INNOVATION and the ECONOMIC DEVELOPMENT of AUSTRALIA

© 2008, 2013 John ED Barker, PhD
jedbarker@iinet.net.au

1. SCOPE OF THIS PAPER

This paper, *which is a work-in-progress*[1], describes a model for analysing how and where innovation can be used to strengthen the Australian economy by establishing new industries while simultaneously strengthening the existing economic base- particularly in resources and agriculture. The model starts with the establishment or enhancement of relationships between local world-class enterprises, and researchers to solve immediate problems of production (process innovations), leading, through a four-stage process, to new, or expanded, knowledge-based companies providing new goods and services to international markets. Although the model describes what already happens "naturally" to some extent, it provides a detailed analysis to enable weaknesses in present industry development processes to be identified and remedied. Thus, the model can be used as a basis for development of programs and strategies in government, industry and research organisations that enable better economic outcomes to be delivered.

It is recognised that this process is not the only way that new industries can be established, nor is it necessarily the most significant way. For example, enterprises can be established by direct investment attraction, by the supply of non-technical know-how or by backward or forward integration in the supply chain. A comprehensive analysis of new industry development models is provided by Lester (2005)[2]. However, the model as described is seen as a very effective way in which science and innovation can be used in the economy.

The model aims to provide an alternative view of innovation to the conventional invention-R&D-commercialisation model that pays limited regard to either the source of the initial problem that inspired the invention, or the marketing issues post-R&D. The present model emphasises the role of the "first-user" in providing both the problem and the market. Critical to the success of this development path is the ability of small-to-medium-sized enterprises (SMEs) to participate in the innovation process as a partner to both large companies and research institutions.

The paper therefore suggests a direction for industry development that offers a "no regrets" strategy, where the minimum outcome is the solution of a technical problem in an existing enterprise, with transaction costs being recouped with the initial customer and where the Nation gains from benefits accruing to that customer, even if no new industry develops.

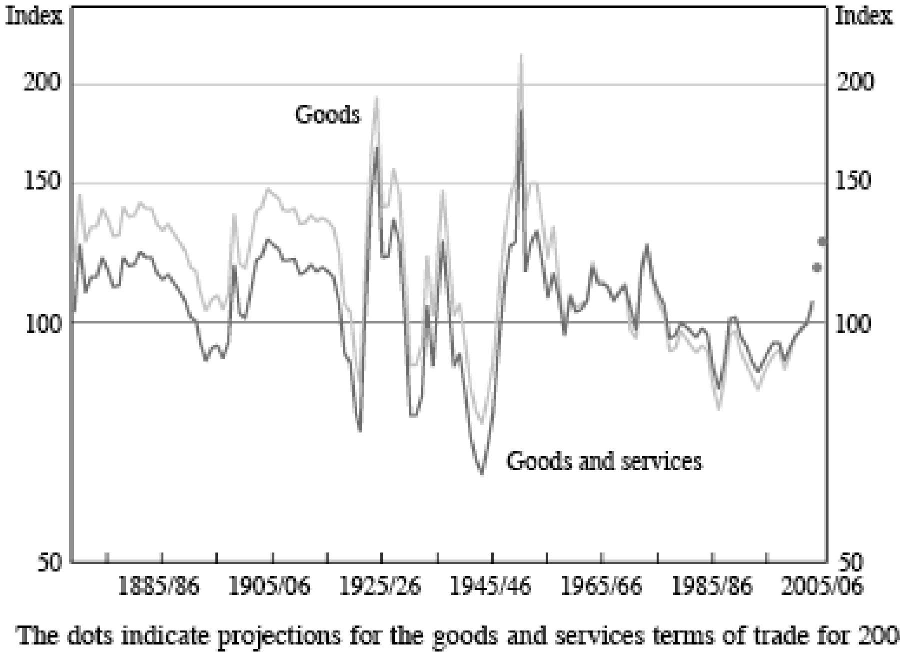
This strategy also overcomes the perennial debate of new technology-based industries *or* traditional resource- and agriculture-based industries. Indeed, the strategy is predicated on a strong symbiosis between the new and traditional industries.

2. THE NEED FOR DIVERSIFICATION

The existing economic base of mining and agriculture in Australia draws heavily on strong comparative advantage coupled with a very high degree of mechanisation. It is substantial and robust and has brought a standard of living to Australia that is comparable to the best in the world. However, this base is very sensitive to the demand cycles of commodities and it is generally acknowledged that a broadening of this base would lead to greater stability. Fig 1 shows the global decline in commodity prices relative to the prices of manufactured goods from 1903-2003[3]. Although commodities have seen remarkable increases in the past several years, it is unlikely that this trend will prevail indefinitely. These figures would suggest that an economy that balances its trade in manufactures, services and commodities is more likely to remain stable and prosperous than one relying mainly on commodities[4].

While downstream processing of commodities represents one option for diversification, another is *the expansion of the production of tradeable goods and services based on innovations in the supply of goods and services to major economic sectors*, including the resources sector. These options are not mutually exclusive- indeed, they can be highly synergistic. Importantly, the process of supplying these goods and services can be used as a major springboard for diversification of production into industries that are enjoying growth and profitability.

Figure 1: Australia's Terms of Trade
2002/03 = 100, log scale



Notes: The dots indicate projections for the goods and services terms of trade for 2004/05 and 2005/06. The construction of these is outlined in Appendix A.

ABS-5206.0-AustralianNationalAccounts-NationalIncomeExpenditureProduct-KeyNationalAccountsAggregates-TermsTrade-Index-

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Figure 2: Relative Commodity Prices and Australia's Terms of Trade

1901 = 100, log scale

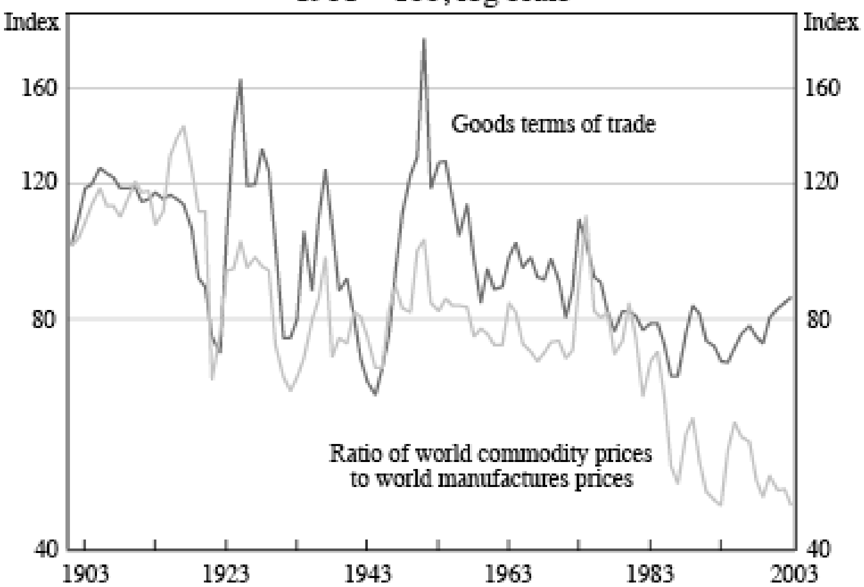


Fig 3: The most recent Australian Terms of Trade Index[5].

