:

- In 2002, Uniquest at the University of Queensland, generated \$39.1m in technology transfer revenue and \$11.6m in international projects and consulting revenue (Unisearch Limited 2004).
- In 2003, Unisearch, at the University of New South Wales, generated income of \$10m in expert opinion and consulting services and \$4m from technology transfer (commercialisation) activities (Unisearch Limited 2004).
- Total revenues from commercial activities at the University of Sydney in 2003 were \$66m. Most of this was from contract research and consulting.

In 2001–02, CSIRO generated \$17.1m from technology licenses, an increase of \$5.5m over the previous year. However, in the same year, CSIRO generated \$104.3m from 2857 contracts with *private sector* clients. This represented 38% of all external revenue (CSIRO 2003).

These performance data explain why universities and research organisations are turning their attention to generating income from project research and consultancy and placing less emphasis on IPRs a source of revenue. Nonetheless, IPR remains an important lever in marketing, negotiating, and sealing business-oriented commercial ‘deals’ for project research and consultancy work. This relates to IP in patents as well as in trade secrets. This occurs for example, in civil engineering, economics, and finance.

There is a substantial amount of management research, which indicates that the prospects of establishing commercial relationships are higher when a high level of trust has been established between senior managers in purchasing and supplying organisations. Web-based technology exchanges serve as technology yellow pages, but as experience elsewhere demonstrates, internet relationships make personal, trust-based, relationships *more* important.

Trust-based relationships are established through both formal and informal processes. In the networked economy it has become clear that people do business with people they trust. Trust relates to an understanding of the capacity to perform and deliver the products and services intended—quite often in ways that exceed the formal provisions of a contract.

University leaders are also beginning to appreciate that over-emphasis on extracting revenue from IPRs can stand in the way of developing business relationships that are likely to be much more lucrative over the longer term.

University senior managers are becoming aware that, in some areas of engineering and the social sciences, there is more value to be created from marketing and delivering *services* generated from using IP than from licensing or selling it for others to use. Service delivery through contract research and consultancy allows for both explicit and tacit knowledge to be applied.

Attachment 2: The role and function of intellectual property rights in research commercialisation

The creation of intellectual property rights (IPRs) is envisaged to play a key role in research commercialisation. Much of the discussion about IPRs has related to legal and contractual issues and articulation of rights, obligations, and access to revenue streams. However, research commercialisation has a business focus, and it is important to see IPRs in that business context.

It is therefore important to understand, from a business perspective, why universities and research organisations seek to proprietise knowledge in the form of IPRs, identify differences in approaches among research fields and industries, as well as the limitations and risks associated with an overly restrictive, or exclusive, approach.

The propensity to patent

Research funded by the Association for Institutional Research in the United States indicates that faculty make decisions in relation to patenting in terms of:

- their perceptions of professional and personal benefit
- their perceptions of the time and resource 'costs' of interacting with technology transfer offices (TTOs), and the competencies of TTO staff
- their general beliefs about the campus environment for technology transfer (Owen-Smith & Powell 2000).

The research suggests that the propensity for scientists to disclose inventions and pursue patents varies widely across research fields. The researchers reported that: 'physical scientists patent for freedom of action, life scientists patent for strategic advantage'. The following characterisations were identified:

- Physical scientists, covering the natural sciences and engineering, whose inventions tend to be incremental improvements on established processes or products, tend to use patents to develop relationships with firms, and as 'chips' to exchange for use with other proprietary technology, to secure access to equipment, and other opportunities. In keeping with the more *relational* approach, physical scientists:
 - expect less personal gain from patent royalties
 - favour non-exclusive versus exclusive license arrangements
 - are less concerned about finding the right licensees.

In the current innovation environment, many of the inventions in the natural sciences and engineering are heavily oriented towards software applications.

- Life scientists, whose inventions often involve therapeutic compounds and medical devices, tend to use patents as more tangible properties to be protected and sold. Rather than use patents to establish relationships with multiple partners, life scientists endeavour to find the single best partner to develop a drug or medical device and shepherd it through the Federal Drug Administration (FDA) approval process. In keeping with this more proprietary approach, life scientists:
 - expect more personal gains from patent royalties
 - favour exclusive over non exclusive licensing arrangements
 - are more concerned with protecting IP.

Physical scientists often have a goal to transfer technology to industry, to build relationships with companies, and to educate students. They do not necessarily want to make money from the technology per se, but to have something to bring to the table in negotiations for contract research and consultancy. The outcome is leverage and relationship-building. Similar considerations apply in the social sciences and humanities.

In these respects it is important to acknowledge the IP includes instruments such as trade secrets, know-how, experimental data, reports, manuals, files, drawings, specifications, databases, software source code, and confidential information—much of which is not protectable through codification in patents. Moreover, patenting, by making the information public, could destroy the commercial advantage created by the IP. In businesses, internal 'knowledge management' systems attempt to capture and control the use of this information.

The lesson from agricultural innovation has been that patenting has let inventions out in the field and they moved into adoption at a very high rate. The rural research and development corporations have been at the forefront of this process.

Life scientists, by contrast, tend to put in invention disclosures when they think they might have value. They know that most of them will not, but they do not want to take chances and miss something; they are looking for the golden egg that will generate multimillion dollar returns. The outcome is about protection—and income. With enterprising venture capitalists they might be able to put a 'block' in the innovation process as a way of securing a revenue stream. This is causing concern in policy circles.

Implications of the relational versus the proprietary approach to patenting

The approaches outlined above underscore the difference between the relational view of patents, characteristic of the natural sciences and engineering, and the proprietary view, characteristic of the life sciences.

The proprietary view has come to dominate thinking in public policy—aided and abetted by representations from venture capital investors, lawyers and accountants—although its industrial and economic impact may be much less than is often asserted, and less significant by comparison with the relational strategies of patenting in the natural sciences and engineering and in the social sciences.

Discussions and consultations for this study indicated that a relational approach is becoming more clearly articulated in universities and research organisations. This reflects both the limitations and disappointments associated with pursuing the proprietorial approach reflected in the biomedical model of technology transfer. It may also mean that academic staff in universities and research organisations have much better relationships with business and government than is understood by venture capital deal-makers.

However, both the life sciences and the natural sciences and engineering see patent protection as enabling freedom to act, but:

- Physical scientists want to be able to go to conferences and present findings without being restricted by fear of losing potentially valuable property rights; it also extends to freedom to market a finding to work out if it's worth following up. *IP establishes academic freedom for faculty members.*
- Life scientists want to patent to undermine or counteract the patenting agenda of a potentially aggressive commercial firm by removing their ability to control a key resource (information) and conduct research without externally imposed constraints. *Patents afford protection by keeping others from holding exclusive rights.*

Protection also provides leverage differently:

- Physical scientists see patents providing leverage at multiple levels—university, relationships with firms, grant applications, and sponsored research.

- Life scientists see patents as a means to leverage simple investments in their research from firms and venture capitalists; it is less about building relationships and more about capital infusion.

Both life and natural scientists see status benefits in patenting: the exercise of patenting also opens new realms of basic science investigation; it gives academic prestige by attesting to the novelty and usefulness of their work; and is seen to aid in the development of basic science research programs.

In addition, an institutional culture supportive of patenting attracts faculty interested in pursuing commercial endeavours as well as socialising new staff into that pursuit. Academic status becomes attached to commercial outcomes and technology transfer endeavours come to reinforce traditional academic status hierarchies.

Income generated from patents and patent licenses

Following the lead of the Bayh–Dole Act in the US, Australian Governments and research funding agencies have been keen to ensure that IP created with public funds is captured for the benefit of the institutions. Moreover, there is an expectation that commercialisable IP will be promoted by universities and research organisations for national economic benefit. The current Australian policy is contained in the document *National Principles of Intellectual Property Management for Publicly Funded Research* (Australian Research Council, Australian Tertiary Institutions Commercial Companies Association, Australian Vice-Chancellor’s Committee, Department of Education Training and Youth Affairs, Department of Industry Science and Resources, IP Australia, and National Health and Medical Research Council 2001).

Profile of licensing revenues

The recently completed Department of Education, Science, and Training survey of research commercialisation indicates that licensing revenues are quite small and concentrated in only a few universities. This is indicated in Table 15.

The licensing data indicate that, in 2001, 35% of licensing income is generated by the University of Queensland. In 2002 the proportion stood at 33%. Only 14 institutions covered in the survey generated more than \$1m in license revenues. These data support the proposition that most IP is worth very little and it is hard to know in advance which has any value.

These findings are consistent with international data. It has been observed that, notwithstanding the perception of riches, even the most successful universities see licence income as a happy bi-product of patenting activities. In most cases, technology transfer office managers see their role as providing a service to the faculty to help get ideas into practical use and to support the development of business relationships initiated by researchers.

Academic reputations are earned by creating something with value to an end user; this may not generate a lot of money from licenses. It may generate revenue from the sales of the products or services where the IP is embedded. Careful negotiation of business deals may ensure that faculty and universities participate in these returns over the longer term.

Concentration of IP licensing activity

Technology licensing activity tends to be concentrated in a relatively few departments and faculties at each university. This is reflected in the results of the research commercialisation surveys undertaken by the Department of Education, Science and Training and the ARC.¹³ The concentration of licensing in the health and biomedical/life sciences is indicated in Table 16.

