Triple Helix 5

The Capitalization of Knowledge

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The Emerging Business of Knowledge Transfer:

From Diffusion to Engagement in the Delivery of Economic Outcomes from Publicly Funded Research[1]

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Abstract

The role and significance of higher education and publicly funded research institutions in the knowledge economy is well appreciated. Their role has often been interpreted in terms of knowledge production, with institutions sometimes perceived as 'knowledge factories' creating and selling intellectual products. This role is captured in the concept of 'research commercialisation'. The paper argues for a broader approach to addressing knowledge transfer built around concepts of communicative interaction. It suggests that transfer processes also need to comprehend diffusion, relationship and engagement processes. Finally the paper suggests that the role of higher education and public research organisations might be more appropriately comprehended in terms of their role as service organisations – where the value of their output is in the service provided rather than in the intellectual products themselves. This has implications for the way in which economic performance is measured and assessed.

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1 Introduction

A feature of the triple helix model of industry-university-government relations is an assumed institutional convergence between universities, business and government agencies. Such models tend to overlook the important changes that are going on within those institutions that are not impacted by cross-institutional relationships. They also gloss over fundamental differences in, and influences of, the cultures, structures and routines that occur in each institutional category that impact on either the creation of knowledge and/or its application. To address these influences it is not only important to understand the features of the structures, cultures and routines *within* each institutional setting but also the institutional characteristics of the modes of interaction that form the basis of engagement *between* institutions.

The ways in which universities and publicly funded research organisations benefit the economy and society is contemporary and significant 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.

Approaches to measuring the contribution of knowledge to economic performance have typically focussed on the level and extent of commodity knowledge. Measures such as numbers of publications and patents issued have featured strongly in national and international comparisons. An input measure, such as expenditure on research and development, which reflects the investment in knowledge production, also receives prominence.

There is now a growing awareness that research commercialisation is only one of a number of ways that knowledge is transferred from a research environment into industrial application and use—and the subsequent creation of wealth.

This paper sets out to explore and categorise the ways in which universities and research organisations generate useful economic benefits. It proposes a framework for identifying, tracking and understanding the economic impact 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 via which universities and research organisations generate economic benefits.

The paper argues that the ‘standard’ research commercialisation model associated with a linear sequence linking expenditure on basic research to commercial outcomes is largely specific to the bio-medical sciences. Like the ‘linear model’ of 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 bio-medical 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 via 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, potentially distorting policies and practice, including misallocation of resources across the spectrum of research-industry interaction.

The paper 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 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.*

Recognition of the different knowledge transfer processes creates the conditions for richer and more powerful understanding of the 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 a broader understanding of diffusion, relational and engagement processes.

2 Context

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 capabilities 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 (Moras-Gallart, Salter, *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.

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, *et al.* 1998).

There is a substantial literature that 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 that can be defined, valued and exchanged in market-based transactions (Burton Jones 1999; Etzkowitz, Webster, *et al.* 1998). Just as the definition of private property rights in agricultural land increased the value of agricultural production in the 18th century, the definition of property rights in knowledge should be able to facilitate its contribution to wealth. The statutory and regulatory framework of intellectual property law is, at least in the first instance, intended to define and clarify ownership rights in ways that will facilitate the dissemination of knowledge and bringing 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 *propertisation* of knowledge.

Knowledge propertisation and rights of access

Propertisation 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 propertisation 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 firm level perspectives on knowledge products

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 appropriable *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).

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 Australian agriculture and mining sectors. Public policy support for the formation of 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 is 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 that is 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 and the delivery of *services* based on the application of knowledge generated through research.

While businesses (and individuals) tend to be interested in knowledge products that are 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—that will 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 discipline and across industries. This paper 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 that 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.

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 how it is applied and used. 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 2003).

Businesses argue that research providers need to understand more about the way in which 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 the services they provide (research contracts, expert advice 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.

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. But, the capacity to generate revenue relies less on selling intellectual products and more on building relationships with partners and the wider community based on value and service quality. This is the essence of engagement.

As resource pressures become more acute, and expectations from non-government funding grow, all forms of knowledge transfer arrangements will become increasingly important to university strategies. It is becoming clear that success in a full range of commercial relationships and 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 business-like 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 that are relevant to the task.

