Submission to

House of Representatives Standing Committee on Science and Innovation Inquiry into Business Commitment to Research and Development

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Executive Summary

This submission, prepared on behalf of the Faculty of Applied Science of RMIT University, provides a response to questions from the HRSC on Science and Innovation into Business Commitment to Research and Development (R&D). We set out our understanding of the key issues in the context of a science and investment framework and we draw on studies in the literature to support many of our assertions. We believe that successful innovation is not only dependent on firms having strong technical competencies but also on them having strong co-ordination competencies. Businesses, therefore, need to invest in the physical and engineering disciplines as well as in the behavioural and social sciences. Our discussions centre on why businesses invest in R&D; on the impediments to greater investment; and on the implications for public policy. Challenges are identified for both local factories and university managements. To enhance linkages, a number of questions remain open for further consideration and discernment.

We conclude that companies will not increase their expenditures on R&D unless they can see the value proposition in doing so. Companies, especially small to medium enterprises (SMEs), see R&D as a very personal investment. While companies of all sizes fund research to gain proprietary advantage and to develop new products, processes and services that provide them with substantial economic returns that are sustainable over time, SMEs have a more difficult task. They often do not have the technical, financial or organisational resources available to them to identify needs or to develop a comprehensive R&D plan in the context of their business plan. In most cases they also need to develop a research partner.

We strongly recommend that government policies and expenditures need to:

- Promote more generic research and encourage businesses to pool their contributions through industry and professional bodies. This is particularly true when appropriability is weak. Consideration should be given to defraying expenses of industry funded research organisations to develop and broker research projects for SME client companies.
- Fund more diffusion coordinators in universities, industry and professional bodies for networking and for developing well argued R&D projects and value propositions.
- Enable universities to more strategically develop and market specific areas of expertise and improve timeliness of outcomes to meet the shorter time frames of business.
- Encourage and develop collaborative models that allow businesses and universities to access scientific and technological talent. For example, a suggested model is the funding and support of sabbatical exchanges between academics and industry professionals. This would enhance knowledge transfer and stimulate new avenues for industry-university interaction.
- Provide tax rebates and other incentives to encourage business to specifically employ graduates in auditable R&D activities in-house.
- Enhance tax deductibility and provide accelerated depreciation schedules for projects focussed on national priority areas.
- Reinstate the R&D Start programme with increased funding. Demand for this scheme has demonstrated the considerable willingness of SMEs to take advantage of incentives offered by government. Such policies are appropriate.

Prelude

In responding to the questions raised by the Science and Innovation Committee it is tempting to launch directly into a discussion of the benefits of R&D investment in the physical sciences and engineering disciplines (if only to show why business should be doing more); to identify impediments to such investment; and to discuss how public policy can encourage more private investment. While this response is valid, the Committee also needs to consider that successful innovation requires more than a strong physical science and technology research base. Research in the social sciences is also important. Businesses need to be encouraged to invest in the social sciences as well, particularly in research relating to organisational design, development and behaviour. Management and organisational researchers over the last twenty five years have spent considerable time and effort trying to understand why some firms succeed when others fail; why even in "unattractive" industries firms are successful; why performance differences within industries are often greater than those between industries[1,2,3,4].

Sustained superior performance, it seems, has as much to do with the way firms accumulate, integrate and use unique combinations of resources, skills, knowledge and behaviours to give them a distinctive competency, as it has to do with any advantage that they may enjoy from structural plays. The evidence suggests that competency is not only about developing positioning strategies and business processes, and acquiring tangible assets but, equally, it is about developing people as strategic assets. All these elements appear to be an integral part of the organisational competency equation and need to be considered when putting together a successful science and innovation framework.

Eminent scientists of the past have recognised a need to consider broader possibilities when looking at a reference framework. Niels Bohr's concept of complementarity is manifested in his consideration of the dual nature of light. In the early part of the twentieth century he made significant contributions to the interpretation and development of quantum mechanics in showing that particle and wave descriptions of natural phenomena are mutually exclusive, yet that both are necessary for their description[5]. Perhaps Bohr's *principle of complementarity* was pre-empted and metaphorically articulated in the words ascribed to Sir Ronald Ross who received the Nobel Prize in Medicine in 1902 for his discovery of the link between mosquitoes and malaria. "Science is the differential calculus of the mind. Art is the integral calculus; they may be beautiful when they are apart, but they are greatest only when combined."