3. AUSTRALIA'S COMPETITIVE ADVANTAGE IN PRODUCTION OF GOODS AND SERVICES

With relatively high labour costs, a small population, a narrow infrastructure base and a small and diminishing success in mass production, Australia is unlikely to develop a sustainable competitive advantage of the same kind as many newly industrialised countries, such as China (manufacturing) and India (services). However, Australia has a well-educated and technologically sophisticated community with a strong tradition of cooperation, free enquiry and innovation, which is well-suited to *solving complex technical problems efficiently and effectively.*

As it is possible to claim proprietary rights over knowledge generated in solving these problems, suppliers can service international markets and continue to charge for the use of this knowledge. These proprietary rights are generally called "intellectual property" and may take the form of patents, copyright, design or industrial secrets. Intellectual property rights law is well developed and adhered to by many of our major trading partners, with marked improvement in recent years in some trading partners with a weaker tradition in this regard. Therefore, goods and services with a high "knowledge content" represent a substantial opportunity for development of expanded trade for Australia. There are now many examples of local "knowledge-based industry" and there appear to be many more opportunities for further development through expansion and proliferation. International trends point to increasing trade in intellectual property from advanced economies. The significance of the future in this area is further emphasised by its dominant position in the agenda of recent international bi-lateral and multi-lateral negotiations and agreements[6].

Indeed, the kind of intellectual property that can be developed in association with our traditional industries is turning out to highly profitable. Although we are accustomed to constant price and profit squeezes on our unprocessed goods, we note that many areas of consumer goods are now experiencing the same effects of maturation and "commoditisation" with mass production and mass consumption. *It is the suppliers of sophisticated intermediate goods, and the suppliers of equipment and services to producers at all stages that are remaining profitable with limited competition while both ends of the production chain become commoditised with strong competition*. (Fig 4). As intermediate goods are less amenable to mass production, they are, in principle, more suited to the productive capacities of "middle economies", such as Australia, particularly if they are associated with local industries that are internationally competitive and dominant.

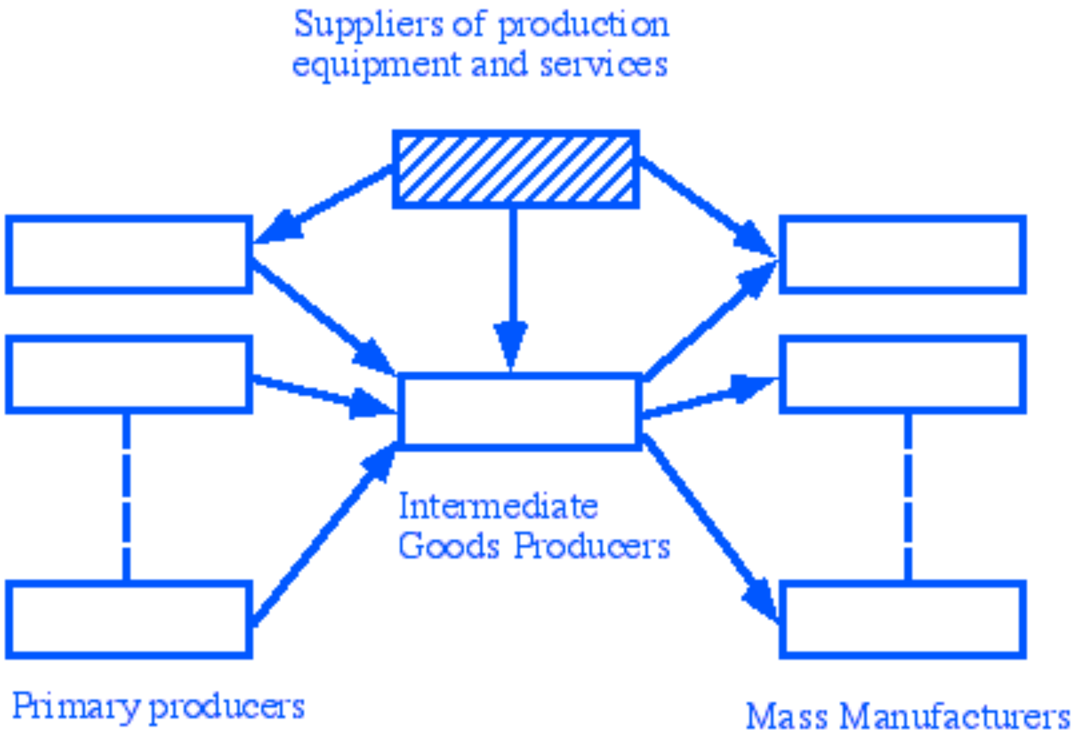


Fig. 4: While strong competition is eroding profitability at both ends of the production chain, profits remain high for intermediate producers and suppliers of process technology at all stages.

4. THE NEED FOR A MODEL

The economic activity of any sophisticated society is a complex web of activity that defies simple description. However, for present purposes, a fairly straightforward and robust model can be used to describe how science and technology can be applied to economic development in Australia. A model, in the form of a framework, needs to be *descriptive, predictive and prescriptive,* ie it can be used in the following ways:

- Developing a shared understanding of the system of innovation
- Distinguishing between different areas and modes of activity
- Identification of areas of strength and areas needing attention
- Developing dynamic goals for activities

The model is based around the idea of *research and development as technical problem solving*. This is similar to Dr Terry Cutler's definition of innovation:

> I describe *innovating* and *being innovative* as the creative problem solving designed to produce practical outcomes. The outcome of this process is the introduction of novel solutions to real problems, needs or opportunities[7].

Problems of all kinds occur continuously in industry, and in one sense, management can be considered as 'solving the problems of production' with the solutions providing 'incremental' improvements. Although *technical* problem solving or technological process innovation is but a subset of all of the innovations in an enterprise, it is the wellspring of much new industry.

Frequently, however, the technical problems encountered can only be solved by systematic investigation of the situation - that is, by the use of formal R&D. This R&D can be conducted in-house, or contracted out to a private company, a university or government research laboratory. *When the problem is solved, the enterprise usually adopts the solution and continues with its core business*. What happens to the new knowledge generated in solving the problem is of critical interest to the present discussion. In some cases the enterprise choses to keep the outcomes confidential, as it is seen as being central to its competitive position; in other cases the enterprise is indifferent to its wider adoption, or may even promote its use within the industry in the belief that all will benefit by its use. The ongoing supply of the innovation may become the basis of a new enterprise.

However, there are frequent 'market failures' and the full potential of the innovation may not be realised. The extent to which the innovation is adopted depends on a wide range of factors described below. This model therefore serves to identify the key steps in the development or evolution of a new industry starting from the basis of technical problem solvers serving an existing major industry. Analysing those steps will enable the points of potential market failure to be identified, and thereby enable decision-makers to formulate coherent action-plans to avoid these potential failures and maximise the opportunities for successful exploitation of the new knowledge generated by the solutions. The following is a brief, generic summary of the essential elements of the model. Subsequent sections of this paper provide a more detailed analysis of those elements that can be used to develop action-plans.

5. A BRIEF SUMMARY OF THE MODEL

Background

This model has its origins in the work of Bengt-Åke Lundvall, a Danish professor of Economics, World Bank and European Commission consultant and internationally recognised authority on the development of national innovation systems. Lundvall first outlined this model in 1985[8], when he described how Denmark diversified from being principally reliant on the export of agricultural commodities, particularly dairy products, to being a world-leading exporter of quality manufactured goods, ranging from pumps to wind turbines. *Lundvall attributes much of Denmark's success to its strong emphasis on the need for education at all levels, the development of strong relationships between people in all sectors and the significant role of small to medium-sized enterprises (SMEs).* Although Lundvall has continued to use the principles outlined in his original paper, to my knowledge he has never developed it in a detailed diagrammatic form. This much I can claim as original. His most recent paper (2008) is a detailed analysis of the Danish economy and its national system of innovation[9]. The model presented here also reflects some of the ideas first developed in the UK in the 1980s by Matthew Bullock, a financial consultant[10]. In his description of the "Cambridge Phenomenon"- the growth of knowledge-based enterprises around Cambridge University- Bullock introduced the idea of "soft entry", whereby academics could gain ideas and even start companies based on their initial consulting to industry. Unlike Bullock, the following model does not necessarily emphasise the growth of "clusters" or technology parks. *Rather, the establishment of close, ongoing relationships between industry, SMEs and institutional researchers is emphasised.*

More recently, various authors have been examining "value chain models", focussing on the kinds of relationships between "users" and "producers". For example, Sturgeon[11], of MIT has posed questions such as 1) what activities are bundled in one node of the chain or split among various nodes; 2) how is knowledge, information, and material passed from one node to the next; and 3) where are the nodes located? Sturgeon comments the "The need for serviceable theory is great."