13 Australia. Department of Education Science and Training, (2004); Australian Research Council, Commonwealth Scientific and Industrial Research Organisation, and National Health and Medical Research Council (2002)

Table 15: Income from licences, options and assignments (LOAs), 2001 and 2002

	2001		2002	
	Gross LOA Income (\$'000)	Number of LOAs Yielding Income	Gross LOA Income (\$'000)	Number of LOAs Yielding Income
University				
The University of Queensland	27 518	29	27 927	26
The University of New England	6 018	62	6 020	62
The University of Melbourne	3 431	14	4 125	12
The University of New South Wales	1 718	24	2 176	40
University of Wollongong	1 547	2	1 650	2
Swinburne University of Technology	807	5	133	5
The University of Sydney	783	36	1 521	34
Macquarie University			1 092	12
Royal Melbourne Institute of Technology	756	9	433	8
Queensland University of Technology	691	8	347	8
The Australian National University	635	8	451	7
The University of Adelaide	549	38	872	46
The University of Western Australia	464	7	150	8
University of South Australia	339	11	358	0
University of Technology, Sydney	144	6	6	2
The Flinders University of South Australia	120	5	236	9
The University of Newcastle	97	2	170	3
La Trobe University	42	1		
Central Queensland University	20	1	20	1
James Cook University	15	1	237	4
Murdoch University			234	1
Curtin University of Technology			135	4
University of Tasmania			192	1
University of Western Sydney			5	1
Victoria University of Technology	13	1	5	1
Total universities	45 704	270	48 525	297
Medical research institutes				
Ludwig Institute for Cancer Research	5 546	13	3 538	14
Austin Research Institute	3 000	2	3 168	5
Garvan Institute of Medical Research	2 214	9	1 863	12
Walter and Eliza Hall Institute of Medical Research	1 670	10	4 421	8
Murdoch Childrens Research Institute	1 621	2	1 712	2
Peter MacCallum Cancer Institute	412	3	185	2
Telethon Institute for Child Health Research	370	1	808	2
Howard Florey Institute	350	2	550	6
Macfarlane Burnet Institute for Medical Research	250	1	220	1
Melbourne Health			165	1
Queensland Institute of Medical Research			122	2
Royal North Shore Hospital			78	2
St Vincent's Institute of Medical Research	83	2	6	2
Prince Henry's Institute of Medical Research			29	1

Continued

Table 15: Income from licences, options and assignments (LOAs), 2001 and 2002 (continued)

	2001		2002	
	Gross LOA Income (\$'000)	Number of LOAs Yielding Income	Gross LOA Income (\$'000)	Number of LOAs Yielding Income
Victor Chang Cardiac Research Institute	60	1		
Centenary Institute of Cancer Medicine & Cell Biology	..	1	..	1
Total medical research institute	15 577	47	20 173	61
CSIRO	17 115	294	12 110	279
Cooperative research centres				
Eye Research and Technology	717	1	2 215	1
Discovery of Genes for Common Human Diseases	575	2	630	3
DSTC Pty Ltd	227	9	593	24
Innovative Wood Manufacturing			170	1
Cast Metals Manufacturing			100	1
Sustainable Tourism	90	1		
Molecular Plant Breeding	50	1		
Value Added Wheat	48	0	55	1
Polymers			25	1
Catchment Hydrology	30	0		
Total cooperative research centres	1 737	14	3 788	32
Other publicly funded research agencies				
Defence Science and Technology Organisation (DSTO)	654	7	994	6
Total all respondents	80 787	632	8 589	675

Source: Australia, Department of Education, Science and Training (2004)

Table 16: Distribution of licenses by originating areas of research, 2000–03

Field of research	Licenses executed (%)		
	2000	'2001	'2002
Biological sciences and biotechnology	42	37	29
Physical, chemical and earth sciences	10	9	15
Mathematics, information and communication sciences	7	19	21
Engineering and environmental sciences	17	15	21
Health and clinical sciences	19	10	8
Social, behavioural and economic sciences	2	1	1
Humanities and creative arts		2	1
Other	1	7	4
TOTAL	100	100	100

Source: Australian Research Council et al. (2002); Australia, Department of Education Science and Training (2004)

As indicated earlier in this report, the relative success of technology licensing in the life sciences has in many ways provided a foundation for the current emphasis in public policies and programs for the commercialisation of all university research. The trends in Table 16 would support this observation. Nonetheless, the overall level of licensing activity is not large.

The data point to a substantial increase in the proportion of licenses in the mathematics, information, and communication sciences area. This probably reflects a trend towards software product and related services making a progressively greater contribution to industrial innovation. However, given that information and communications technologies are enabling technologies in other areas of research, it is likely that licenses relate to applications in areas outside the ICT industry (Howard 2004b).

Supporting small-to-medium-sized enterprises through licensing IP

The technology boom of the 1990s encouraged governments to approach industry policy and economic growth by supporting and encouraging the formation of new technology-based companies with strong entrepreneurial foundations. Policy drew on a considerable amount of evidence which associated innovation with small-to-medium enterprises (SMEs). SMEs were seen as a main driver of employment growth, which is an underlying plank of economic policy.

Data from the *National survey of research commercialisation* indicates that the largest proportion of technology licensing is in fact to established medium-to-large companies. This is indicated in Table 17.

Table 17: Licences executed by Australian universities and medical research institutes, 2000–03

Licences executed to:	2000	2001	2002
Start-up companies	41	47	43
Small companies	49	34	43
Medium companies	27	49	57
Large companies	102	130	132
TOTAL	219	240	275

Source: Australian Research Council et al. (2002); Australia, Department of Education, Science and Training (2004)

Despite the glamour of entrepreneurship, the reality is that most of the effort in technology licensing from universities and research organisations relates to large, established companies, not to SMEs. A similar pattern emerges for the CSIRO and other research organisations (Table 18).

Table 18: Licences executed by CSIRO and other research organisations, 2001–03

Licences executed to:	CSIRO		Other PFRA's		CRCs	
	2001	2002	2001	2002	2001	2002
Start-up companies	4	0	0	0	9	4
Small companies	30	58	3	3	4	11
Medium companies	26	52	4	2	7	11
Large companies	98	78	1	2	8	20
TOTAL	158	188	8	7	28	47

Source: Australian Research Council et al. (2002); Australia, Department of Education, Science and Training (2004)

There are many reasons why universities and research organisations find it relatively difficult to engage with SMEs. These include a preference by SMEs to develop their own technologies and to acquire knowledge through less formal relationships, including graduate recruitment. Many SMEs are formed by staff and students leaving universities and research organisations to set up businesses. However, research organisations such as the DSTO and Meat and Livestock Australia have a strategy of seeking out SMEs to develop technologies.

Investment returns from spin-out companies

Information about spin-out companies formed in 2002, together with companies that were operational in that year is provided in Table 19.

Table 19: Start-up companies formed in 2002

	Start-up companies formed	Companies that became non-operational at year end 2002	Companies operational at year end 2002	Companies operational at year end 2002 with institution holding equity
University				
The University of Queensland	9	2	34	28
Macquarie University	4	0	3	3
Monash University	4	0	8	8
La Trobe University	3	1	6	2
The University of Melbourne	3	0	3	3
The University of Sydney	3	0	25	19
The University of Western Australia	3	0	3	3
The Australian National University	3	0	3	3
James Cook University	2	0	2	2
Swinburne University of Technology	2	0	2	2
Curtin University of Technology	1	0	2	2
Griffith University	1	0	3	3
Murdoch University	1	0	1	1
The University of Adelaide	1	1	1	1
The University of New South Wales	1	0	9	6
University of South Australia	1	0	2	2
University of Technology, Sydney	1	0	1	0
Victoria University of Technology	1	0	1	1
Flinders University of South Australia	1	0	1	1
Deakin University	0	0	1	1
Total universities	45	4	111	91
Medical research institutes				
Telethon Institute for Child Health Research	8	0	0	0
Austin Research Institute	3	3	3	3
Macfarlane Burnet Institute for Medical Research and Public Health	1	1	1	1
Murdoch Childrens Research Institute	1	0	2	2
Garvan Institute of Medical Research	0	0	3	3

Continued next page

Table 19: Start-up companies formed in 2002 (continued)

	Start-up companies formed	Companies that became non-operational at year end 2002	Companies operational at year end 2002	Companies operational at year end 2002 with institution holding equity
Centenary Institute of Cancer Medicine & Cell Biology	0	1	1	1
Royal North Shore Hospital	0	0	1	0
Walter and Eliza Hall Institute of Medical Research	0	0	2	2
Total medical research institutes	13	5	13	12
CSIRO	3	0	3	1
Cooperative research centres				
Bioproducts	1	0	1	1
Cast Metals Manufacturing	1	0	1	1
DSTC Pty Ltd	1	0	1	1
MicroTechnology	1	0	1	1
Clean Power from Lignite	1	0	1	1
Sustainable Tourism	0	0	2	2
Total cooperative research centres	5	0	8	7
Other publicly funded research agencies				
Australian Institute of Marine Science (AIMS)	1	0	1	0
Total all respondents	67	9	136	111

Source: Australia, Department of Education, Science and Training (2004)

The data (third column of Table 19) indicate that spin-out companies are concentrated in the research intensive universities: Queensland, Sydney, New South Wales, Monash.