The proceedings of a three-part conference[6] celebrating the 50th anniversary year of the publication of the Vannevar Bush Report, *"Science: The Endless Frontier"*,[7] provide

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[1] Rumelt, R.P., "How Much Does Industry Matter?", Strategic Management Journal, 12 (3), 1991.
[2] Prahalad and Hamel, "The Core Competence of the Corporation", Harvard Business Review, May-June, 1990, pp79-91.
[3] Klein, Edge and Kass, "Skill-based Competition", Journal of General Management, 16 (4), 1991, pp1-15.
[4] Sparrow, P. "Organisational Competencies: A Valid Approach for the Future?", International Journal of Selection and Assessment, Vol 3, Number 3, July 1995, pp168-177.
[5] Abraham Pais, "Physics in Denmark: The First Four Hundred Years", Address March 6, 1996, on the 75th Anniversary of the Niels Bohr Institute, www.nobel.se/physics/articles/pais/index.html
[6] "Science: The Endless Frontier 1945-1995, Learning from the Past, Designing for the Future", Centre for Science, Policy, & Outcomes", Columbia University, New York. Conference Highlights Part 1: 9 Dec, 1994; Part 2: 9 June, 1995; Part 3: 20-21 Sept, 1996. www.cspo.org/products/conferences/bush/

much food for thought for this Standing Committee. The conference, *"Science: The Endless Frontier 1945-1995, Learning from the Past, Designing for the Future"*, was sponsored by the Centre for Science, Policy & Outcomes (CSPO), Columbia University, New York. By design this conference, in reflecting on the legacy of the Bush Report, provided an important forum for historic analysis and new concept development. In opening the conference, Provost Jonathan Cole, Dean of Faculties at Columbia University, made reference to President Roosevelt's letter of 17 November 1944 to Vannevar Bush. A question asked by Roosevelt was one that continues to engage governments to this day. It is the same question being asked by this Standing Committee – "What can government do now and in the future to aid research activities by public and private organisations?"

A Science and Innovation Investment Framework

A treatise presented by Professor Donald Stokes at the abovementioned conference provides a very useful framework for considering the R&D question[8]. In this framework the dichotomy between basic and applied research and the competing rationales for funding are largely diffused. Rather than looking at the question of funding in terms of opposing goals - whether the quest for fundamental knowledge and understanding is a more noble pursuit than considerations of usefulness – Stokes' model proposes that both dimensions be considered together. Hence the debate ought to be considered not as a question of basic versus applied research but, in two dimensions, as the quest for fundamental understanding on one axis inspired by considerations of usefulness on the other. Stokes maintained that this better reflected the actual experience of science.

The Stokes' framework is illustrated in Figure 1. Here three quadrants are identified. These he called the Edison Quadrant (EQ), the Pasteur Quadrant (PQ), and the Bohr Quadrant (BQ). The fourth quadrant he did not name although he maintained that it was not empty. This, he believed helped make the point that his model presented a genuine two-dimensional conceptual plane and not just a more elegant version of the Bush basic to applied research linear continuum. Some believe that the fourth quadrant is the quadrant of "junk science"[9]. Others have suggested that it might be called the Darwin Quadrant (DQ)[10] because Darwin, while noting differences in traits in species on the Galapagos Islands, had to be urged to publish his observations. It is said that he was not initially motivated by a quest for fundamental understanding or that he had any useful purpose in mind. Few will doubt, however, that a whole new paradigm was spawned by Darwin's thesis! *This highlights the fact that "considerations of usefulness" are driven by value judgements and/or are bound by the existing paradigm.* Because this dimension is imprecisely defined, culturally and philosophically dependent, it might be considered a

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[7] Bush, Vannevar "Science: The Endless Frontier", U.S. Office of Scientific Research and Development, Report to the President on a Program for Post War Scientific Research, Government Printing Office, Washington, D.C., 1945.
[8] Donald E. Stokes, "Science: The Endless Frontier as a Treatise – Completing the Bush Model: Pasteur's Quadrant", Part 1 – December, 1994. Published in a book by Donald Stokes, "Pasteur's Quadrant: Basic Science and Technological Innovation". Brookings Institute, 1997.
www.cspo.org/products/conferences/bush/partone/treatise.pdf
[9] Peter J. Denning, "Flatlined", Communications of the ACM, June 2002, Vol 45, No. 6.
[10] Phillip Miller, E.J. Taylor, "R&D Funding and the Innovator's Dilemma",
www.circuitree.com/CDA/ArticleInformation/features/BNP__Features__Item/0,2133,26779,00.html

dangerous criterion. Pragmatic considerations of usefulness and "Group Think"[11] can preclude us from considering other possibilities. Nevertheless, rightly or wrongly, more funding for research is likely to ensue if proposals are connected to what the funder or client perceives to be of value.