The following framework, or model, is somewhat less than a theory, in that it does not presume to have any strong predictive capabilities –although it can address the questions 'what should happen next?' and 'are the right resources available for the next step?' quite effectively. Nonetheless, it has a manageable number of modules and is essentially dynamic, therefore enabling policy makers and industry strategists to ask better questions about innovation and industry development, as well as suggest the likely form that answers should take.

The Model

The model is most clearly depicted as a sequence of interactions or relationships, unfolding over time, between two groups:

- Suppliers (or technical problem-solvers); and
- Users (of the supplied solutions to improve their businesses).

This is illustrated in Figure 5.

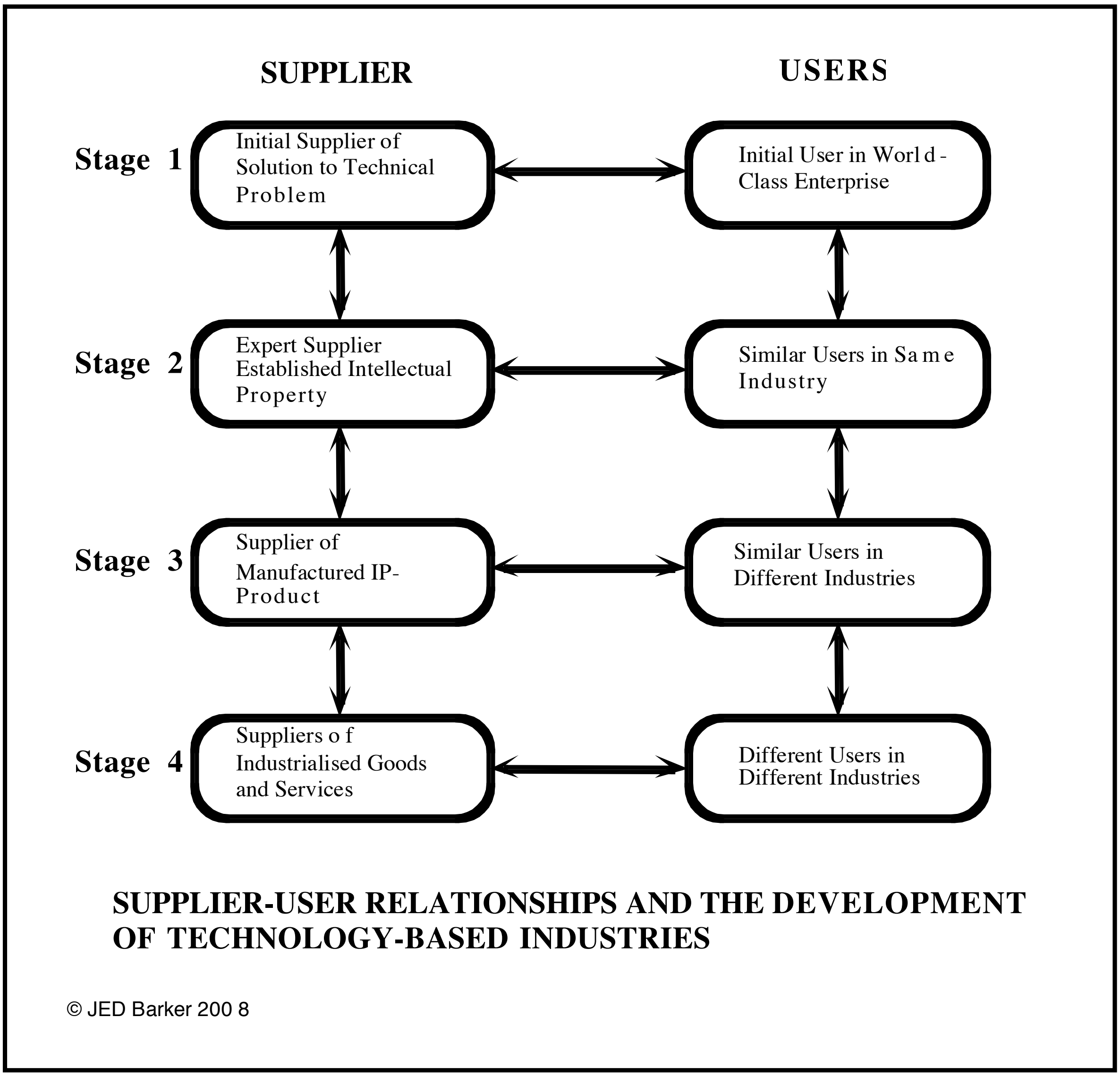


Fig. 5: The Basic Supplier- User Relationship model for new industry development.

There are four principal stages to the model:

- In *Stage 1* a major enterprise (called a 'user') identifies a problem in its production chain for which an off-the-shelf solution does not exist. A solution is required to enable the enterprise to maintain or improve its international competitiveness. Although production problems may be solved in-house, external expertise is sometimes required. A problem-solver (called a 'supplier') is identified and contracted by the enterprise to work on the problem. The solution to the problem is new knowledge, possibly in the form of either a new product or process which may be amenable to intellectual property rights, or, more commonly, company-specific know-how (intellectual capital). The relationship between suppliers and users is highly interactive in this first stage and the solution is in the form of advice, company-specific data or once-off, prototype-like equipment that is useable only by the user-enterprise.

- In *Stage 2*, by solving the problem, the initial supplier has gained user-experience and has developed a 'product' that may be of value to other enterprises (users) in *the same* *industry with the same problem* as the first enterprise. With the imprimatur of the Stage 1 success, further sales of the 'solution' may ensue, with the supplier gaining further experience, enabling the solution to be refined into a more generally useable form. The Stage 2 supplier is often the same as Stage 1, or somebody who has close links to the initial supplier who can 'package' the knowledge in a form that can be readily used industry-wide. This mode of problem-solving is more akin to conventional consulting than to R&D.

- *In Stage 3*, the supplier identifies companies in *other industries* who may also have use for the same or similar 'products' to solve generically similar problems. The growing market for the 'product' enables it to be developed into a standardised form as manufactured hardware or software or routine services. The supplier may be the same as in Stages 1 and 2, who has grown a company- *typically an SME*- around the product-solution, or it may be a company that has acquired the rights to produce the product. The original supplier may also have competition from other suppliers who may have been working in parallel with other users, or who have copied unprotected knowledge.

- *In Stage 4*, the supplier(s) has gained production and marketing experience and reputation as well as having developed an integrated, complex product and production system that could be seen as a collection of separate products and processes. At this stage the supplier may diversify, by selling the system components separately, as well as collectively in the initial 'product'. By this final stage the supplier has usually attracted competitors as well as value-chain collaborators. What may have started out as a one-on-one relationship between a supplier and a user has evolved into a network of new companies that not only maintain the competitiveness of the original major industry, but also create new products for other industries - in other words, *a new industry has been born*.

An important aspect of this model is that the elements on the *left* side can be viewed as the stages of technology development as new knowledge is first formed into a service, then a product, followed by a company then an industry. The process of *knowledge flow* and development down the left side is generally called *technology transfer*. The elements on the *right* side can be viewed as the development of the *market* for new knowledge from a first, discerning customer (a *lead-user*), then to *early adopters* and finally to a widespread (major) market. This development is often called *market diffusion*, and has been well-described by authors such as Eric von Hippel[12] and Everett Rogers[13]. The arrows that connect both the vertical and horizontal flows are double-ended, indicating that the flow of knowledge in both directions is important.