Apart from the University of Queensland, the data in Tables 19 and 20 do not suggest a relationship between the number of spin-out companies and the value of equity.

Table 20: Value of all equity holdings at year end 2002

Value of all equity holdings at year end 2002	
(\$'000)	
University	
The University of Queensland	46,431
The University of Western Australia	11,400
The Flinders University of South Australia	10,551
The University of Sydney	8,942
The University of Melbourne	4,388
The University of New South Wales	1,142
Griffith University	658
University of South Australia	579
Swinburne University of Technology	511
Macquarie University	364
Deakin University	360
Charles Darwin University	250
The University of Newcastle	172
La Trobe University	130
Central Queensland University	50
James Cook University	20
Total universities	85,947
Medical research institutes	
Austin Research Institute	3,168
Garvan Institute of Medical Research	3,100
Centenary Institute of Cancer Medicine & Cell Biology	3,000
Murdoch Childrens Research Institute	1,063
Queensland Institute of Medical Research	199
Howard Florey Institute	130
Lions Ear and Hearing Institute	30
Total medical research institutes	10,690
CSIRO	18,994
Cooperative research centres	
Sustainable Tourism	7,500
Clean Power from Lignite	50
Total cooperative research centres	7,550
Other publicly funded research agencies	
Total all respondents	123,181

Source: Australia, Department of Education, Science and Training (2004)

Issues and implications

The growth of patenting in scientific, as opposed to technological fields, has expanded the coverage of IP over the inputs to science rather than technological artefacts, which are candidates for commercial development. Patenting has been seen as a key enabling factor in the process of technological development: without clear ownership rights on IP, commercial investors would not make the necessary investments to bring inventions to market. However, as patenting is extended to cover research tools, it is seen to have a negative impact on 'open science' and amounting to an enclosure of the 'knowledge commons'.

The Bayh–Dole Act encouraged universities to protect the intellectual property created from Federal funds and license it to the private sector. This initiative has largely been seen as a success. A number of problems have emerged in the biotech–health sciences area, however, where researchers are getting too dependent on the provisions of the Act and are ‘torquing their research’, keeping their results to themselves and not discussing it with other researchers because they do not want to do the patent work up front (Davenport 1993; Jaffe & Lerner 2004; United States, Department of Commerce Technology Administration 2002).

Policy-makers are seeing a need to get the best out of the Bayh–Dole provisions without impeding the science by keeping it bottled up and not getting an outcome.¹⁴ It is believed that resolution requires some leadership—on the basis that it is good business and good science to have *non-exclusive* licences to various gene technologies and charging a modest amount of money and making these tools readily available. It is considered that this will create a better outcome than holding it exclusively (United States, Department of Commerce Technology Administration 2002).

It follows that there is a need to think more about non-exclusivity and pricing in a climate of true innovation rather than concentrating on the tools under which it operates. This involves a trade-off between maximising revenue, the advancement of knowledge, and promoting adoption and use. A serious problem emerges, for example, when a researcher finds an opportunistic venture capitalist and they decide to put a lock on cascading events. The lesser institutions and venture capitalist sector are seen to be pursuing IP protection in the hope of finding the blockbuster—but according to the evidence are really wasting their time and money (Rogers, Yin & Hoffman 2000).

Apart from these considerations, a recent appraisal of the impact of the Bayh–Dole Act has found that the Act’s emphasis of patenting and licensing as a critically important vehicle for the transfer to industry of academic discoveries, and that inventions lacked a strong evidentiary foundation at the beginning. Strategies viewing patenting and licensing as indispensable components of technology transfers are seen to have had mixed impacts (Mowery et al. 2004).

It has also been argued that the enthusiasm of policy advocates in nations outside the United States for policies that require universities and research organisations to implement technology transfer policies resembling the US Bayh–Dole Act often fail to see the distinctive characteristics of the US innovation system: the US has a long history of university–industry collaboration and technology transfer going back to the period of industrialisation at the turn of the century. Moreover:

In the absence of structural reforms in national university systems, emulation of the Bayh–Dole framework is likely to accomplish little and could well prove counter productive. (Mowery et al. 2004)

These structural reforms in an Australian context would include greater emphasis on, and rewards for, interdisciplinary research, the formation, management and resourcing of industrially oriented research centres and institutes within universities, and arrangements for interchange and interaction between faculty and industrial R&D divisions (currently inhibited by industrial relations practices), and the value placed on informal interactions and relationships between the community of science and industrial organisations. These aspects are addressed in later sections.

¹⁴ For example, because of the many ways of gene expression, a company may have to license many intellectual properties making the royalty requirements to universities wipe out any profits. Some patents—e.g. a gene sequence—create a bottleneck and anything done beyond that requires a license. Some universities cannot do their work or they have to license a patent to do so. Thus, the problem with the Bayh–Dole provisions is that it is possible to patent essentially the tools of research—gene line, cell line, a gene, or a way to manipulate the gene. This has worked to hinder biomedical research.

It is also important to acknowledge those structural features of the Australian economy that will work against the emulation of the Bayh–Dole framework for other reasons. In particular, the manufacturing base in the Australian economy is predominantly foreign-owned; global corporations undertake R&D on a global basis with international business units competing to undertake R&D. With the small size of the Australian market the, foreign R&D commitments have actually declined.

Australia is moving towards a service economy: there are substantial opportunities for the commercialisation of research in the services sector. Commercialisation in this sector may rely less on patenting and licensing and more on other commercialisation processes.

Attachment 3: Engagement and outreach commitments at Australian universities

The way in which some Australian universities have reflected third mission activities in their strategies and objectives is outlined below.

The University of Sydney has strategic goal of 'Engagement with industry and the professions': 'to make a significant contribution to the well-being and enhancement of the wide range of professions with which it engages'. The specific objectives are summarised below.

University of Sydney: Engagement with industry and the professions

In pursuing its goal of Engaging with Industry and the Professions the University will seek to:

- ensure high-quality, relevant curricula which prepare accomplished graduates to take a leading role in their occupations;
- provide graduates with expectations of, and opportunities for, ongoing graduate education, including refresher and extension courses and research training;
- work with professional associations to develop their professional goals and enhance their competencies;
- improve the quality of graduate training and skills, while emphasising high standards of community service and ethics, to enhance the quality of professional service;
- maximise the University's contribution to the community through the involvement of its staff in professional associations, government agencies and professional regulatory bodies;
- work closely with other educational providers in the post-secondary school sector to ensure the provision of course offerings relevant to industry and the professions; and
- contribute, in partnership with other countries, to the ongoing development and upgrading of vocational skills through provision of relevant training programs and other support.

Performance against these goals and objectives is reported in terms of technology licenses, ARC industry-linked grants, collaborative and contract research, consulting, joint ventures and spin-out company formation. Professional and personal achievements of staff are also reported.

The university is involved in a number of joint ventures with technology companies for the construction and operation of research facilities.

The University of Melbourne has a goal to 'serve Victorian, Australian and wider regional and international communities through welfare programs, cultural activities, educational, scientific and artistic developments, and by promoting informed intellectual discourse and political debate (University of Melbourne 2004a). Announced strategies are as follows:

Melbourne University: Strategies for Serving Wider Communities

1. Making the resources and expertise of the University available to enrich the intellectual, cultural, educational, economic, and social life of the City of Melbourne, the State of Victoria and the wider Australian community;
2. Taking a leadership role in the development of Australian society by promoting informed, constructive public discussion, debate and policy formation, and by encouraging the academic staff to engage in public intellectual discourse;
3. Promoting greater public awareness of the crucial significance of higher education, nationally and internationally;
4. Consulting and working with Indigenous Australians in order to assist Indigenous communities to meet their social and educational needs and aspirations;
5. Strengthening links with the Victorian and national schools community;
6. Enriching the cultural, literary, artistic and recreational life of the wider community
7. Promoting awareness of and support for the University within the local Parkville-Carlton community as well as the communities surrounding each of the smaller campuses of the University;
8. Developing an effective, strategic approach to internal communications, public relations and media liaison designed to maximise understanding of and support for the Melbourne Agenda;
9. Ensuring that State and Federal politicians understand the Melbourne Agenda, and remain well informed about the current issues, priorities and problems facing the University;
10. Encouraging the Federal Government to recognise higher education as a major public good, and to accept the importance of strong, consistent policy and funding support for universities as vital if Australia is to keep pace with international competition in the knowledge-based economies of the future;
11. Strengthening links with the University's graduates, particularly through the alumni networks, and ensuring that, wherever possible, they understand and support the Melbourne Agenda;
12. Maintaining the momentum of initiatives in Shepparton and the Goulburn Valley designed to establish a major regional focus for selected University initiatives; and
13. Monitoring and evaluating the effectiveness of all community service functions.

Clearly the outreach and engagement strategies are much broader than the economic, industrial, and commercial.

The university reports that each year it undertakes hundred of projects in collaboration with industry ranging from one day to multiyear programs, from one-off contracts to ongoing strategic alliance agreements—and may involve consulting, testing, fundamental research, applied research, staff interchanges and student placements, clinical trials, software design, extension and education. It adds:

Through these relationships, University staff and students gain valuable access to funding for their projects, access to industry facilities, and experience and engagement in real-world problems. In return, industries gain access to world-class expertise and facilities, insights in breakthrough areas and new technologies, and opportunities to work with some of the University's finest researchers and potential future employees.