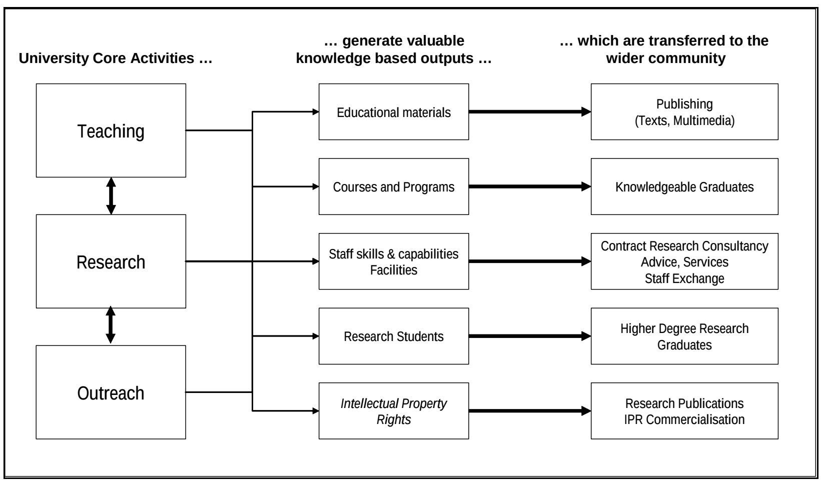
Commercial management extends beyond the traditional focus of technology transfer offices which have tended to concentrate on contract administration and the legal and compliance aspects of protecting intellectual rights. Commercial management involves assessing the opportunities, the commercial returns, and the risks of alliances, partnership and joint venture projects. *It involves negotiating deals.* In some universities 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. In Australia, the commercialisation of Proteome Systems and Radiata provide contemporary examples where the host University missed opportunities for significant revenue streams (Matthews and Frater 2003; West 2003)

3 A framework for knowledge transfer processes

Overview

A framework for representing the processes for knowledge transfer is represented in below.



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 available for commercial use. However, what is of interest in this research are the *processes* by which knowledge is transferred, and subsequently adopted, applied and used in ways that create wealth.

The processes under which knowledge is transferred can be described generically as knowledge diffusion, knowledge production, 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). Their characteristics of each are summarised in the Table 1.

Table 1: Process Models f knowledge transfer and commercial relationships

	Knowledge Diffusion	Knowledge Production	Knowledge Relationships	Knowledge Engagement
Mode of Communication Discourse	*Tell* target users about the benefits of adoption	*Sell* 'knowledge products' to users as tights 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	
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—eg 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 multidiscipli-nary	Strong industry and government involvement
Commercialisation objective	Focus is on adoption. Cover costs through industry contributions	Make money from sale of 'knowledge products'—patents, multi-media, 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. A 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 competitive-ness	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 *and read* 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 *industry* 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 *businesses and public programs*	Evidence of engaged research organisations. Regional economic indicators—jobs, sales, exports, etc
Third Mission Interpretation	Out-reach, 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 role and importance of the various categories of knowledge products and service in the knowledge transfer processes identified is represented in Table 2 below. The representation is indicative and intended only to provide a point of reference—and accentuate the properties of the different research commercialisation processes.

Table 2: Research processes and knowledge products

Knowledge product category	Knowledge transfer 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 commer-cialisation 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 below.

Knowledge diffusion processes

Knowledge *diffusion* refers to the creation of *awareness* and interest about 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 provides 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, in effect, useless without users who would 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. These observations create a link with the engagement processes for knowledge transfer discussed below.

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. Mowery and Nelson have 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, Nelson, *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. Australian 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 and Prusak 2001).

Research in the US 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 inter-organisational linkages. This investment in social capital is viewed as a major driver of US industrial resurgence (Fountain 1998; Howard and Matthews 1999). It is also recognised that trust and the formation of trust-based relationships are often the basis of knowledge transfer and sustainable business relationships (Maister, Green, *et al.* 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.

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 has 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.

Economists have sought to explain the economic and industrial impacts of cluster development (Enright, Hagstrom, *et al.* 1999; Porter 1998, 1999) and the implications for government policy and business strategy. The experience of Silicon Valley has been written up extensively as a model for 'cluster' based economic development (Saxenian 1996). 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 and 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 to promote and facilitate 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, *et al.* 1997), universities and research organisations (Walshok 1995; Walshok, Furtek, *et al.* 2002), government (Great Britain. 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 association have started to emerge around the rapidly growing technology sectors of information technology, biotechnology, environment and medical devices.[2]

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. Whilst 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.

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 health[3]
- *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 in terms of contributions to economic, industrial and firm level performance.

Knowledge production: the standard model of research commercialisation

A ‘standard model’ of a research commercialisation process is reflected in much of the public policy discourse on science and innovation. It is widely 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.