An Example

The remote sensing industry in Western Australia is now significant and flourishing. It began many years ago in the form of air-borne photogrammetric interpretation of aerial maps and photos for agriculture and mining. With the advent of satellite imagery and spectrally selective sensing in the 1980s, further opportunities emerged for more sophisticated analysis, bringing benefits to mineral exploration, agriculture and environmental monitoring in the State. Local scientists, originally from CSIRO, Curtin University and the WA State Government have been able to develop new techniques and technologies that have been adopted by commercial companies to serve both local and international markets. What started as a modest technical service to local major industries has now become a major export of technical products and services in its own right. The willingness of local mining companies and government land-management agencies to use these services has been crucial in the development of this export industry in Western Australia and elsewhere.

The Need for Further Examples

Although the literature is replete with cases studies of regional innovation, most seem to be either very general or focus on a few technical or relational aspects. Papers, such as that by Hatakenaka et al[14], which compares the innovation milieu of Stavanger and Aberdeen, provide a very useful start. A similar study of the developments in the North West Shelf of Western Australia and Bass Strait would be very valuable, given the significance of the oil and gas industry to Australia. The present model was used to a limited extent by Algie[15] in 1999 in his TIAC report on R&D in the Western Australian minerals and energy industries, but an in-depth update is needed.

- ***Case studies of this kind on the innovative aspects of Australia's major industries and their relationships with research institutions and SMEs are essential if a clear understanding of Australia's "National System of Innovation" is to be achieved.***

The Model as a Policy and Strategy Tool

The objective of the model is to provide a sense of direction and a framework for action for innovation-suppliers, innovation users and innovation policy makers. Both the parts and the whole of the model can be useful for policy and strategy development. Altogether, the model comprises four groups of suppliers, four groups of users and ten interactive linkages, or *relationships*, between suppliers and users, suppliers and suppliers, and users and users (Note the use of double-ended arrows to indicate that the relationship and knowledge-flow is two-way). Each of these 18 elements constitutes a focus for issues such as provision of supply and coordination of human resources, infrastructure and information, funding of market failure points, encouragement of interaction, intellectual property regulation etc.

- ***Overall, the model provides a comprehensive and dynamic picture of the system for the successful development of new products, enterprises and industries based on the problem-solving (ie innovation) needs of existing enterprises and industries. As such, it can provide a sense of direction and a broader context for policies and programs.***

A Brief Characterisation of Innovation in Australia

Criticisms of Australia's innovative activity generally fall into the following categories:

- We are good inventors but not good at commercialising our ideas
- Large companies only see Australia as a market for finished products
- SMEs are too risky for big business and research organizations to deal with
- We are good at growing it or digging it up, but not good at value-adding
- Large companies look to their overseas "home-base" for problem solving
- Our labour costs are too high to contemplate a large manufacturing sector.
- Our home markets are too small to achieve critical mass before export

While there are many examples to verify each of these claims, there are also many exceptions. Countries such as Sweden, Denmark and Finland have smaller populations and relatively less natural resources, but are all relatively wealthy and are successful at exporting value-added goods and services.

- ***The key to their success appears to be their focus on problem-solving research based on strong relationships between solution-suppliers and solution-users and SMEs***.

6. A 'MARKET-DRIVEN' APPROACH

The key feature of this model is that it is 'market-driven' and based on *high quality local markets*. This is quite distinct from the 'technology-driven' model that is frequently envisaged wherein inventors develop a product, only to experience extreme difficulties in finding initial customers. It is often said that the greatest challenge of marketing is not to gain 1% of the world market, but to find the *first* customer- von Hippel's 'lead-user'. The approach used here assumes that it is the first customer who is looking for a solution to a problem, rather than an inventor looking for a customer for a preconceived solution. A 'market driven' strategy is not necessarily a simple 'demand-side' strategy. The model also recognises that new industry development needs to have a balanced approach between 'supply-side' and 'demand-side' factors. For example, encouraging companies to identify technical problems is of limited value without also developing a source of potential technical problem solvers. In other words, it is necessary to develop a supply of *intellectual capital* in the form of capable and available researchers before market demand can stimulate the production of *intellectual property*.

However, even assuming that an unsolved problem exists in a world-class local enterprise, there are two major issues likely to be encountered in achieving a solution:

- First, the problem needs to be identified, and recognised by the user as being amenable to technical solution.
- Secondly, a 'problem-solver' (ie supplier) has to be identified and a workable relationship formed between the user and the supplier.

Only then can the problem be worked upon and, with luck, a satisfactory solution is found. There are many challenges on the way to transforming a problem in a local world-class enterprise into a new industry.

The first, and perhaps the most significant challenge, is *getting started*. This requires the establishment of a viable *relationship* between the enterprise with the problem, and a potential problem-solving partner.

7. THE SUPPLIER-USER RELATIONSHIP

The basic element of this model is the 'supplier-user relationship'. 'Users' are the major enterprises that have identified a problem that needs to be solved, and 'suppliers' are potential technical problem solvers- ie *applied researchers*. The 'problem' may be related to the processes of production of the enterprise's product, or it may be in the specification of the product itself. In general terms, it may be at any point of the firm's 'value chain', ranging from inbound logistics to final delivery and servicing of the product. Either process innovation or product innovation is required to solve the problem, ie, an improvement of an existing production system or the development of a new one. *The supplier and user, therefore, establish a relationship for the primary purpose of solving a problem.*

The important characteristics of users are that they are *large, internationally competitive enterprises*. Although size *per se* is not necessarily important, it does provide some imprimatur to successful suppliers, which may assist them when seeking other markets. International competitiveness- or international comparability- provides the supplier with a strong benchmark for its competitive standing. *Such users are generally mature enterprises with well developed international benchmarking for their suppliers and will usually seek the best solutions available anywhere in the world.* Chosen suppliers therefore have a strong signal that they have the best solution available internationally.

As with relationships of any kind, each partner must have characteristics that make a relationship possible and viable. In general, each partner must:

- be open to the prospect of a relationship;
- have qualities that will attract a partner;
- be able to locate and identify prospective partners;
- be able to signal intentions to form a relationship;
- be able to negotiate the commencement of a relationship; and
- be capable of sustaining a relationship.

Table 1 lists the characteristics that users *must* have to be attractive to suppliers, and some of the deficiencies that may make them less attractive to suppliers. Table 2 provides similar lists for suppliers. To extend the metaphor, *it takes two partners to form a relationship*. Table 3 lists some of the frequently encountered problems that occur in establishing relationships between users and suppliers. ***These problems must be addressed if the relationship is to be established and develop. Each element of these lists provides a point of analysis for private and public policies and programs.*** The following sections provide some examples of the analysis and courses for policy action.

Desirable Characteristics of Users	Frequent Problems with Users
• Large • Complex • Internationally oriented • Long term view • Problems amenable to technological solutions • International quality standards for supply • Local autonomy in decision making • Industry still maturing or revitalising • Vertically disintegrated (sub-contractor-oriented) • Research-oriented • Operations near suppliers • Similar social culture to suppliers • Similar technical culture to suppliers • Patriotic	• Often vertically integrated • Industry is mature-standardised equipment and procedures • Remote from local suppliers • Distance insensitivity of supply • Do not have research culture • Do not interpret problems in terms of technical solutions • Limited sense of local allegiance • Distrust of suppliers • Lack of mandate to interact with innovative suppliers • “Not-invented-here” syndrome

Table 1: Desirable characteristics and possible problems with Users from a Supplier’s perspective.

Desirable Characteristics of Suppliers	Problems with Suppliers
• Industry-oriented • Available to users • International quality (price/time/standard) • Critical mass teams • Motivated • Appropriate management	• Lack international standards • Lack international orientation • Lack of contact with users • Lack of mandate to interact with users • Not always available • Lack of contact with other suppliers • Institutionalised attitudes • Lack of critical mass • Lack of experience • Lack of commercial credibility • Lack of management capabilities

Table 2: Desirable characteristics and possible problems with Suppliers from a User's perspective.