Figure 1: Stokes Framework – Adapted from Pasteur's Quadrant: Basic Science and Technological Innovation, Stokes, 1997.

EQ: research for practical needs with little desire for a fundamental understanding eg: best light filament material • Moderate risk • Faster response • Engineering / Applied Science solutions • Process improvements • Product evolution / development • Technology development • Incremental improvements • Client / customer focus • The How and When	PQ: research simultaneously motivated by a quest for fundamental understanding of disease and microbiological processes as well as a study of spoilage in milk, cholera in chickens and anthrax in cattle • Higher risk • Longer response times • Science solutions • Quantum leaps • New products • New disciplines / paradigms • Research & Development • Client / customer focus • The Why and How
Not named by Stokes DQ ? (see discussion above) • Low perceived usefulness / utility • Low risk • Low expectations • Observation / confirmation • Skills training • Poorly defined or unknown benefits • Potential dismissed / constrained by current paradigm / value system? • The What	BQ: research into the structure of the hydrogen atom directed towards a fundamental understanding without consideration of its potential use. • Higher risk • Longer term focus • Theoretical developments • Quantum leap potential • New paradigms • Uncertain ill-defined utility • Research / knowledge focus • The Why

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[11] Irving Janis, "Victims of Groupthink" 1972. Boston: Houghton Mifflin.

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Low **High**

DESIRE FOR FUNDAMENTAL UNDERSTANDING / KNOWLEDGE

Included in Figure 1 are a number of attributes associated with each quadrant. While not exhaustive, they help to illustrate features and motivations pertinent to particular projects in Stokes' conceptual framework.

Figure 2 attempts to interpret, from a business perspective, the relative attractiveness of projects. Other things being equal, higher risks and longer lead times tend to discount the perceived value and reduce the attractiveness of PQ and BQ projects. Funding gaps need to be closed by addressing these impediments through appropriate policies.

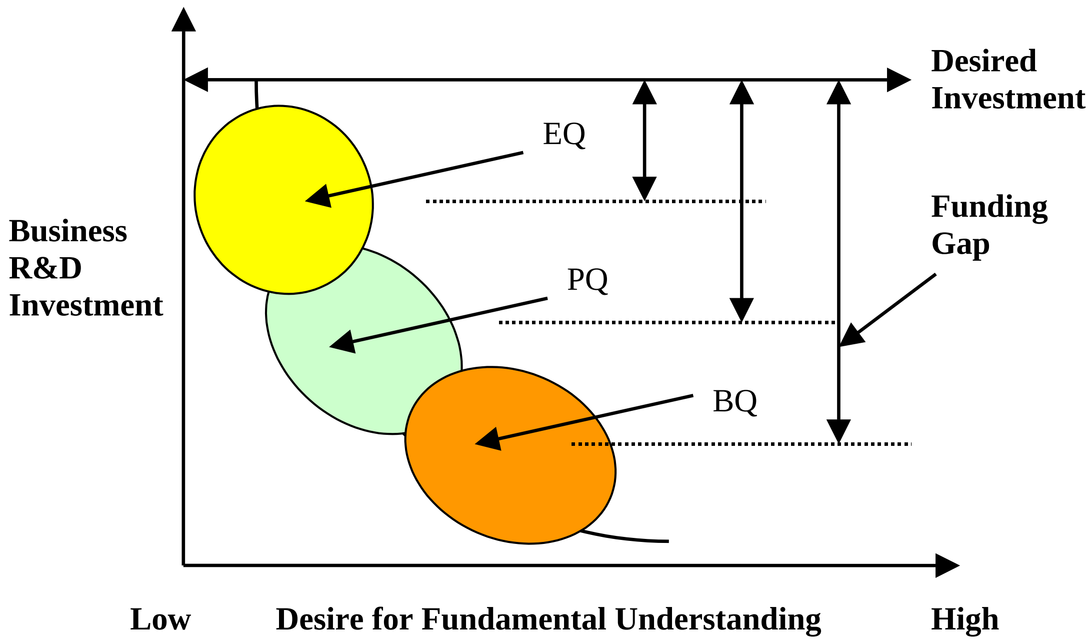

Figure 2: Business investment in R&D is moderated by higher risks and longer time frames of PQ and BQ projects.