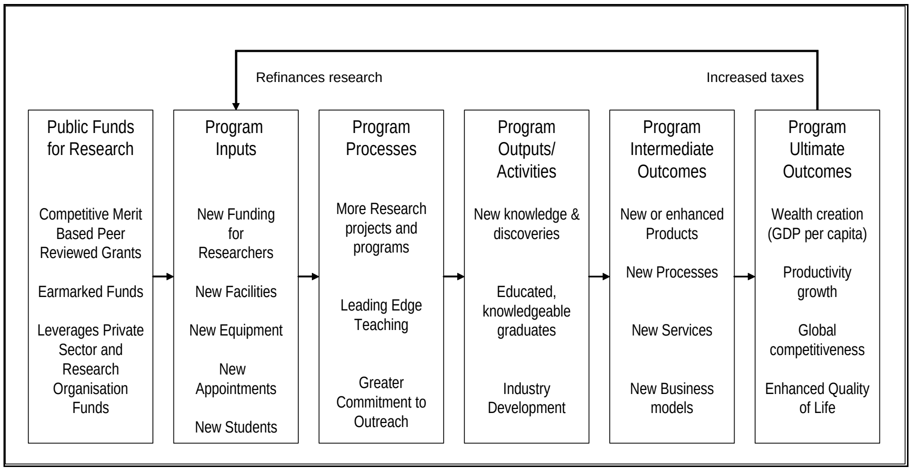
Context: The standard model as a ‘virtuous cycle’

Public funding for research is generally seen to increase the creation of new knowledge. In the context of the research university, research funding is linked with education and research

[2] In Australia, 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.
[3] Hazard Analysis and Critical Control Point procedures are now widely adopted in the food processing industry.

training. Public funding is also intended to leverage other funds within universities, from the private sector and philanthropic sources, and from State Governments—generally on some form of matching basis.

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 below.



Through this process, publicly funded research assists universities acquire the resources (people, facilities, knowledge) necessary to enter new scientific and technological areas, and catalyse new forms of relationship with the private sector. Through the marketing and sales of new products and services that result, 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 specifically 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.

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 securing 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 in the standard model of research commercialisation.

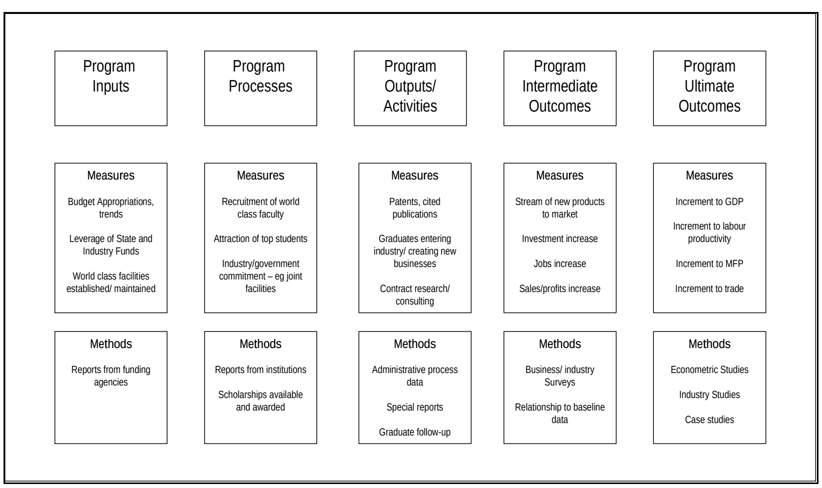
Measures of knowledge production performance

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.

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 below.



Inputs refer to the resources being allocated and available for research. They cover: funding, taxation deductions and concessions, and investments in physical capital measures (facilities and equipment acquired), human capital measures (research personnel recruited and appointed), social capital measures (teams, collaborations and networks established) and structural capital measures (management capacities, capabilities and performance). Input measures are relatively easy to collect and report. They reflect the investment commitment to research.

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. Notwithstanding the importance of inputs, and the attention that is focussed on funding for research, quite diverse economic, industrial and business outcomes are associated with similar level of investment. The way in which resources are combined in the form of *processes* and the efficiency and effectiveness of those processes is being recognised as a major factor in investment impact.

Process measures assess the way that knowledge creation is approached, organised and managed to create the outputs at given levels of resources. Cost and cycle time are typically process measures. Measures can be a direct by-product of the 'production' process, but do not measure the attributes of the final product *per se*.

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

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

A matrix of output measures is provided in Table 3 below. The material included as descriptors is indicative only.

Table 3: Output measures in knowledge production

Typical Measure	Quantity	Timeliness	Quality	End user 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 or impact measures in relation to knowledge production are generally taken to include the following: new/improved products, processes and services, new business creation and growth in established businesses, increases in employment, increased sales, spill-over effects to other businesses.