Frequent Problems with User-Supplier Relationships
• Inadequate knowledge of each other • Lack of mutual trust • Spatially remote from each other • Cultural incongruence • Lack of shared vision • Minimum order size too large (financial, temporal) for supplier • Intellectual property ownership uncertainty

Table 3: Frequent problems with Supplier-User relationships.

8. ESTABLISHING THE RELATIONSHIP

An important question is "how do relationships get started?" In business, (and especially in new forms of business such as science and technology), getting started can be as difficult as establishing new personal relationships. As with personal relationships, there is no one, simple formula. On a personal level, joining a bushwalking club may work, and so might going to a singles bar or joining an internet dating service. Similarly, belonging to the same business club, going to a conference or replying to an expression-of- interest advertisement might also help establish the relationship between an enterprise with a problem and a potential problem-solver. Fig. 6 indicates some of the many ways that relationships may be commenced or mediated. Each of these ways may be appropriate in some circumstances, and each situation needs to be reviewed to determine which is most suitable.

- ***In general, however, many of these ways are not adequately developed and the role of government in facilitating this stage needs closer investigation. Again, as in personal relationships, the demand on resources at the establishment stage may be high, with a correspondingly high risk of failure.*** **It is frequently seen as the role of government to offset these risks by providing facilitation and/or subsidies.**

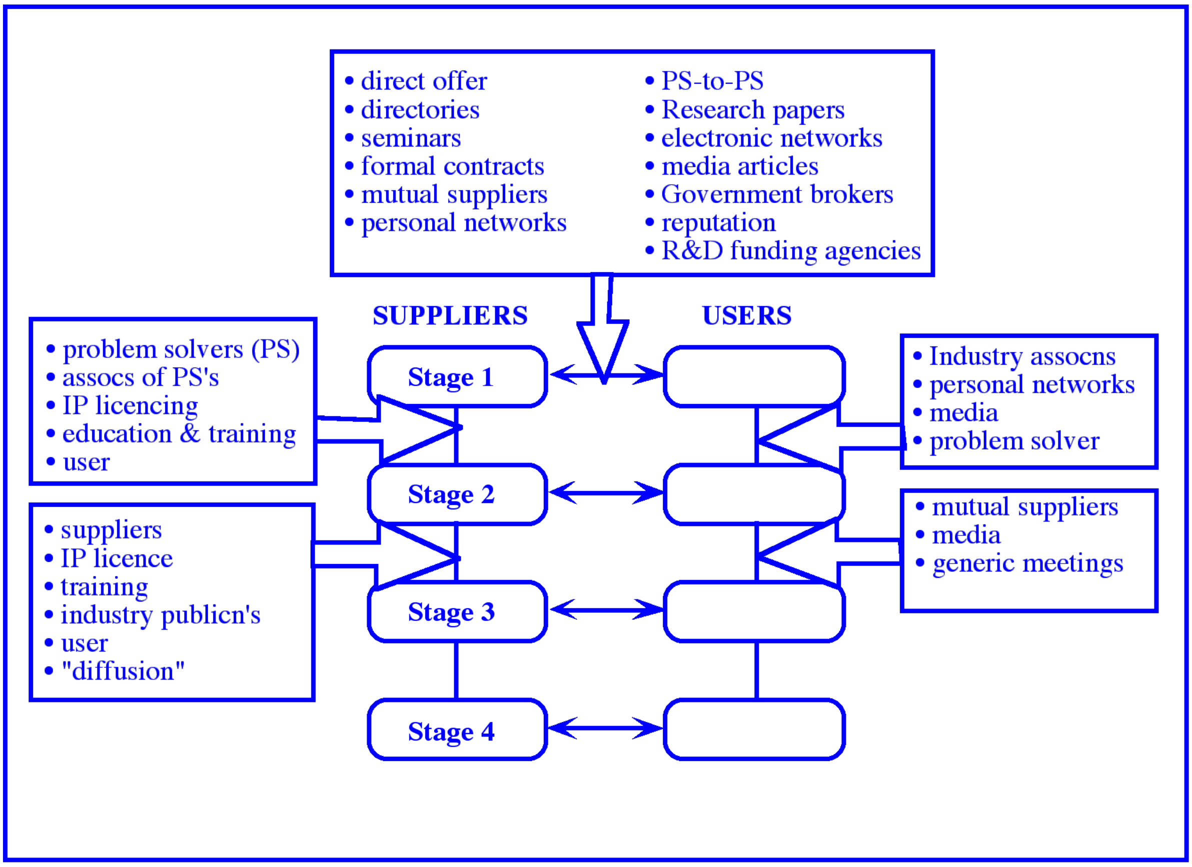


Fig 6: Illustrating some of the many ways in which relationships between suppliers and users can be initiated. Each bullet point represents a point of investigation by government to rectify any market failure.

9. THE ROLE OF PROBLEM-SOLVERS IN INITIAL INFRASTRUCTURE DEVELOPMENT

Given the magnitude of the initial infrastructure demands of the Nation's major users, it may seem that best opportunities would exist for local suppliers to get in on the ground floor of new initiatives. If this could be achieved, then an even greater number of local enterprises would be internationally competitive with exportable goods and services with a substantial intellectual property content. However, the economic history of Australia would suggest that in most cases, *the initial infrastructure is usually based on fairly mature technology*, or it has been designed elsewhere- sometimes on information supplied from within Australia.

With new and significant ventures, the major challenge for enterprises in Australia has been to compete against suppliers elsewhere as sub-contractors on a "build-to-print" basis. It is usually only after the enterprise has been established that there are opportunities to improve its performance from local "process innovations".

Although this situation is understandable, it is far from ideal, and has an increasing number of critics. Historically, as Australia simply did not have the expertise to contribute to the infrastructure design "world best practice" had to be implemented by the instigators of the new venture. "World best practice" is, almost by definition, tried and tested, or mature, technology. It is chosen on the assumption that it comes with well-specified performance and is essentially "problem-free". However, Australia is now the most significant centre in the world for a number of industries (see Table 4, below, for Western Australia), and the local expertise in these industries is second to none, particularly in its understanding of the potential or present "problem" aspects of the industry. There are already examples of major ventures encountering significant difficulties as a consequence of insufficient attention to local problems, for which local problem solvers may have been available.

Major West Australian Commodities	$ million
Iron Ore	$51,021
Petroleum	$24,433
Gold	$9,352
Alumina	$3,649
Nickel	$3,783

Output of minerals and energy	$ million
Western Australia	$96,854
Australia (DMP estimate)	$185,000
WA minerals	$72,421
WA petroleum	$24,433

Merchandise Exports	$ million
Western Australia	$114,219
Australia	$248,332
WA share	46%
WA exports of minerals and energy as % share of all State Merchandise exports	87%

Table 4: Western Australia's major mineral exports (Calender year 2012), indicating the scope for entry of "problem solvers" to global markets. (Source: WA Dept of Minerals and Petroleum http://www.dmp.wa.gov.au/7846.aspx)

Although this model essentially focuses on process innovations in existing major enterprises as the starting point for new technology-based industries, it can easily be widened to consider local problem solvers participating in the basic design of proposed new enterprises- the new enterprise being "the problem to be solved". Although increased participation may follow as a consequence of maturation of local problem-solving enterprises, it may also require a greater assertiveness by both the problem solvers and the government on their behalf.

10. A DETAILED ANALYSIS OF THE MODEL

Stage 1
In the first stage, a world-class enterprise recognises that it has a problem that is amenable to technical solution, and for which an acceptable solution is not available.

Obtaining a toe-hold in supplying to such enterprises is a challenge, and the problems presented to suppliers can be represented as "market imperfections". These problems are summarised in Table 5.