Initiatives at the Federal and State levels and the imperatives of the knowledge-based economy give further encouragement to such collaboration between universities and industry, and also between public research agencies, government and the private sector. (University of Melbourne 2004a)

The university is a partner in Bio21, a \$400m development with the Victorian Government, the Walter and Eliza Hall Institute of Medical Research, the Royal Melbourne Hospital and private investors. It is expected that Bio21 will generate 100 new biotechnology companies. The university has also received support under the state's STI Infrastructure Grants Program: under Round 2, seven projects were supported to a level of \$290m to build world-class facilities for strategic innovation initiatives.

The University of Queensland has a mission is to 'create a community dedicated to achieving national and international levels of excellence in teaching, research and scholarship, one that makes significant contributions to the intellectual, cultural, social and economic life of the State of Queensland and the Australian nation'. The university's strategic objectives in relation to 'community partnerships' are reproduced below.

University of Queensland 'Community Partnerships' strategic objectives

Recognising that its activities and resources represent a remarkable State and national resource, the University will:

- develop closer and more numerous links with the wider community of which it is a part
- establish strategic partnerships and identify priorities that mutually serve the interests of the University and its stakeholders
- collaborate in strategic activities for community benefit with industry, business and professional groups and with instrumentalities at city, State, national and international levels
- champion the role of education and research in underpinning the economic health and social well-being of local, state, national and international communities
- provide staff with the opportunity to contribute to the community while achieving educational and personal development outcomes
- build on the University's strengths in the services it is able to offer the community, helping to find and promote innovative and sustainable solutions to community challenges
- maintain the University's role as a provider of specialist services to the community through its libraries, museums, clinics, collections and other specialised scientific, cultural and public performance facilities.

The University of Queensland has obtained \$50m from the Queensland Government, together with resources from the private sector and philanthropic organisations to assist in the construction of research facilities on campus. The Queensland University of Technology (QUT) has also received significant support from the Queensland Government (Queensland, Department of Innovation and Information Economy 2003).

The Australian National University has an Outreach Plan as a component of its Strategic Plan. These are currently being updated. A number of initiatives are underway, involving the construction of joint facilities adjacent to the campus.

Macquarie University has a clearly articulated third mission framework expressed in terms of a Community Outreach Vision to 'engage with the community and to promote open access to high quality scholarship and services'. The university sees its mission in this regard as providing a sustainable and mutually beneficial interface between selected, high-priority constituencies in the Ryde region and at state, national and international levels.

The 'dominant themes' in Macquarie's strategy are identified as: technology transfer and commercialisation, entrepreneurship and management; environment and sustainable development; community health; internationalisation and multiculturalism; English language services; education and lifelong learning; and arts and culture. The university's specific outreach goals are represented below.

Macquarie University Community Outreach Goals

1. To develop and maintain a network of relationships and two-way communication supported by timely and appealing information services.
2. To utilise the professional expertise of staff and apply research and scholarship to help external constituencies in the analysis and handling of commercial, cultural, environmental, ethical, health, social, scientific and technological issues.
3. To promote access to high quality education, contributing to a sense of life-long learning and personal development, and engaging in continuing education for the professions, business, industry and the public sector.
4. To serve as a cultural centre for the University community and the region by supporting the arts.
5. To share spare capacity in the University's physical and intellectual infrastructure and facilities.

Macquarie University has powerful links with local industry and the CSIRO in the north Ryde area of Sydney. Industry linkages have given Macquarie a leading role in the biosciences, particularly biotechnology.

In addition to the R&D links with industry, Macquarie also provides educational resources and community facilities and services to the broader regional community. These include courses, venues, the library, gallery, museums and performing arts as well as a range of recreational and sporting facilities. The Macquarie Graduate School of Management provides conference and hotel facilities for a very wide range of targeted industry programs.

The James Cook University (JCU) of North Queensland, a regional university, provides an example of a regional university committed to the engagement mission:

James Cook University—Priority Objective 3: Engagement

To continue the process of engagement with our region so that the University is increasingly an integral and inseparable element of the economic, cultural and intellectual life of northern Queensland

Strategies

- Promote and support the concept of community engagement amongst JCU staff, fostering a culture in which the JCU community identifies with the engagement objective in practical terms.
- Consult internally and externally on appropriate engagement activities and opportunities
- Develop and enhance relations with external professional and community organisations in all locations.

Desired Outcomes

- Closer two-way interaction, on an individual and an institutional level, with alumni and the community
- Maintenance and development of participation in regional educational, cultural and development activities
- JCU is strategically allied with an increasing number of the businesses and industries of the region
- Recognition of JCU as a key stakeholder in and contributor to regional industrial, economic, social, cultural and environmental dialogues

JCU is currently leading a project to establish better linkages between six research institutes and centres located in the Townsville area.

The University of Western Sydney 'Regional and Community Engagement Plan 2004–2008' has a commitment to 'excellence in community engagement' which is 'grounded in education, scholarship, and research'.

Community engagement at UWS:

- Collaborative research and development programs with local industry
- Development of academic programs in partnership with regional organisations
- Consultancy and problem solving for local communities
- Community involvement in the development of University Policy
- Community Service learning for students
- Development of communication, mutual respect and understanding between the University and its diverse communities
- Social justice programs to address educational under-representation

It has not been possible to undertake a complete review of community outreach and engagement activities across the higher education sector. But from the material surveyed, it is apparent that the engagement is much broader than commercialisation of research outcomes and covers the full spectrum of relationships between science and society.

Attachment 4: Research commercialisation processes across research fields and industries

The purpose of this attachment is to address issues in the study brief concerned with the various paths to commercialisation success and which reflect the application of different commercialisation processes. These processes differ across research fields, industries and industry segments.

The material provided below does not cover all industries or industry segments. However, it serves to illustrate the diversity of commercialisation processes and outcomes.

Plant production and animal production

The public sector has had a major role in financing and undertaking research in Australian primary industries. The Australian Government, through the CSIRO, and state governments, through their departments of agriculture/primary industries and research centres and institutes have played an important role in undertaking and promoting the adoption of research outcomes. The rural research and development corporations and Australian Government support for cooperative research centres have been important vehicles for funding this research.

Over the past decade Australia's rural research and development corporations (RDCs) have shaped the direction and outcomes of national research and development covering wool, dairy, fisheries and aquaculture, beef, lamb and mutton, pig production, forest production, grains, sugar, cotton, grapes and wine, tobacco, more than 40 horticultural industries, natural resources and new and emerging rural industries such as rice, agro forestry, kangaroo meat, venison, emus products, rambutans and longans (Australia, Department of Agriculture, Fisheries and Forestry 2001)

Australian Rural Research and Development Corporations

Australian Pork Limited* (APL) (formerly Pig Research and Development Corporation (PRDC) and Australian Pork Corporation (APC))

Australian Wool Innovation Company* (AWI) (formerly Australian Wool Research and Promotion Organisation (AWRAP))

Cotton Research and Development Corporation (CRDC)

Dairy Research and Development Corporation (DRDC)

Fisheries Research and Development Corporation (FRDC)

Forest and Wood Products Research and Development Corporation (FWPRDC)

Grains Research and Development Corporation (GRDC)

Grape and Wine Research and Development Corporation (GWRDC)

Horticulture Australia Limited* (HA) (formerly Horticultural Research and Development Corporation (HRDC) and Australian Horticultural Corporation (AHC))

Land & Water Australia (the communication name for Land and Water Resources Research and Development Corporation (LWRDC))

Meat & Livestock Australia* (MLA)

Rural Industries Research and Development Corporation (RIRDC)

Sugar Research and Development Corporation (SRDC)

Tobacco Research and Development Corporation (TRDC)

* The asterisks indicate the RDCs that have become industry-owned companies

Collectively, the RDCs form the RDC model, one of the longest standing government commitments to innovation in any Australian industry. It has been argued that, as a consequence of this approach, the Australian rural sector uses processes and technologies that are among the most advanced in the world.

A fundamental feature underlying the RDC model is that it is a partnership between the Australian Government and rural industries to invest in R&D which promotes internationally competitive and sustainable practices and benefits the wider community. One of the original reasons for establishing the RDCs was to encourage industry investment and involvement in agricultural research.

RDCs complement the role of rural research providers such as the CSIRO, cooperative research centres, state and territory agencies and universities, as well as that of the Australian Research Council. Fifteen of the current 71 CRCs undertake research and development in the area of agriculture and rural-based manufacturing. State governments spend around \$250 million per annum on rural R&D. Their research generally focuses on solutions for local or regional production problems and includes extension of relevant information to producers.

The RDC and the CRC framework has provided critical support for primary industries research and development, particularly that undertaken by state governments. As indicated earlier, the main form of research commercialisation has been through:

- adoption of new practices through communication and dissemination strategies
- building industry capability
- education of people who subsequently work in industries.

The CRC–RDC model has enabled the ‘old’ economy industry of agriculture and rural based production to adopt and apply quite sophisticated new technologies in the areas of ICT, biotech and nanotechnology. It reflects an increasing use of science in agricultural production and through the value chain.