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 based on a production function approach. Research organisations and institutes are able to establish and demonstrate impressive economic benefits flowing from publicly funded research. National econometric growth models have been used widely in an endeavour to demonstrate the economic benefits of public funding channelled through cooperative research centres (Howard 2003).

Case study methods are also widely used to demonstrate benefits of publicly funded research. There have been numerous case studies of a relatively small number of businesses that 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 publications
- Technology licenses, patents, invention disclosures
- 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.

Limitations of the standard model

The general applicability of the standard knowledge production model of knowledge transfer is seen by many to be have been overstated (Lester 2003; Mowery, Nelson, *et al.* 2004). The following observations have been made:

- 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 percent 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 research for this project and in previous research for the Australian Research Council (Howard, Johnston, *et al.* 2001) and the Department of Communications, Information Technology and the Arts (Howard 2004b).

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. These companies, which grow sales and invest their retained earnings, become sustainable over time, 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 bio-medical 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 US 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, Nelson, *et al.* 2004).

Knowledge relationships: collaborative processes

An important aspect of research commercialisation occurs through the formation of 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, Limoges, *et al.* 1994) in a rapidly growing knowledge intensive services sector.

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 highly interactive between 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.

In a report for the Australian Research Council, *Mapping the Nature and Extent of Business-University Interactions in Australia* (Howard and Matthews 2001) several categories of business-university relationship were identified. These covered:

- *Gifts and bequests*—donations from alumni and businesses relating to objectives of philanthropy and corporate social responsibility
- *Corporate sponsorship*—such as 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 that support 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.

The growing importance of contract research, teaching and consultancy

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 reinsurance 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)

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, and the academy
- 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 usually 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 by reconciling the basis of public funding that supports disciplinary research through the peer review system (research excellence) and the need for research centres to undertake interdisciplinary applicable research that is relevant to business and industry (research relevance).

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 that is 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 through curiosity about the logic and complexity of nature. Sometimes this results in new disciplines that gain academic respectability, such as biotechnology.

Jointly owned and funded industrial research centres have been developed to facilitate ways that 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, 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 that hopefully lead to economic development in their own states and the global economy (Tash 2002).

Industry supported research institutes and centres sit at the interface between discipline-based faculties and business. In reality, many staff are part-time or seconded from their host organisations. Quite often, career academics have little interest in working long term 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 and Stamps 1997; Savage 1996). The image of virtual centres allows academics to provide fractional commitments and without the discipline of strategic direction and management oversight. However, virtual centres are at great risk if only for the reason that virtuality often defies the basic and fundamental principles of leadership and management.[4]

Australian 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.

Issues to address

Collaboration, creativity and innovation are stimulated when people work in very close proximity. This builds the social capital that is essential in building distinctive capability (Cohen and Prusak 2001; Fountain 1998).

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.

Protection and management of intellectual property has also emerged as an issue in research centres. 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, Nelson, *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, Nelson, *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.

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

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[4] 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, Peter F. 1999. *Management Challenges for the 21st Century*. New York: Harper Collins.

use knowledge and other university capabilities outside academic environments; they are concerned with interactions between universities and the rest of society (Molas-Gallart, Salter, *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 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 that 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.

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 taking a close interest and involvement 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 and international focus whilst 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* that work at the interface not only between scientific disciplines but also between universities and society. Building these institutions is a non-trivial issue (Howard 2004a; Johnston and 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, Salter, *et al.* 2002). However, third mission activities extend beyond research and its commercialisation to all forms of engagement that 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, Salter, *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'.

In Australia, over the last 10 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 that advocated a closer relationship between the organisation and universities, including construction of facilities on university campuses (Australia. Department of Education 2004).

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 2004) and the Smart State Research Facilities Fund (SSRFF) strategy in Queensland (Queensland. Department of Innovation and Information Economy 2004).

Third mission and knowledge-based economic development

Over the last 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 growing 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 willingness to commit to sizable 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 Australia with the Queensland, Victorian, and the ACT governments having 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 over the last several years from a real estate focus (technology parks to develop surplus land) toward an integrated set of technology infrastructure investments, including incubators, accelerators and research parks. Funding has moved from single tenant arrangements to facilities that support multiple tenants and to reflect the needs of many technology firms that have an interest in developing a product, not owning a building (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 involve innovative structured finance arrangements with investment banks. These property and facilities management strategies that build bridges between research, teaching, and business are becoming more central to the delivery of universities' core missions.

Conclusion

Just as manufacturing business have been shifting their emphasis from products to services, there is a discernable trend in the maturing of understanding of the knowledge economy that involves less of an emphasis on the sale of intellectual products to one that the recognises the value of the services relating to the knowledge embedded in those products. It has become well accepted that a patent, or other form of intellectual property, has little or no economic value unless it is put to use in the form of a business model. Intellectual property lawyers and accountants have been grappling with the issue of how to value unused intellectual property.