Table 5: Examples of World-Class Users in Australia
• Mining companies and mining services companies • Mineral and petroleum processors • Resources processors • Forest products companies • Shipbuilders • Casinos • Water Authorities • Power Authorities • Road Authorities • Health Departments and Hospitals • Public transport authorities (Bus/rail) • Large Service companies • Defence agencies • Legal • Accounting • Large retailers • Educational Institutions

11. ANALYSIS OF SOME STAGE 1 PROBLEMS AND SUGGESTED POLICY RESPONSES

- **Users often vertically integrated**

Vertical integration means that the user owns and manages many of its sources of supply of goods and services along its value chain. For example, a resource company may also perform all of its own exploration, resource characterisation, transportation and refining, together with maintenance of these systems. Until recently, this was fairly common in Australia. An example is Esso (ExxonMobil), which owns the Bass Strait oil and gas fields and the associated production platforms, pipelines, and refineries. Technical problem solving was mainly in-house, leading to a lack of experience in the petroleum-related technologies in Australia. In part, this was understandable, as Bass Strait was the first major oil and gas field in Australia and at the time of establishment (1970s), there was little local expertise available. By comparison, the North-West Shelf and Timor Sea petroleum reserves are characterised by a relatively large number of players performing exploration and extraction, with some of these players being too small to contemplate total vertical integration. This situation has created opportunities for many suppliers, including, for example, Curtin University, UWA and CSIRO, who have undertaken research into the unique characteristics of the oil and gas reservoirs in these areas[16]. These opportunities never arose in the Bass Strait fields because Esso performed this kind of problem solving in-house.

- ***If research institutions can demonstrate sufficient capabilities, then the tendency to vertical integration may be avoided, and some of the present vertical integration may be reduced. Vertical integration may be a deliberate company policy or a consequence of the evolution of the enterprise in the Australian environment.***

During the past decade or so, many companies have reviewed their strategies and structures and decided to "outsource" many functions that have hitherto been performed in-house. Flatter organisational structures have been accompanied by the need to manage a greater amount of externally supplied goods and services. While this has increased the scope for external innovation, it has sometimes had the reverse effect as greater specification of supply is generally required. Further supply has often been globalised using "international best practice", leading to innovation being performed elsewhere. Nonetheless, outsourcing has provided the possibility of supply by local problem solvers, along with the scope for growth of these problem solvers into substantial enterprises and industries.

- ***The focal point for user-producer relationships has shifted from the "major" resource companies, who are "prime-contractors" to the technology-intensive "sub-contractors".***

- **The benefits and dis-benefits of public sector users**

Most Australian public sector organisations, such as utilities, health departments, educational institutions are recognised as being of world standard in the services they deliver and the way in which they operate. As large and discerning purchasers of technologically sophisticated goods and services, they are a desirable customer for many suppliers for the following reasons:

Imprimatur: Because of the high standards, purchase by public agencies is seen as a significant endorsement of those goods and services that can be used for promotion to other customers. This is particularly important when companies are trying to export to Asian countries where government purchasing predominates, although it has been found to be an important factor in most international markets.

- *Non-competitive:* As most public agencies are not in competition with other local organisations, then there is generally no difficulty, in principle, with the supplier selling the same product to similar organisations in other states or countries. As discussed below, being able to sell the solution of a sophisticated technical problem to other potential users is often a major problem in the private sector.

However, it is often difficult for small innovative companies to become suppliers to these organisations. Reasons include:

- *Conservatism of procurement:* This problem has been recognised for a long time and its implications for Australian industry have been reported on in-depth to numerous Parliamentary committees. The conservatism in procurement is founded on several basic principles:

    - *Lack of mandate to assist industry development:* Most government agencies are established under Acts of Parliament that prescribe quite precisely the agencies functions and powers. Although these corporate powers seem, at first sight, to be very similar to those of private enterprise, they are usually interpreted to only extend to discharging the functions and obligations of the agency. Assistance in development of local innovations is very limited, despite the fact that it could be argued that local supply could in many cases improve the fulfilment of the agency's mandate.

    - *Stringent demand for continuity of supply of service:* Australian society is accustomed to, and to a large extent depends upon, a very high performance from its public utilities. Electricity, gas and water are expected to be available at the highest quality at all times. Roads are expected to be open, medical services are expected to have minimum risk to patients. Any factor that is likely to reduce the standard of supply (quality or quantity) is generally avoided.

    - *Best-practice vs innovation:* User-agencies are generally more interested in performing their mandated functions than engaging in technical problem solving. Although adopting international best-practice can vastly improve efficiency, effectiveness and/or competitiveness in the short term, in the long term it may not be sufficient, as, by definition, it relies on relatively widely available knowledge. *Sustainable* competitiveness can best be achieved by securing knowledge that cannot easily be gained by competitors. The most secure source of this knowledge is innovation sponsored by the enterprise itself.

- *Vertical integration of supply*: Until recently, many public agencies had extensive workshops that were charged with the task of maintaining equipment and solving technical problems peculiar to the particular agency. As such, they did not have a general mandate to assist in solving problems outside their parent agency. Many opportunities for industry development were thus missed. The service function of these units presented many opportunities for development of world-class goods and services, as in the process of repairing and maintaining equipment, these workshops gained unique insights into the strengths and faults of the best available products. In many cases they were able to specify or build superior products on a once-off basis. In most cases opportunities for commercialisation were not taken due to lack of mandate to do so. In the past decade or so, competition policy has seen the break-up and/or sale of many public utilities. This has been accompanied by elimination or down-sizing of in-house technical problem-solving functions. However, this has not necessarily led to greater levels of innovation as the "conservatism of procurement" problem as described above as replaced the vertical integration problem.

• *Public perceptions:* Whilst some agencies may be willing and able to develop wider markets for technologies produced in-house, concern has been expressed regarding possible negative public perceptions regarding priorities. For example, public knowledge of extra-mural commercial activities could be perceived as a mis-direction of priorities by dissatisfied customers.

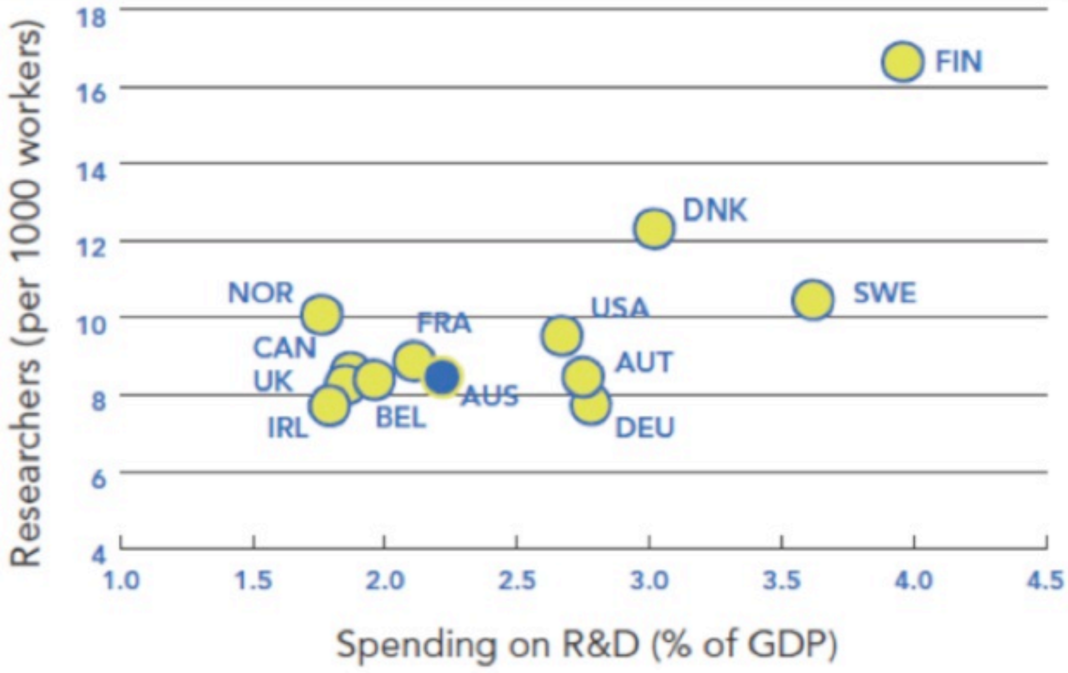
• *Conflict with existing suppliers:* Most agencies have many service contracts with suppliers of mainly imported goods. Indeed, in many cases the suppliers profits are mainly derived from service contracts. These suppliers are often in a strong negotiating position and may take a dim view of agencies entering competition with them.