Food, beverages, and tobacco

Food processing is one of the largest manufacturing industries in the OECD, including Australia where it makes up 23% of the manufacturing sector. However, the industry is fragmented, and with many firms operating at each level of the supply chain interorganisational cooperation is a challenge. The demand by stores for products in bulk and at a relatively low cost and the high transportation costs pose particular challenges for firms in this sector.

Investment in food processing R&D is low by broad industry standards. However, food processing uses an extensive array of enabling technologies, many of which are associated with industries outside food processing. This is illustrated in Table 21.

Table 21: Activities and knowledge/technology in food processing

Activity	Technology/knowledge area ¹⁵
Selection and preparation of raw materials	Filtering, centrifugal, washing technologies; steaming (thematic treatment) sensorics; molecular biology and micro biology; chemistry and biochemistry
Processing	Process lines (engineering); IT and informatics; logistics; heating and refrigeration technologies; molecular biology and microbiology; bacteriology; chemistry; biochemistry; gastronomic skills
Preservation and storing	Cooling/freezing technology; vacuum; hermetics and modified atmosphere packing; sterilisation; pasteurisation and homogenisation; biological preservation; biotechnology; biochemistry; bacteriology and microbiology; analytical chemistry
Packing, wrapping, and coating	Disposal technology and environmental issues; materials technology; process lines (engineering informatics); design; consumer preferences and marketing; microbiology and bacteriology; biochemistry and analytic chemistry; cooling/freezing technology; vacuum; hermetics and modified atmosphere packing
Hygiene and safety	Microbiology; bacteriology; biochemistry and analytic chemistry
Quality and nutrition	Chemistry; microbiology; additives; texture; sensoric analysis and evaluation
Quality control and documentation	Testing/measurement technology; spectroscopy; sensorics; microbiology and bacteriology; biochemistry and analytic chemistry
Transport and distribution	Logistics; IT and informatics; general transport technology; cooling/freezing technology; microbiology and bacteriology; biochemistry and analytic chemistry
Trading, marketing, sales	Sociology (consumer preferences and trends); economics (price elasticities etc.)

Source: Smith (2000)

These core knowledge areas can be grouped as food science, including food-related chemistry; biology and physics; and food technology, including biotechnology, electronics, instrumentation, and engineering.

Although the food industry has low levels of internal R&D, it can be argued, on the basis of the framework in Table 21 that food processing is probably one of the most knowledge-intensive sectors of the entire economy. This is not unrelated to the fact that many of the food industry sub-sectors are rapidly growing (Smith 2000).

The National Food Industry Strategy has as one of its objectives to increase the level of R&D in food processing. Initiatives have included creation of the centres of excellence for functional foods and for food safety.

¹⁵ It is worth noting that, while the food industry has a reputation for low-technology intensity based on official R&D statistics, the technologies listed in Table 21 have involved substantial R&D effort. However, this effort is 'counted' in other industries. On the basis of the technologies being adopted in the food industry, it could be regarded as being highly technology-intensive.

A key challenge for the food industry, and a driver for research, is logistics management across the value chain. In retail, employees can use information technology (in the form of hand-held units) to improve ordering and even in some stores where customer self-scanning is being introduced.

Manufacturers are more interested in the larger efficiency gains made possible through collaboration, information sharing, and integration with suppliers and transporters outside the store. Computer-assisted ordering (CAO) and vendor-managed inventory (VMI) are examples of such collaboration. However, independent retailers are reluctant to use VMI for fear of transferring control of a critical store system to suppliers.

For manufacturers, outbound scheduling is key: trucks should be full, deliveries on time, and the product should have maximum shelf life when it arrives to the distribution centre and the store. Perishables must move as quickly as possible. On the inbound side, where food is coming from farmers and upstream in the system, preservation is an issue with vast logistical implications.

Organic foods pose the challenge of keeping them separate in the supply chain. Protection from disease, like BSE (mad cow disease), also pose substantial challenges. An emerging effort in the industry is collaborative logistics.

Chemicals and petroleum products

The transformation of the US chemical industry through 1920–1946, establishing the foundations for the petrochemical industry that matured in the post-war era, has been seen to be a result of achievement of the chemical engineering profession. The development of this academic discipline was reflective of the evolving relationships between US universities and industry during the pre-1940 era.

Chemical engineering seeks to fuse an understanding of chemistry with the process technologies necessary to produce petroleum-based products in large volume. The discipline was associated closely with the MIT where teaching and research began during the 1888–1915 period. It built on links between the MIT and industry around research contracts and cooperative education. It also involved academic placements in industry.

Developments in organic chemicals were reinforced by fundamental research in polymer chemistry by German scientists. The Institute of Polymer Research at Brooklyn Polytechnic played a major role in training students who went to work for companies like DuPont. The war effectively reduced patent-based barriers to entry in the chemicals industry.

Other references in relation to chemicals and petroleum products include Arora, Landau and Rosenberg (1999); Mowery and Rosenberg (1999); Murmann (2003).

Pharmaceuticals

The Second World War provoked a transition in the US pharmaceutical industry: companies relied on in-house research and stronger links with universities moving to the forefront in biomedical sciences were developed. During the war the United States Government initiated a 'crash program' to manufacture penicillin: 20 pharmaceutical companies, several universities, and the USDA were involved. Solutions actually came from chemical engineers, working with microbiologists, and represented the first successes of biochemical engineering.

There has been huge public support for biomedical research in the post-war era. Large pharmaceutical companies have experienced substantial growth and large profits with an ability to finance high R&D expenditure. This research funding has also supported the growth of biotechnology and has created new methods for drug discovery.

Start-ups have a prominent role in biotech in applying biotechnology to drug manufacture and involve a complex division of labour: investments by pharmaceutical companies in promising start-ups and joint ventures

and licensing and acquisition by larger firms of small companies. But applications of biotechnology to discovery and development of new drugs have been accomplished more successfully by a small number of established pharmaceutical companies with strong links to the academic research community and the National Institutes of Health (NIH). Several Australian medical research institutes have connections to the NIH.

The majority of US biotechnology start-ups have been tightly linked to university departments. But the strength of the science base was complemented by the mobility characteristics of the scientific labour market which made it relatively straightforward for leading academic scientists to become deeply involved with commercial firms (Henderson, Orsenigo & Pisano 1999). The strength of these factors is seen as more important than the strength of the science base per se.

Venture capital has been important to fuelling the growth of early stage biotechnology-based firms. More important, however, have been collaborations between new firms and established larger firms. But the links between biotechnology spin-outs and big pharmaceutical companies are no longer 'biotech for hire' deals, but are more complex arrangements, with greater sharing of risk and reward. Technology and know-how flows both ways, with the roles being distributed opportunistically between the partners.

The role of government in fostering links between small biotechnology firms and pharmaceutical companies is often regarded as critical. For example, the government of Ireland decided 40 years ago to target software and pharmaceuticals in its strategy to transform its economy. It provided cheap, educated workers and gave tax breaks to big investors. Ireland is now a major drug manufacturing centre. Multinational drug companies account for 20 000 jobs and one-third of exports.

Ireland's approach has been copied in Asia and Eastern Europe. While Ireland's corporate tax rate is 12.5%, Singapore's is zero. Australia's is 30%, with few incentives. Companies in Hungary can deduct 200% of R&D expenses from taxable income. For Ireland to stay in the game, however, it has had to upgrade from basic manufacturing to more sophisticated R&D. The government is hoping to persuade drug makers to choose Ireland to do everything from basic research to manufacture of high end biotech products (Capell 2004).

Ireland offers a wide range of incentives and the strategy appears to be working: in September Pfizer announced a \$294m upgrade to one of its nine Irish plants; J&J subsidiary Centocor plans to build a \$700m biotech facility in Cork to develop drugs for diseases such as arthritis and cancer. In 2003, Glaxco invested \$42m in R&D in Ireland, and in 2005, Wyeth Pharmaceuticals will open a \$2 billion biotech facility (Capell 2004).

It is important to note that most of the value created in the pharmaceutical industry comes from marketing compounds that improve on the effectiveness of an established drug, have fewer or less side effects, or can be used against a broader range of diseases (Booth & Zemmel 2004). Of the 32 blockbuster drugs introduced over the last ten years, only a quarter targeted novel mechanisms of action. Three main points of differentiation were efficacy, safety, the breadth of approved use and convenience.

It is also understood that pharmaceutical companies which license externally generated drug candidates enjoy far greater R&D productivity than those relying solely on internally generated ones (Booth, Lennon & McCafferty 2004). Licensed compounds cost between an average of \$5m to \$9m less to acquire at the pre-clinical stage than do internal candidates; they are twice as successful at clinical trials and achieve similar commercial results.

It follows that strategic alliances are particularly important in the pharmaceutical industry. Of the top 25 drugs on the market today, 12 were discovered or developed by a company other than the one which launched them (Mallik, Zbar & Zemmel 2004). This trend is likely to continue, but as R&D productivity continues to decline smaller companies with attractive products have taken advantage of a sellers market for new compounds.

Businesses that only recently would have been happy to sell marketing rights are now expecting participation in the design of clinical trials and the formulation of marketing campaigns—and a larger share of the profits. Progressively, alliances are becoming more complex and challenging to manage.

These observations have implications for the way in which universities and research organisations pursue drug discovery strategies and address the way in which they form alliances with large pharmaceutical companies. It is clear that venture financing deals are becoming more complex and require a highly knowledgeable and sophisticated venture capital investor. These skills are in short supply in Australia.