This trend follows what has been occurring more generally in the services sector. Global management consulting firms have worked out that there their intellectual property has little value unless it is applied in the service of clients by their people – who possess the experiential background and tacit knowledge that gives life to the explicit knowledge that is reflected in methodologies, documents and reports. Thus McKinsey, Booze.Allen, Accenture, Boston Consulting, AT Kearney and others widely distribute articles, papers and monographs that contain a high level of intellectual property. This material is a way of marketing and establishing competitive advantage by creating a reputation for capability through what has become known as 'thought leadership'.

Similarly, universities and research organisations need to think about building their reputations and networks as sources of knowledge that can be transferred into industrial and commercial application. It is not only a matter of demonstrating that these institutions possess knowledge, but they are also capable of assisting in its application, adoption and use through value added service work. In many respects, it is a way of bringing together what Ernest Boyer defined as the four domains of scholarship – the scholarship of discovery, the scholarship of integration, the scholarship of application and the scholarship of teaching (Boyer 1990; Braxton, Luckey, *et al.* 2002). This common thread in all of these domains is communication – and the way in which communication is received, interpreted, acted upon, and results in change.

4 From public research to economic benefits—a framework of measures and metrics

The first sections of this paper provide a framework for identifying and defining economic benefits. In this Section attention is given to the way in which economic benefits can be identified, measured and assessed.

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 relating to profitability, viability and sustainability
- At 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 canvassed 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-rivalness. 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 above, 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 that nurture innovation, and provide incentives for individuals to be inventive.

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.

Due to difficulties of tracing the way in which knowledge generated from research finds its way into application, it is not possible to know 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 that 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. The $100m Australian National Food Industry Strategy, for example, 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 Australian Government Productivity Commission (and its predecessor agencies) has undertaken assessment of industry level performance, from the perspective of industry economics, regularly and systematically over many years. Industry 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).

Adoption by industry 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 basis 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 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.

Regional policies and strategies are heavily focused on (Pages, Freedman, *et al.* 2003):

- 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 that teach entrepreneurship has increased substantially in recent years. There has been an associated interest in social capital and social entrepreneurship (Pages, Freedman, *et al.* 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).

There is a very wide and extensive range of measures to assess the performance of public policy initiatives and program interventions. 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 and Feller 2003).

Methodological approaches for measuring the economic benefits of publicly funded research have been canvassed extensively by the Science Policy Research Unit for the UK Treasury in 1996 (Martin and Salter 1996). A detailed assessment of performance measures and indicators is contained in the Australian context is contained un the Report *The Emerging Business of Knowledge Transfer* (Howard 2005). A summary of measures is provided in Table 4 below.

Table 4: 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 higher levels of cooperation and collaboration	Industry-research-government partnership in economic development
Reflected in	Evidence of: • Workable communication strategies • Capacity building' • Education • Production and marketing standards	Discoveries and inventions adopted and applied in business contexts Graduates who work in industry	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—eg 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 varies considerably. 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 an 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 is sought form business owners and managers about performance
- 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 is used widely in the knowledge production process; bibliometrics provides 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.

5 Conclusion: From diffusion to engagement as the basis for knowledge transfer

The knowledge economy sees knowledge as both a commodity and factor of production. This has promoted an econmistic view of knowledge built around manufacturing analogies – where in fact universities and research organisations are seen as knowledge factories – and where value is reflected in a tangible commodity or product.

This approach overlooks the tacit and relational value of knowledge capital – and the value that is in its application and use rather than what it is. Like various forms of physical capital (land, buildings, machines), an asset has no economic value unless it can be used in some way. Similarly, knowledge has value in the services it can provide, and universities and research organisations in the knowledge economy are increasingly being seen as services organisations as well as creators of knowledge capital. Value is in use, rather than in intellectual products based on a property right of ownership.

As indicated, this awareness is becoming increasingly apparent in the manufacturing sector, where companies are realising that value is created much more in the services that their products provide rather than in the tangible products they create. Why else would General Electric be selling ‘power by the hour’ and IBM giving more attention to the services aspect of computer manufacture – evidenced by their purchase of consulting firm Pricewaterhouse-Coopers?

The recognition of the services value of knowledge also shifts attention to a broader concept of knowledge transfer, involving the social sciences and the humanities. In this way, universities are also nodes in the knowledge production process, performing a role alongside private sector professional services organisations, and public sector and non-government agencies working in areas such as health, education and the environment.