12. MEETING THE DEMAND FOR HUMAN RESOURCES

- **Closing the Gap**

It is clear that if Australia wishes to have greater fruits from R&D then it will have to perform more of it. Although there has been a significant improvement in the past five years, at 1.8% of GDP, Australian R&D is still about 0.5% of GDP lower than the OECD average, and about half the R&D level of the leading countries (Sweden, Finland and Japan). Both private and public R&D are below the OECD average.

Figure 1: Researchers (per 1000 workers) vs. spending on R&D (per cent of GDP)



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Put in concrete terms, 0.5% of GDP translates to a $5 billion/year shortfall in R&D. The number of R&D personnel implied by this figure is about 30-40,000, taking a weighted average of the cost of funding private and public researchers.

- ***If a ten-year catch-up strategy were adopted to reach this figure, then about 3-4000 extra researchers would be required every year, with an implied extra $500 million in R&D per year. In perspective, there are about 1000 PhD graduates per year from Australian universities, about a quarter of whom are from overseas[17]. Clearly if this figure were to be achieved then either the universities would have to adopt an accelerated program of producing S&T postgraduates, or a sizeable proportion of these researchers would have to be found from elsewhere.***

13. THE ROLE OF UNIVERSITIES, COOPERATIVE RESEARCH CENTRES AND GOVERNMENT RESEARCH AGENCIES (INCLUDING CSIRO)

The Universities

Public research institutions have been the centrepiece of most national innovation policies since the early 1980s. While public institutions clearly have much to contribute, successive government policies have demonstrated significant misconceptions about their inherent scope and limitations with regards to innovation. This distorted view has been both a source of distraction from the "main game" and a source of destruction of universities. The origins of these misconceptions are numerous- not the least of which was the desperate need for economic revitalisation at that time (the 1980s), which coincided with the emergence of Silicon Valley as a significant new industrial zone. The main misconception has been a romanticized, heroic, or "Horatio Alger" view of academics who have commercialised their scientific discoveries. The early Silicon Valley "heroes"- Shockley, Hewlett, Packard, Noyce and Moore are now legendary, as are the academic "dropouts"- Gates and Jobs. However, none of these high-tech pioneers were beneficiaries of direct government programs aimed at enhancing the outcomes of academic research. Indeed, although the myth surrounding this model has long been dispelled in the innovation-policy literature (see, for example Feller (1990)[18]), it endures. Perhaps the more recent analysis by Lester (ref xx) will finally put the myth to rest. In summary, *while the contributions of academe to the wider areas of knowledge creation and teaching are vital, the direct contribution to innovation has been insignificant.*

- ***As such, universities can be seen to be mainly operating in stage 1 of the model, the principal "users" being other academics posing fundamental knowledge problems. Diffusion of this knowledge is mainly via senior level undergraduate teaching and the ultimate placement of PhD graduates in industry.***

- **Government Research Agencies**

An equally erroneous view of the role of government research agencies (GRAs) has compounded the problems of innovation policy mis-direction. At the State level, most GRAs have provided valuable services to agriculture and the environment. Agricultural, forestry and fisheries GRAs were originally established in recognition of the "market failure" related to the small size of most farms relative to the cost of research in all aspects of the value chain from paddock to plate (the "indivisibility" issue). In most cases, research results have been widely (and mainly freely) disseminated on the basis of "public benefit". Their knowledge diffusion methods have been exemplary and have enabled Australian farmers to be highly productive and competitive. Whereas agricultural GRAs can be seen to be effective at stages 1 and 2 of the model (ie initial problem solving and consulting to other members of the same industry), they have been relatively ineffective at capturing direct commercial benefit at stage 3 (users in other industries). Environmental GRAs have operated mainly as public benefit on issues related to water, soil and air quality and conservation of non-commercial vegetation. Government analytical laboratories have generally been downsized in recent years, with many functions outsourced to the private sector, leaving only "market failure" activities (*ie*, small, non-commercial, uncertain or public safety) in the public sector.

- **CSIRO**

In principle, CSIRO is well positioned to follow the model through to the beginning of stage 3. CSIRO operates in a number of modalities, which are expressed in its purpose statement:

We deliver great science and innovative solutions for industry, society and the environment…CSIRO is a research enterprise dedicated to delivering benefit to industry and the community through world-class science.

The modalities include science-based solutions for the community, delivering incremental innovation for existing industries, solving major national challenges, creating new or significantly transforming industries, advancing frontiers of science and satellite roles.

In one modality, it collaborates with industry to solve its problems. Other modalities are more akin to GRAs and universities. The CSIRO website and annual report provide many examples of problem solving that has led to intellectual property that has been licensed for widespread production. Given CSIRO's broad mandate, and that it has been operating in stages 1 and 2 (and relating to stage 3) for many years, it is an open question as to why Australia is still perceived to have an innovation problem. CSIRO earns royalties of about $20 million on a total budget of almost $1 billion. If it were operating solely in a commercial R&D modality, this would be a 2% return on investment- in comparison with industry averages of 7-14%. However, as only a proportion (that is hard to determine) of its activities are R&D and only a proportion of that is commercially directed, its performance is actually somewhat higher than this figure would suggest. As CSIRO's performance has been reviewed almost continuously for many years, it would be presumptuous to draw any conclusions here, other than to note that the context of the reviewing would suggest that there is some basis for dissatisfaction. *Much of this dissatisfaction seems to revolve around its relationships with SMEs, which are the key to new industry development compared with existing industry enhancement.* In general terms, though, it might be inferred that CSIRO's allocation to each major industry has been inadequate to make a real difference. The formation of its "Flagship" programs seems to be an attempt to form critical mass groups in priority areas. Even so, the budget for each Flagship seems to be in the order of $10 million, which is usually spread over a wide range of activities. An independent review examining the issue of critical mass in the Australian R&D context is necessary.

- ***Further analysis of CSIRO's relationships with SMEs is required. This should be done in the context of a wider review of SMEs in Stage 3 mode.***

- **Cooperative Research Centres (CRCs)**

The CRC program commenced in 1990 with the intention:

"to enhance Australia's industrial, commercial and economic growth through the development of sustained, user-driven, cooperative public-private research centres that achieve high levels of outcomes in adoption and commercialisation."

With that objective, it would seem possible to resolve the major issues raised in this paper. However, despite the approximately $12 billion of cash and kind contributed from all sectors (including about $3 billion from the federal government), there continues to be a widespread feeling that "we haven't got it right". Such a large program is bound to have many successes and failures in program management, structure, direction and outcomes. The present author has provided a separate detailed analysis of some of these issues to the *2008 Review of the National Innovation System*, which includes a review of the CRC program. In the context of the present paper, attention should be paid to the effectiveness of the CRCs at developing industry through the model described here. In many ways, the CRCs are similar to the CSIRO, by problem solving in areas of National importance. Although the CRCs essentially have a wide mandate to follow solutions through to commercial success, they seem to suffer the same weakness as CSIRO, in that their main attention is to stages 1 and 2. Part of this weakness is due to the way that CRCs need to be structured to achieve initial funding- that is, by having financial support from large corporations. *Although this is very desirable for stages 1 and 2, the participation, or development of SMEs is required to go to stage 3.* It is well known that many SMEs are eager to participate in problem solving, but do not have the capacity to make cash contributions that are significant to the CRCs. A further challenge is that as a major role of the CRCs is postgraduate training, addressable problems need to be "PhD-able"- in other words, the problems that are taken on by the CRCs need to be amenable to subdivision so that each segment can be resolved in the context of a 3 year PhD program.