Aerospace

It is understood that the mature sectors of the industry value higher education institutions principally for their graduates at all levels. Industry places more value on the researchers than the research itself (National Academy of Engineering 2003). The indirect benefits of academic research are frequently not recognised, despite the contribution to the knowledge base, and ultimately new technologies, for example, microprocessors in avionics, development of composite materials in academia applied in jet engines, rocket motors and other airframe components.

Large aerospace companies no longer have central R&D laboratories: they use contract research capabilities when they are available and they fund universities philanthropically to support centres and institutes for research in specific areas; for example, Rolls Royce university technology research centres (UTCs) at 12 universities in the United Kingdom. They are particularly interested in computational fluid dynamics and research results of the Lean Aerospace Initiative.

Universities contribute substantially to support for research rather than making money from research (National Academy of Engineering 2003). Many academics consider that too much emphasis on industry ties can seriously impede academic progress. Such faculty are often poorly informed about industry needs and are poor role models for students who want to work in industry. To address this, Boeing introduced an academic fellows program that brings 10–15 academics to work in the company during the summer. The objective is to overcome long-standing cultural differences.

Transport, distribution, logistics

With the exception of software companies and some airlines, very few transport and logistics companies undertake R&D. A few of the integrated logistics service providers conduct some internal research and sponsor research at universities. Most innovations in integrated logistics have come from academic research in transportation/logistics research centres affiliated with university engineering and business schools and from applied research and product development by software companies.

Transport and logistics research is multidisciplinary and covers applied mathematics, computer science and engineering, industrial engineering, operations research, software engineering, materials science, social and behavioural sciences and business and management sciences. Business schools tend to focus on management and organisation aspects, while engineering schools tend to focus their research on software.

In the United States transportation research institutes and centres have been established with government support to serve as intermediaries between academia and industry and translate research results to industry. These institutes function primarily as 'conduits' between the academic community and transportation practitioners, adapting technology research results to meet practitioner needs and give them a voice in setting research agendas (National Academy of Engineering 2003). Many centres also run executive courses, symposia and seminars. Conference attendance and presentations are also seen to be important.

The other major avenue for the dissemination of the results of academic research to the transportation and logistics industry is through graduating students entering the workforce who subsequently apply what they have learned at university. Most successful employers acknowledge this vector of knowledge transfer and try to maximise the expertise of new hires by providing opportunities for them to contribute to changes in company practices (National Academy of Engineering 2003).

Information and communication services

In the US much of the government-funded research in ICT has been carried out in universities. Strong research institutions are recognised as being among the most critical success factors in high-tech economic development (National Research Council 2003). In addition to creating ideas, universities often import forefront technologies to their regions and serve as powerful magnets for companies to relocate.

Public policy legitimised computer science as an academic discipline through funding from the Advanced Projects Agency and the National Science Foundation during the 1960s. University-based computer science activities have been important sources of innovations and have spawned new products and firms in the US. University research has also played a role in the growth of the software industry by training skilled personnel whose movement into industrial employment transfers university research findings to industry. In other countries, shortages of skilled personnel have impeded industry development (Mowery 1999).

A US study concludes that the US network systems and communication sector has benefited greatly from a national research culture in which individuals move frequently between academia and industry, thereby increasing their knowledge of both and their contribution to both. In this environment personal relationships are crucial. Moreover, universities are seen to not only invigorate the research culture with fresh students each year, but they also house open research projects that anchor technical disciplines.

These and similar studies (Tornatzky, Waugaman & Gray 2002) point to the diverse relationships between research organisations and business in the ICT sector, and also the relationship between research organisations and small businesses. Technologies are often born in academia, taken up and extended by other academic or industrial groups, and become the seeds of start-up companies or new products in larger companies. All paths to market are erratic and can take up to 15 years. However, the diversity of the academic and industrial sectors is seen to give robustness to the process (National Academy of Engineering 2003). Features of the innovation pathway include:

- Unexpected results are often the most important.
- Research stimulates communication and interaction: ideas flow back and forth between research programs and development efforts and between academia and industry.
- Research trains people, which start companies, or form a pool of trained talent that existing companies can draw on to enter new markets quickly.
- Doing research involves taking risks: not all public research programs have succeeded or led to clear outcomes, even after many years—but the record suggests that public investment in computing and communications has been very productive.

The contributions of universities to industrial innovation in the computer and networked systems industry are represented in Table 22.

Table 22: Strengths of universities in contributing to industry in information and communication services

Human capital	Undergraduates and graduates have become key players as individual researchers, development engineers, technical leaders, and entrepreneurs; research experience in universities is highly valued by businesses—even for non research employees; as faculty and students flow to industry and start-ups, they provide an effective form of technology transfer
Long-term fundamental research	With proper funding, academic research is able to work on long-term problems that may be ignored by industry, or may be an anathema to dominant industry businesses, technologies, regulations or prejudices
Intellectual diversity	Academia provides an open setting that can engage colleagues in various disciplines and industries; the results are reported in the open literature; concurrent research projects and different approaches provide a ‘kind of redundancy’ and expand the community of researchers on promising topics; shared artefacts of experimental research, especially software, are an important way to disseminate research
Collaboration with industry	Direct collaboration between industry and academia, both on specific projects and longer-term relationships, has produced significant contributions to networked systems and communications. There are many collaborative structures, but no dominant or ‘best’ collaborative schemes
Test beds	University laboratories can serve as test beds for new technologies; most of the early participants in ARPAnet were universities which played an important role in testing and refining the technology; the pattern has continued with the Gigabit Testbed, vBNS, and other networks.
Nuclei for start-up companies	University research can lead to technologies and people which become the seeds of new businesses e.g. Google and Yahoo as spin-offs of research at Stanford

Source: National Academy of Engineering (2003)

In electrical engineering and computer science, academic research has built a foundation of techniques and analysis tools widely used as enabling tools by industry. These are not techniques that have spawned businesses, but they have been important to the industry as a whole. The development of object-oriented programming took 30 years, and most of the research was necessarily conducted in universities and research organisations because businesses typically do not invest in risky research that offers only long-term prospects for payoff—and there is no certainty that an investing business will capture the returns.

In Australia, researchers find it more difficult to move freely between academia and industry. Many businesses interviewed for a related study (Howard 2004c) suggested that, if researchers do leave the research environment to work in industry for a period of time, they will be viewed as a renegade, and generally not be welcomed back.

There is a strong view that this attitude is also hindering interactions between academia and industry and the diffusion of innovation. However, when Redfern Broadband Networks (RBN) was spun out of the Photonics Cooperative Research Centre many of the researchers went to the newly created company: when the company closed following the fallout from the technology downturn, researchers were readily re-engaged in the cooperative research centres environment where they are working in new projects.

See also Bresnahan and Malerba (1999) in relation to computers and Mowery (1999) in relation to software.

Financial services

Universities and public research organisations have played an important role in the financial services industry along with financial services companies (individually or in consortia), government regulatory agencies, software developers, hardware manufacturers, spin-off companies, and consulting companies (National Academy of Engineering 2003).

The main contributions of academic research have been grouped as:

- *Conceptual breakthroughs*: in areas such as portfolio theory, linear programming and derivative pricing theory, brand new concepts have laid the foundation for entirely new financial products and services. At least nine Nobel prizes in economics have been awarded to university researchers for major conceptual breakthroughs relevant to financial services (National Academy of Engineering 2003).
- *Financial products and tools*: academic research has formed the basis for specific products in financial engineering and optimisation, such as pricing models and portfolio methods.
- *Consumer research*: academic research has contributed to the understanding of large data sets and financial aspects of consumer behaviour (in parallel to work in marketing and the social sciences).
- *Research on legal, regulatory and institutional issues*: academic research has been instrumental in analysing legal and regulatory constraints on industry and reforming the regulatory environment. Due to the complexity of global markets, such as energy, securities and foreign exchange, regulators and economic policy-makers now depend on models as a basis for making 'objective' decisions in markets that are too diverse, or take too long, to provide feedback.
- *Research on industry infrastructure*: academic research has contributed in areas such as encryption technology and networking, including electronic payment systems, automated teller machines, and electronic commerce.

Commercial and investment banks rely heavily on academic economists who exert a substantial influence in risk management, with their contributions of development techniques and modelling tools, and have insights into the macroeconomic developments that are inputs into the models. The flow of human capital from universities into financial services firms has been crucial to the evolution of the industry. The industry draws on people with skills in mathematics and financial modelling from a variety of disciplines.

Information also flows through publication and networks. Although the academic literature is stimulating for some, it can seem esoteric and confusing to others: it is often incomprehensible to non-academics. But the dissemination of research results is essential for continued innovation. So-called 'quants' in the industry and in government are the most likely to try to keep abreast of academic research by reading journals and attending conferences.¹⁶

Academic research in a number of disciplines will continue to be important for the financial services sector, including engineering, natural sciences, economics, mathematics, social sciences, and public policy. Interdisciplinary concerns cover capital allocation, market dynamics and microstructures, issues associated with globalisation (regulation, capital flight, tax havens, money laundering), issues associated with privacy, trust, security, and contract law, risk and ethics.

Connecting the academic research base with the industry remains an ongoing challenge, as well as a potentially important opportunity.