Knowledge transfer processes built around technology diffusion have been seen to be insufficient in securing a movement to creation to application. Diffusion which involves 'telling' people about a discovery or a technology, such as in a report or book, is unlikely to lead to adoption unless the information is in a form that target audiences can relate to, understand and act upon.

Similarly, offering technologies for sale has limited success if potential purchasers have little or no demand. Universities and research organisations establishing their own spin-out companies to create demand has limited success – except where those companies are providing *a service*. In the era of open innovation corporations are acquiring R&D capability through investments in, and relationships with, newly established technology firms that have a research capacity based on a technology platform.

Increasingly however, it is being recognised that knowledge moves into adoption and application where there is a high degree of user involvement in its creation. This involves research partnerships, established on the basis of project research and consultancy, and close engagement with users in the design of research programs and projects. Many fear that this compromises the independence and objectivity of scientific enquiry.

But if knowledge is truly a factor of production in the knowledge economy then it follows that those who invest in the formation of that productive capability, and have responsibility for adoption and application, need to be fully engaged with the process of its creation. This is the essence of the Mode 2 concept. *It means establishing the institutions for effective engagement between science and the economy and ensuring that they are performing efficiently and effectively.*

The paper has not addressed in detail the institutional arrangements that support the operation and performance of knowledge transfer processes. The role of research centres was canvassed, but also important are knowledge communities built around disciplines and technologies, university business management offices, and an emerging market for knowledge. This market, where buyers and sellers of knowledge meet and interact, is seeing the rapid growth of intermediaries, or market makers.

Knowledge market intermediaries are funded and supported through a range of mechanisms – from government programs, to industry association and professional body initiatives, subsidised independent and 'honest broker arrangements, through to commercial for profit businesses. This paper has indicated that industry associations are now being seen as key players in knowledge transfer processes and national innovation performance.

The performance of these *institutions of engagement* is an important area for ongoing research. Success of knowledge transfer processes in achieving economic, industrial and business outcomes – quire apart form social and environmental results and impacts - is highly contingent on the performance of these institutions.

The structure, management, operation and performance of engagement institutions is only recently being addressed on a systematic basis. The management and business processes governing the way in which industry, government and research organisations engage is of paramount importance in securing the capitalisation of knowledge as a basis for economic wealth creation.

Bibliography

Allen Consulting Group. 2003. *The Economic Impact of the Commercialisation of Publicly Funded R&D in Australia*. Brisbane: Australian Institute for Commercialisation.

Australia. Department of Agriculture Fisheries and Forestry. 2001. *Innovating Rural Australia: Research and Development Corporation Outcomes*. Canberra.

Australia. Department of Agriculture Fisheries and Forestry. 2002. *National Food Industry Strategy: An Action Agenda for the Australian Food Industry*. Canberra: Department of Agriculture, Fisheries and Forestry.

Australia. Department of Education, Science and Training. 2004. *Review of Closer Collaboration Between Universities and Major Publicly Funded Research Agencies*. Canberra: Commonwealth of Australia.

Australia. Department of Education Science and Training. 2004. *National Survey of Research Commercialisation: Years 2001 and 2002*. Canberra: Department of Education, Science and Training.

Australia. Department of Industry Science and Resources. 1999. "Action Agendas." Canberra.

Bhidé, Amar V. 2000. *The Origin and Evolution of New Businesses*. New York: Oxford University Press.

Bollier, David. 2002. *Silent Theft: The Private Plunder of Our Common Wealth*. London: Routledge.

Boyer, Ernest L. 1990. *Scholarship Reconsidered: Priorities of the Professorate*. New York: John Wiley & Sons.

Braxton, John M, William Luckey, and Patricia Helland. 2002. *Institutionalising a Broader View of Scholarship Through Boyer's Four Domains*. New York: Jossey Bass.

Bresnahan, Timothy F and Alfonso Gambardarella eds. 2004. *Building High-Tech Clusters: Silicon Valley and Beyond*. Cambridge: Cambridge University Press.

Burton Jones, Alan. 1999. *Knowledge Capitalism: Business, Work and Learning in the New Economy*. London: Oxford University Press.

Chesbrough, Henry. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Boston: Harvard Business School Press.

Cohen, Don and Laurence Prusak. 2001. *In Good Company: How Social Capital Makes Organizations Work*. Boston: Harvard Business School Press.

Coldsteam, Patrick. 2003. "Engagement: an Unforlding Debate," in *The Idea of Engagement: Universities in Society*. Svava Bjarnason and Patrick Coldstream eds. London: Association of Commonwealth Universities.