- ***The participation of SMEs in the CRC program needs further attention in the context of stage 3 modality ie transferring solutions to other solutions in a fully commercial context. The role of PhD programs also need analysis in this context.***

Stage 2

The second stage of the model involves the technology being transferred to other users with a similar problem to the first user. These users are generally members of the same industry. On the problem-solver-supplier side, we see a shift of emphasis from original problem solving (research) to producing similar solutions to much the same problem (production). This can be in the forms of goods or services. In the case of goods, for example, an original piece of equipment or instrument that was developed for the initial user might now be produced in limited numbers for other members of the same industry. In the case of services, the original research that led to provision of advice to the initial user can now be used as the basis for similar advice to other users. This is generally called "consulting".

At this stage there are possibilities for the supplier to make a significant profit from the reproduction at a premium of knowledge over which they have a monopoly. *The challenge for development is to "transfer the technology" to an environment in which it can flourish commercially.* However, as in stage 1, there are often a number of impediments to commercialisation.

The major challenges at this stage are encapsulated in the concept of "technology transfer". In the first stage, a solution to a technical problem has been developed through a successful relationship between the supplier and user. Although the form of this solution may be tangible, there is still much knowledge about the product and its production that has not been fully recorded- it remains as "tacit knowledge". It is essentially the same as a "working prototype" situation in most production environments. The researchers who have developed this solution still have much of the information in their heads and notebooks and although and it would be difficult for anyone else to reproduce the solution for other users. Frequently, much of the knowledge gained in solving the problem has not been codified as "intellectual property".

At the same time this situation is a commercial advantage and a problem. The advantage obtains from the difficulty of potential competitors to copy the product; the disadvantage arises in that the researcher may not be in a situation to work further on the product, as summarised in Table 1, nor to on-sell the knowledge in the form of licenses of intellectual property. Many of these problem solvers work in public institutions where the conditions of employment or reward structures that are not conducive to efficient technology transfer. Academics, for example, are essentially in a "publish or perish" environment, where it may be possible (with some restrictions) to gain publications as a by-product of the initial problem solving exercise, but further publications are not possible from the process of consulting using the same knowledge. Researchers in government agencies may also have their mandate to consult circumscribed, although for different reasons.

Even when these issues are overcome, further difficulties may be encountered regarding the ownership of the intellectual property. This occurs with both the initial user of the technology and the researcher's employer. Frequently, the initial user (from Stage 1) perceives the solution as comprising a competitive advantage against others in the same industry and therefore may have a strong interest in the knowledge not being disclosed to others. In many of these cases the suppliers and users have not clearly defined the contractual arrangements because of ignorance of intellectual property laws, or simply lack of foresight that such a situation might arise. This situation is likely to occur with even greater frequency as interactions between external suppliers and users increase. To add to this problem, intellectual property disputes between the researcher's employer and the researcher are becoming common. These disputes are caused partly by the newness of this working environment, together with the complex nature of both the explicit IP laws and implicit relationships between researchers and their employing institutions. The past few years has seen a proliferation of publications from private and public organisations on explanation and interpretation of IP laws and regulations. At present very little consensus exists on this matter and this uncertainty in itself presents a barrier to effective technology transfer.

• DEFINITIONS

For the purpose of this paper, the following definitions are used:

Science is the process of creating new knowledge or theories through the processes of systematic information gathering and experimentation. Part of this process is identification and solution of problems regarding the nature of the physical world. Science is often considered to be a body of public knowledge based on reason and logic.

Technology is application of knowledge for practical purposes. Historically, technology evolved through trial and error in usage, with science only being used for refinement after the basic technology had been developed. Increasingly, this process is being reversed, with technology being developed from theoretical consideration of science, with refinement coming from trial and error in usage. This latter process is often called “high technology”.

Research is the process through which scientific knowledge is gathered. It is essentially the systematic gathering of new knowledge through experimentation. The purposes of research may be simply to satisfy human curiosity- ie **basic (or pure) research,** or practical- ie **applied or strategic research**.

Development is the process of transforming existing scientific knowledge into practical forms or “technologies”.

Research and Development (R&D) together can be considered to be technical problem solving.

Innovation is the process of bringing the results of R&D to a market, or user.

Product innovation relates to the development of new or improved goods or services.

Process innovation relates to the development of new or improved means of production.

Suppliers are companies, organisations or individuals who provide knowledge, goods or services to other companies or organisations. In the context of this paper suppliers provide solutions to technical problems.

Users are companies or organisations that purchase technical solutions in the form of goods or services from suppliers.

References

[1] Readers are invited to comment directly to the author. All serious comments will be acknowledged.
[2] Lester, Richard K., *Universities, Innovation, and the Competitiveness of Local Economies: A Summary Report from the Local Innovation Systems Project* – Phase I, MIT IPC Working Paper IPC-05-010, December 2005.
[3] Gillitzer, Christian and Kearns, Jonathan, *Long Term Patterns in Australia's Terms of Trade*, Research Discussion Paper 2005-01, April 2005 Economics Research Department, Reserve Bank of Australia.
[4] Stiglitz, Joseph, Humphreys, Macartan and Sachs, Jeffrey, *What Is the Problem With Natural Resource Wealth?* In: *Escaping the Resource Curse*, M. Humphreys, J. Sachs, and J.E. Stiglitz, eds., New York: Columbia University Press, 2007, pp. 1-20.
[5] ABS 5206.0 - *Australian National Accounts: National Income, Expenditure and Product,* Dec 2007, Latest issue released 05/03/2008.

[6] See, for example information on the WTO's TRIPS agreement at http://www.wto.org/english/tratop_e/trips_e/trips_e.htm.
[7] Cutler, Dr Terry, *Innovation – What it is and Why it Matters,* Speech at the Australian Industrial Research Group's annual conference, Melbourne 25 Feb 2008.
[8] Freeman, C. and Lundvall, B.-Å. (eds.), *Small Nations Facing the Technological Revolution*, London: Pinter Publishers, 1988.
[9] Lundvall, Bengt-Åke, *The Danish Model and the Globalizing Learning Economy – Lessons for developing countries*, Department of Business Studies, Aalborg University, First Draft for the Wider-project January 2008.
[10] Bullock, M. *Academic Enterprise, Industrial Innovation and the Development of High Technology Financing in the United States* (London, Brand Brotherss and Co.), 1983.
[11] Sturgeon, Timothy J., *From Commodity Chains to Value Chains: Interdisciplinary theory building in an age of globalization*. This paper will also appear as Chapter 6 of the forthcoming book Frontiers of Commodity Chain Research, Jennifer Bair (ed.), Stanford University Press, 2008, MIT IPC Working Paper 08-001.
[12] Eric von Hippel, The Sources of Innovation**,** *New York Oxford* Oxford University Press 1988
[13] Rogers, Everett. M. (2003). *Diffusion of innovations (5th ed.).* New York: Free Press.
[14] Hatakenaka, Sachi, Petter Westnes, Martin Gjelsvik, and Richard K. Lester, *The Regional Dynamics of Innovation: A comparative study of oil and gas industry development in Stavanger and Aberdeen*, MIT IPC Working Paper 06-008 (2008)
[15] Algie, S, *Western Australia's Minerals and Energy Expertise: How can it be optimised?- Growing the R&D Sector*, Technology and Industry Advisory Council (TIAC) Report, 1999
[16] The author was directly involved in the 1990s, with the Western Australian Government, in the initial negotiations for the establishment of the Australian Resources Research Centre (ARRC) at Technology Park Bentley. CSIRO indicated at that time that there were very few opportunities to participate in problem solving in the Bass Strait venture due to Esso's vertical integration and long-established relationships with overseas problem solving institutions.

[17] DEST *Australian Science and Technology at a Glance* 2004.
[18] Irwin Feller, *Universities as engines of R&D-based economic growth: They think they can*, Research Policy, 1990, vol. 19, issue 4, pages 335-348.