16 The same considerations apply in the relationship between management research and management practice.

Medical devices and instrumentation

Medical devices cover a broad group of products, ranging from the low-tech, such as disposable needles, to sophisticated devices, such as implanted therapeutic devices and diagnostic machines. Basic advances in physics, materials sciences, optics, analytical methods and computer science have resulted in many new device capabilities. Bioengineering research has emerged as a separate discipline.

Much of the research is carried out in cross-disciplinary research centres. In Australia, the Queensland Government, the Universities of Queensland and the Queensland University of Technology and Atlantic Philanthropies have established two research centres which will focus on innovation in medical and health services: the Institute of Health and Biomedical Innovation and the Institute of Bioengineering and Nanotechnology.

Medical device innovation is inherently interdisciplinary. Advances in engineering and the physical sciences need to be integrated with those in medicine. It has been argued that the commercialisation processes rely on creation of IP as a platform for the manufacture and sale of devices and services to industry.

Academic medical centres and the public support of biomedical research provide a critical infrastructure for medical device innovation in this respect. Departments in academic medical centres are built around medical specialities. The emergence of medical specialities has, in turn, been closely connected to the invention and employment of new medical devices.

The invention of the X-ray machine, for example, spawned the speciality of radiology ... But of course this formulation is excessively static, because the considerable expertise of medical specialists, particularly those in academic medicine, has also become an essential input in the development of new or improved instruments. These specialists conduct basic biomedical research, mostly in the test tube or animal models, and study the basic mechanisms of physiological processes and disease in humans.
(Gelijns & Rosenberg 1999)

Medical specialists are also heavily involved in the development of prototype medical devices and are indispensable in testing the benefits and risks of new devices for a particular clinical indication. Moreover, they have been the driving force in expanding the indications of use for particular medical devices. Consequently, close relationships with both universities and academic medical centres are critical to the successful performance of medical device firms.

The venture capital industry has been pivotal to the development of the devices industry in the US, largely because the development and commercialisation of medical devices can take a great deal of time, and few inventors can survive with debt financing alone. Universities are also unwilling to take risks in development and commit to debt financing. Medical devices therefore account for a substantial proportion of venture capital investments.

The main contributions of academic research in medical devices are in:

- education and training of skilled people in research techniques, particularly in an interdisciplinary framework of engineering, biology and medicine
- research in the physical sciences and engineering: medical devices have exploited technological capabilities and components developed by universities, the military, the electronics industry and firms that manufacture specialised materials such as high-quality glass for fibre optics and special materials for prosthetic devices
- academic medical centres that undertake research and generate knowledge in relation to human physiology and pathophysiology, new product ideas, device prototypes, clinical testing and discovering new indications of use.

The contribution of universities goes well beyond educating new generations of employees and making fundamental advances in scientific and technical knowledge which may contribute to the development of new devices. It includes a high degree of involvement in product development, evaluation and introduction and product modification. This provides a 'model' of technology transfer not found to the same degree in other industries.

Various schools and disciplines in universities contribute to the development of medical devices. But establishing interdisciplinary links in the university between faculty in the natural sciences and engineering with faculty in medicine has been very difficult. With the emergence of new fields such as tissue engineering and encouraged by interdisciplinary research funding, creating interdisciplinary links may be easier.

The Australian company, Proteome Systems, has been documented several times as a case study (West & Ashiya 2003; Williams 2004).

Attachment 5: Publicly funded research: key statistics

Public funding for university research

Australian Bureau of Statistics data indicate that, in 2002, universities undertook just over \$1 billion in publicly funded research. Of this, \$507.3m, or half was sourced from Australian Government competitive grants and \$397.1 was sourced from other Australian Government grants. Australian Government publicly funded research accounts for 26% of total research funding. The distribution of funding according to the research fields, course and disciplines (RFCD) classification is set out in Table 23.

Table 23: Publicly funded research and development undertaken in universities classified by RFCD and by sources of funds for expenditure, 2002 (\$'000)

Research fields, courses and disciplines (RFCD) classification	Common-wealth competitive schemes	Other Common-wealth	State and local	Total publicly funded research	Total research funding	% public funding
Mathematical sciences	10 169	5 464	1 127	16 760	64 002	26.2
Physical sciences	22 674	20 684	2 073	45 431	129 350	35.1
Chemical sciences	24 086	20 219	1 202	45 507	155 227	29.3
Earth sciences	22 835	15 490	2 329	40 654	114 108	35.6
Biological sciences	79 631	59 848	8 751	148 230	410 155	36.1
Information, computing & communication sciences	15 299	13 237	3 626	32 162	144 133	22.3
Engineering and technology	49 803	35 733	8 935	94 471	374 546	25.2
Agricultural, veterinary and environmental sciences	51 000	34 646	13 732	99 378	235 190	42.3
Medical and health sciences	156 887	78 275	39 475	274 637	863 816	31.8
Education	9 552	17 827	6 660	34 039	128 358	26.5
Economics	7 207	13 277	1 782	22 266	83 788	26.6
Commerce, management, tourism and services	6 448	8 347	1 866	16 661	137 227	12.1
Studies in human society	10 169	17 245	3 852	31 266	111 448	28.1
Behavioural and cognitive sciences	13 883	15 092	4 230	33 205	113 275	29.3
Other research fields	27 674	41 786	4 853	74 313	364 975	20.4
TOTAL	507 317	397 169	104 494	1 008 980	3 428 597	29.4

Source: Australian Bureau of Statistics (2004b)

The data indicate that by far the largest component of publicly funded research in universities is for medical and health services. The second largest category is for biological sciences, followed by agricultural, veterinary and environmental sciences and engineering and technology. Together, the physical, chemical, and earth sciences receive \$131.5m. The services categories of education, economics, commerce, management and tourism receive a total of \$73m.

Given the commitment to research in the biological sciences and health and medical sciences, it is probably not surprising that there is a strong public policy focus on the biomedical model of technology transfer as the main

form of research commercialisation. But this model is not necessarily appropriate for other areas of research commercialisation. Taken together, research in the biological sciences and medical and health sciences still only accounts for a total of 41% of publicly funded research.

Public funding for research in other disciplines is more evenly spread. In many of these areas, the most appropriate paths to commercialisation of research outcomes could be technology diffusion or technology relationships. This applies to research relating to commodity-based industries (technology diffusion model) and to manufacturing (technology relationship model).

Business enterprises are major supporters of research in medical and health sciences, although they also contribute significantly, on a proportionate basis to engineering and technology. Universities are also heavily committed to medical research from their own resources. Overall, one-quarter of university research is allocated to medical research. This is indicated in Table 24.

Table 24: Publicly funded R&D undertaken in universities by sources of funds for expenditure RFCD classification, distribution between major categories, 2002 (%)

Research fields, courses and disciplines (RFCD) classification	Business enterprises	General university funds (GUF)	Total other sources	Total
Biological sciences	12.7	10.9	10.8	12.0
Engineering and technology	17.3	11.1	11.6	10.9
Agricultural, veterinary and environmental sciences	9.7	5.2	5.6	6.9
Medical and health sciences	33.1	20.9	24.3	25.2
Other research fields	36.9	51.9	47.7	45.0
TOTAL	100.0	100.0	100.0	100.0

Source: Australian Bureau of Statistics (2004b)

Over the four-year period from 1998 to 2002, ABS data indicate that there has been an almost 50% increase in publicly funded research. Australian Government competitive grants have increased by 22.2% and other Australian Government programs have more than doubled. State and local government funding has also increased by over half. These trends are shown in Table 25.

Table 25: Publicly funded R&D undertaken in universities by sources of funds for expenditure, RFCD classification, change 1998–2002 (%)

Research fields, courses and disciplines (RFCD) classification	Australian Government competitive schemes	Other Australian government	State and local government	Total publicly funded research
Mathematical sciences	0.9	49.5	31.2	14.8
Physical sciences	47.5	157.9	507.9	91.4
Chemical sciences	8.4	63.7	-0.9	27.2
Earth sciences	28.6	24.2	-14.8	23.3
Biological sciences	23.0	159.9	54.1	58.6
Information, computing and communication sciences	-10.8	-10.7	37.6	-7.1
Engineering and technology	-1.7	44.1	8.5	12.9
Agricultural, veterinary and environmental sciences	16.6	94.7	104.6	45.6
Medical and health sciences	44.8	157.5	50.9	66.6
Social sciences and humanities	15.2	159.3	61.0	71.7
TOTAL	22.2	107.8	51.4	49.4

Source: Australian Bureau of Statistics (2004b)

The data indicate the magnitude of the increase in funding for biological and health and medical research, which is consistent with the Wills Review recommendations (Australia, Health and Medical Strategic Review 1999) and government priorities in this area. The data also indicate substantial increases in funding for the physical sciences, the agricultural, the veterinary and environmental sciences, and the social sciences and humanities. Support for engineering and technology has increased at a substantially lower rate than the overall increase in research funding.

The decline in support for information, computing and communication reflects the impact of the technology downturn in 2000. The decline in public R&D is now being addressed through initiatives such as the National ICT Centre of Excellence.

Although there is a high level of publicly funded support for the biological, medical and health sciences, which have a predominant path to market through patents, licensing and spin-outs, the significance of public support for the agricultural and veterinary sciences should not be overlooked. Commercialisation in this area is promoted by dissemination and support for adoption.