De Soto, Hernando. 2000. *The Mystery of Capital: Why Capitalism Triumphs in the West and Fails Everywhere Else*.

Drucker, Peter F. 1988. *Management: Tasks, Responsibilities, Practices*. New York: Butterworth Heinemann.

Drucker, Peter F. 1993. *The Practice of Management*. New York: Harper Perennial.

Drucker, Peter F. 1999. *Management Challenges for the 21st Century*. New York: Harper Collins.

Enright, M.J., Peter Hagstrom, and Orjan Solvell. 1999. "Regional Clusters and Firm Strategy," in *The Dynamic Firm: The Role of Technology, Strategy, Organizations and Regions*. Alfred D Chandler ed. Oxford: Oxford University Press.

Etzkowitz, Henry, Andrew Webster, and Peter Healy eds. 1998. *Capitalizing Knowledge: New Intersections Between Industry and Academia*. New York: State University of New York Press.

Florida, Richard. 2002. *The Rise of the Creative Class and How it's Transforming Work. Leisure, Community and Everyday Life*. New York: Basic Books.

Florida, Richard. 2003. "Entrepreneurship, Creativity and Regional Economic Growth," in *The Emergence of Entrepreneurship Policy: Governance, Start-ups, and Growth in the U.S. Knowledge Economy*. David M Hart ed. Cambridge: Cambridge University Press.

Fountain, Jane E. 1998. "Social Capital: A Key Enabler of Innovation," in *Investing in Innovation: Creating a Research and Innovation Policy that Works*. Lewis Branscomb and James H Keller eds. Cambridge, MA.: MIT Press.

Gibbons, Michael. 2003. "Engagement as a Core Value in Mode 2 Society," in *The Idea of Engagement: Universities in Society*. Svava Bjarnason and Patrick Coldstream eds. London: Association of Commonwealth Universities.

Gibbons, Michael, Camille Limoges, Helga Noworthy, Simon Schwartzman, Peter Scott, and Martin Trow. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London: Sage.

Great Britain. Department of Trade and Industry. 2003. *A Practical Guide to Cluster Development*. London.

Henton, Douglas, John Melville, and Kimberly Walesh. 1997. *Grassroots Leaders: How Civic Entrepreneurs Are Building Prosperous Communities*. San Francisco: Jossey Bass.

Howard, John H. 2003. "Evaluation of the Cooperative Research Centres Programme: A Report to the Department of Education, Science and Training." Howard Partners: Canberra.

Howard, John H. 2004a. "Business, Higher Education and Innovation: Institutions for Engagement in a Mode 2 Society." *Faculty of Engineering*. The University of Sydney: Sydney.

Howard, John H. 2004b. "Interactions Between Research Organisations SMEs in the ICT Sector: A Report to the Department of Communications, Information Technology and the Arts." Howard Partners: Canberra.

Howard, John H. 2005. *The Emerging Business of Knowledge Transfer: Creating Value From Intellectual Products and Services: A Study for the Department of Education, Science and Training*. Canberra: Department of Education, Science and Training.

Howard, John H, Ron Johnston, and Craig Fowler. 2001. "The Feasibility and Efficacy of Commercialising Research Outcomes from Australian Research Council Funded Research: Phase 1. A Report to the Australian Research Council." Howard Partners: Canberra.

Howard, John H and Mark Matthews. 1999. "The Nature and Extent of University Industry Interactions in Australia: A Preliminary Study for the Australian Research Council." Howard Partners: Canberra.

Howard, John H and Mark Matthews. 2001. *Mapping the Nature and Extent of Business-University Interaction in Australia*. Canberra: Australian Research Council.

Humphreys, John. 2004. "AEEMA - Enhancing National Economic Benefits Through a New Cluster Paradigm." Global Innovation Centre: Brisbane.

Johnston, Ron and John H Howard. 2003. "Engagement in an Era of Industrialisation," in *The Idea of Engagement: Universities in Society*. Svava Bjarnason and Patrick Coldstream eds. London: Association of Commonwealth Universities.

Lester, Richard K. 2003. "Universities and Local Systems of Innovation: A Strategic Perspective." *MIT/Tampere Innovation Workshop*: Tampere, Finland.

Leydesdorff, Loett. 2003. "The University Industry Knowledge Relationship: Analyzing Patents and the Science Base of Technologies." *Journal of the American Society for Information Science & Technology*.

Lipnack, Jessica and Jeffrey Stamps. 1997. *Virtual Teams: Reaching Across Space, Time and Organizations with Technology*. New York: John Wiley & Sons.

Maister, David H, Charles H Green, and Robert M Galford. 2000. *The Trusted Adviser*. New York: The Free Press.