The commercialisation path for public support for the natural sciences may be more complex, as the research output from these disciplines might be reflected in general dissemination through publication and the work of cross-disciplinary research centres providing consultancy and advisory services.

The distribution of publicly funded research by socioeconomic category points to a high concentration of support in primary industries and the environment. This is indicated in Table 26.

The high proportion of public funding allocated to primary industries research reflects the distribution of primary industry levies for research to universities. Business funding for research is significant in mineral resources, energy, and manufacturing.

Public funding for government research organisations and agencies

Australian Bureau of Statistics data indicate that the Australian Government allocated \$1.2 billion for expenditure on research through its own research organisations and agencies. State and local government agencies allocated \$594.2m. The composition of this expenditure is detailed in Table 27. Also included is expenditure on research paid for by other governments.

For the Australian Government, the data reflect comparatively high levels of expenditure in areas where the government-funded research agencies focus. They reflect a high level of commitment to earth sciences, ICT, engineering and technology, and agricultural and environmental sciences.

The priority attached by state governments to agricultural research, through their agricultural research institutes is also apparent. The distribution of expenditure among RFCD classifications is illustrated in Table 28.

On the basis of ABS data, the proportion of public funds expended on research in public research agencies amounts to 80.3%. On the basis of the socio-economic classification, this proportion ranges from 99.3% for Defence (mainly the DSTO) to 62.2% for plant production and plant primary products (where the joint business government contribution is 19.7% reflecting the levy system for rural research and development).

The distribution is illustrated in Table 29.

Table 26: Publicly funded R&D undertaken in universities by sources of funds for expenditure, socioeconomic classification: distribution between sources of funds, 2002 (%)

Socioeconomic objective	Total publicly funded	Non Australian Government competitive	Business enterprises	General university funds (GUF)	Other	Over-seas
Defence	36.6	0.4	5.8	52.9	1.0	3.7
Economic development						
Plant production and plant primary Products	45.8	0.3	6.9	42.3	3.4	1.3
Animal production and animal primary products	46.7	0.8	6.2	41.1	3.3	1.9
Mineral resources (excluding energy)	24.8	0.0	12.5	53.9	6.8	2.1
Energy resources	22.7	0.5	8.0	53.0	12.7	3.1
Energy supply	23.2	0.0	9.4	62.1	2.3	3.0
Manufacturing	29.5	0.6	9.4	53.9	3.1	3.5
Construction	22.0	0.1	5.7	70.4	1.3	0.5
Transport	28.3	0.0	7.6	48.8	13.8	1.4
Information and communication services	24.2	0.1	3.8	66.8	3.4	2.1
Commercial services and tourism	15.1	0.1	3.7	79.5	0.8	0.8
Economic framework	18.2	0.1	3.6	76.0	0.9	1.2
Total economic development	28.0	0.3	6.6	59.7	3.5	2.0
Society						
Health	26.4	0.8	6.1	49.7	3.2	7.3
Education and training	26.6	0.1	4.1	66.5	1.8	0.9
Social development and community services	23.1	0.1	1.8	72.4	1.0	1.6
Total society	29.7	0.5	4.9	57.0	2.5	5.3
Environment						
Environmental policy frameworks and other aspects	31.1	0.3	5.0	60.1	1.2	2.4
Environmental management	37.1	0.3	7.5	51.4	2.0	1.7
Total environment	28.6	0.3	7.1	52.7	1.9	1.8
Non-oriented research	36.2	0.2	2.8	65.4	1.4	1.7
TOTAL	29.4	0.4	5.1	59.3	2.5	3.3

Source: Australian Bureau of Statistics (2004b)

Table 27: Expenditure on R&D in government agencies by RFCD classification and source of funds for expenditure, 2002–03 (\$'000)

Research fields, courses and disciplines (RFCD) classification	Australian Government own funds	State and local government own funds	Australian Government – other government	State and local – other government
Mathematical sciences	22 051	6 592	1 805	1 357
Physical sciences	102 282	138	4 340	2 932
Chemical sciences	85 992	11 283	2 032	2 706
Earth sciences	163 449	33 239	11 619	6 474
Biological sciences	108 695	65 032	17 541	11 209
Information, computing and communication sciences	154 612	14 354	1 640	2 667
Engineering and technology	329 516	20 892	4 930	8 120
Agricultural, veterinary and environmental sciences	148 871	346 460	23 348	22 050
Medical and health sciences	19 914	55 768	36 988	14 681
Economics	42 159	5 939	3 559	488
Law, justice and law enforcement	4 786	8 113	1 275	1 284
Other research fields	23 935	26 435	2 920	1 684
TOTAL	1 206 261	594 245	116 997	75 650

Source: Australian Bureau of Statistics (2004a)

Table 28: Expenditure on R&D in government agencies by RFCD classification and source of funds for expenditure, 2002–03 (%)

Research fields, courses and disciplines (RFCD) classification	Australian Government own funds	State and local government own funds	Commonwealth – other government funds	State and local – other government funds
Mathematical sciences	1.8	1.1	1.5	1.8
Physical sciences	8.5	0.0	3.7	3.9
Chemical sciences	7.1	1.9	1.7	3.6
Earth sciences	13.6	5.6	9.9	8.6
Biological sciences	9.0	10.9	15.0	14.8
Information, computing and communication sciences	12.8	2.4	1.4	3.5
Engineering and technology	27.3	3.5	4.2	10.7
Agricultural, veterinary and environmental sciences	12.3	58.3	20.0	29.1
Medical and health sciences	1.7	9.4	31.6	19.4
Economics	3.5	1.0	3.0	0.6
Law, justice and law enforcement	0.4	1.4	1.1	1.7
Other research fields	2.0	4.4	2.5	2.2
TOTAL	100.0	100.0	100.0	100.0

Source: Australian Bureau of Statistics (2004a)

Table 29: Expenditure on R&D in government agencies by socioeconomic objective classification and source of funds for expenditure, 2002–03 (%)

Socioeconomic objective	Total public	Business	Joint government business	Universities	Other Australian sources	Overseas sources
Defence	99.3	0.1			0.6	0.0
Economic development						
Plant production and plant primary products	62.2	3.4	19.7	0.0	13.7	1.0
Animal production and animal primary products	76.8	4.2	13.5	0.1	5.0	0.5
Mineral resources (excluding energy)	78.5	11.1		0.1	6.4	3.9
Energy resources	79.3	7.5			7.2	6.0
Energy supply	78.0	13.7			5.7	2.6
Manufacturing	78.9	11.4	0.4	0.3	6.0	2.9
Construction	79.7	10.0	0.1	0.0	7.3	2.9
Transport	95.1	2.8			1.3	0.7
Information and communication services	85.4	5.3		0.0	4.5	4.8
Commercial services and tourism	89.2	3.0	4.9	0.2	1.6	1.1
Economic framework	96.0	1.4	1.8	0.0	0.1	0.6
Total economic development	76.1	6.0	8.7	0.1	7.3	1.9
Society						
Health	64.8	14.5	0.9	2.2	11.8	5.8
Education and training	96.8	1.0	0.5	0.4	1.0	0.4
Social development and community services	91.8	2.2	1.0	0.3	4.2	0.6
Total society	71.5	11.5	0.9	1.7	9.9	4.5
Environment						
Environmental policy frameworks and other aspects	90.1	2.7	2.2	0.2	4.0	0.8
Environmental management	84.8	2.5	4.4	0.1	6.7	1.4
Total environment	85.2	2.5	4.3	0.1	6.5	1.3
Non-oriented research	87.1	1.7	3.9	0.1	2.3	4.9
TOTAL	80.3	5.2	5.7	0.3	6.6	1.9

Source: Australian Bureau of Statistics (2004a)

The distribution of sources of funds for health research points to a relatively high business component, and the influence of donations and bequests for this form of research.

Over the period 1998–99 to 2002–03, Australian Government funding in its public research agencies increased by 30.9% (compared with a state government increase of 1.4%). The largest increases in Australian Government commitment were in ICT, the natural sciences, medical and health sciences and in the social sciences and humanities. These trends are shown in Table 30.

Table 30: Expenditure on R&D in government agencies by RFCD classification and source of funds for expenditure, change 1998–99 to 2002–03 (%)

Research Fields, Courses and Disciplines (RFCD) Classification	Australian Government own funds	State and local government own funds	Australian Government - other government funds	State and local - other government funds
Mathematical sciences	40.5	348.4	259.6	79.5
Physical sciences	35.8	-97.2	355.9	-32.5
Chemical sciences	29.6	367.0	-30.3	99.7
Earth sciences	25.4	6.3	-32.5	-23.5
Biological sciences	2.8	-18.3	-21.9	92.3
Information, computing and communication sciences	75.5	44.7	-72.0	41.9
Engineering and technology	27.1	432.4	133.2	60.5
Agricultural, veterinary and environmental sciences	19.8	5.0	-49.7	19.7
Medical and health sciences	30.7	-28.7	1,104.8	75.1
Social sciences and humanities	63.7	147.9	-10.9	22.1
TOTAL	30.9	1.4	-21.4	54.5

Source: Australian Bureau of Statistics (2004a)

These data suggest that discussion of research commercialisation should look beyond the natural and life sciences and engineering to initiatives and performance in the social sciences and humanities.

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