Martin, Ben R and Ammon Salter. 1996. "The Relationship Between Publicly Funded Research and Economic Performance: A SPRU Review. Report Prepared for HM Treasury." Science Policy Research Unit, University of Sussex: Brighton.

Matthews, Mark and Bob Frater. 2003. "Creating and Exploiting Intangible Networks: How Radiata was Able to Improve its Odds of Success in the Risky Business of Innovation." Science and Innovation Mapping Taskforce: Canberra.

Moras-Gallart, Jordi, Ammon Salter, Pari Patel, Alister Scott, and Xavier Duncan. 2002. "Measuring Third Steam Activities. Final Report to the Russell Group of Universities." Science Policy Research Unit, University of Sussex: Brighton.

Mowery, David C, Richard R Nelson, Bhaven N Sampat, and Arvis A Ziedonis. 2004. *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer After the Bayh-Dole Act*. Stanford: Stanford Business Books.

National Academy of Engineering. 2003. *The Impact of Academic Research on Industrial Performance*. Washington: National Academies Press.

National Governors Association. 2002. *A Governor's Guide to Cluster-Based Economic Development*. Washington: National Governors Association.

Pages, Erik R, Doris Freedman, and Patrick Von Bargen. 2003. "Entrepreneurship as a State and Local Economic Development Strategy," in *The Emergence of Entrepreneurship Policy: Governance, Start-ups, and Growth in the U.S. Knowledge Economy*. David M Hart ed. Cambridge: Cambridge University Press.

Plosila, Walter H. 2004. "State Science- and Technology-Based Economic Development Policy: History, Trends and Developments and Future Directions." *Economic Development Quarterly*, 18:2, pp. 113-26.

Porter, Michael. 1980. *Competitive Strategy: Techniques for Analyzing Industries and Competitors*. New York: Free Press.

Porter, Michael. 1990. *The Competitive Advantage of Nations*. New York: The Free Press.

Porter, Michael. 1998. "Clusters and Competition: New Agendas for Companies, Governments and Institutions," in *On Competition*. Boston: Harvard Business School Press, pp. 155-96.

Porter, Michael. 1999. "Clusters and the New Economics of Competition," in *Managing in the New Economy*. Joan Magretta ed. Boston: Harvard Business School Press.

Queensland. Department of Innovation and Information Economy. 2004. *Smart State Research Facilities Fund. Round 3 2003-04. Guidelines to Applicants*. Brisbane: Queensland Government.

Ruegg, Rosalie and Irwin Feller. 2003. "A Toolkit for Evaluating Public R&D Investment: Models, Methods and Findings from ATP's First Decade. A Report Prepared for Economic Assessment Office, Advanced Technology Program, National Institute of Standards and Technology." United States Department of Commerce: Gaithersburg, MD.

Savage, Charles M. 1996. *5th Generation Management: Co-creating Through Virtual Enterprising, Dynamic Teaming, and Knowledge Networking*. Boston: Butterworth-Heinemann.

Saxenian, Annalee. 1996. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA.: Harvard University Press.

Stewart, Thomas A. 1997. *Intellectual Capital: The New Wealth of Organizations*. New York: Currency Doubleday.

Stewart, Thomas A. 2001. *The Wealth of Knowledge: Intellectual Capital and the Twenty First Century Organization*. New York: Currency Doubleday.

Tash, William R. 2002. "University Research Centers Rising!" *Scipolicy*, 2:1.

Tuomi, Ilkka. 2004. "Knowledge Sharing and the Idea of the Public Domain." *UNESCO 21st Century Dialogues, "Building World Knowledge Societies"*. Joint Research Centre, Institute for Prospective Technological Studies: Seoul, Korea.

Victoria. Department of Innovation, Industry and Regional Development. 2004. "Science, Technology and Innovation Initiative: Round Three. Competitive STI Infrastructure Grants Program. Guidelines and Notes for Applicants." State of Victoria: Melbourne.

Walshok, Mary L. 1995. *Knowledge Without Boundaries: What America's Research Universities can do for the Economy*. San Francisco: Jossey Bass.

Walshok, Mary L, Edward Furtek, Carolyn W B Lee, and Patrick H Windham. 2002. "Building Regional Innovation Capacity: the San Diego Experience." *Industry and Higher Education*, 16:1, pp. 27-42.

West, Jonathan. 2003. "The Mystery of Innovation: Aligning the Triangle of Technology, Institutions and Organisation," in *Australia's Choices: Options for a Prosperous and Fair Society*. Ian Marsh ed. Sydney: University of New South Wales Press.

Zider, Bob. 1998. "How Venture Capital Works." *HBR*:Nov-Dec.