Australia's Current R&D Expenditures

Recent figures for 2000-01 released by the Australian Bureau of Statistics and reported in *Australian R&D Review*[12] show that Australia's Gross Expenditure on R&D (GERD) as a percentage of Gross Domestic Product (GDP), at 1.53%, is low compared to many OECD countries. Based on this indicator, Finland spends 2.1 times more than Australia; Japan and USA about 1.8 times more; Korea and Germany about 1.6 times more; France, Denmark, Iceland and Canada approximately 1.3 times more; and the UK and Austria about 1.2 times more. The short fall in Australia's investment ratio is largely because of relatively low business investment in R&D. Australia ranks highly amongst OECD countries in terms of the ratio of government spending on R&D (GOVERD) to GDP, although, at 0.35%, this ratio is at its lowest level since 1992-93 when it was 0.42%. (Australian R&D Review, p13).

In a benchmarking context the above figures suggest that there is a need for governments to stimulate more R&D investment in, and to leverage more funding from, the business sector to complement public sector research funding. In the process, however, public institutions, universities and agencies should not become captives of predominately EQ project investments. While they can contribute significantly, they have a larger role to play in undertaking broader based research and for facilitating the diffusion of basic investigative research outcomes for the public good.

Challenges and Linkage Imperatives

Consider the following scenario:
A local factory of a multinational enterprise (MNE) competes with those in the MNE's global network of factories for resources, including R&D investment capital. It can do so successfully only if it creates value for its offshore parent. This value must go beyond normal financial returns. Future investment in the local factory is dependent on the factory's competencies and cost position relative to other factories in the network. If the local factory fails to go beyond just supplying products in national or regional markets then it becomes vulnerable to closure because it will not attract the necessary investment from "corporate centre" to sustain competitiveness in the longer term. If it is to survive, the local factory must become a focal point for certain strategic corporate-wide activities and contribute know-how to the broader network.

Local management recognises that it must develop and implement strategies locally to broaden capabilities, and then, to exploit them. A key requirement will be to develop linkages that acknowledge the dependency, independency and interdependency of various entities, both locally and from within its own network of sister factories. Technical tasks, including process improvement, product customisation, and ultimately product development will need to be strongly influenced and directed by local plant personnel.

[12] Australian R&D Review, July 2002.

To reduce the time to market new products, the company will require increased efficiency in product prototyping and process design as well as faster problem solving capabilities. Concurrent engineering and improved communications between manufacturing, marketing and engineering will be required both locally and between sister plant locations. The factory will ultimately need to acquire the technical scope of a Lead Plant[13].

This scenario is not unique to this local factory alone. Its predicament can readily be translated to the publicly funded university sector and other publicly funded research agencies. They, too, compete in a global economy. If their endeavours are to attract more investment then they also need to be world-class in their "network of factories". They, like the local factory of the MNE, need to realise that they compete for limited capital resources and will survive only if they can provide differentiated capabilities or unique advantages that deliver value to the society at large and to their clients in particular.

Michael Porter[14] argues that economic geography in an era of global competition and high speed communication networks poses a paradox. Theoretically, location should not be a source of competitive advantage but, in practice, location remains central to competition. He argues that competitive advantage lies increasingly in local things - knowledge, relationships, and motivation – that distant rivals cannot replicate. He describes how clusters of linked industries, institutions and government agencies drive the direction and pace of innovation, stimulate new businesses within the cluster, and increase the productivity of local enterprises in the cluster. Geographic, cultural, and institutional proximity together provide companies with special access, closer relationships, better information and incentives that are difficult to gain from a distance. Fortunately for both the business and the university sector, there is a symbiotic and synergistic relationship or, at least, there ought to be!

If linkages between local universities and local factories are to be strengthened and financial returns on research expenditures realised, then many questions having human, process, structural, and strategic dimensions need to be addressed. The questions below relate to the four basic ingredients of innovation, namely: ideas, people, transactions, and institutional context (after Van de Ven [15]).

- **The human problem of managing attention:**
  How are the different priorities and expectations communicated and managed?
  Can we answer four critical questions: What do we want to do? Why do we want to do it? Who cares? And Why?
  Who are the stakeholders?
  What incentives / rewards are required?
  What is the desired balance between fundamental and applied research / engineering?
  Who will champion / sponsor the initiatives?
  What project management tools need to be formally introduced to map progress?

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[13] For a description of the generic roles of international factories see Ferdows, K.; "Mapping International Factory Networks", Managing International Manufacturing, edited by K. Ferdows, Elsevier Science Publishers B.V (North-Holland), 1989.
[14] Porter, M.E.; "Clusters and the New Economics of Competition", Harvard Business Review, November-December, 1998.
[15] Van de Ven, A.H., "Central Problems in the Management of Innovation", Management Science, Vol 32, Number 5, May 1986.

- **The process problem of managing new ideas and converting them into good currency (value):**
  How are different experiences and knowledge best shared and synthesised to deliver positive and timely economic and educational outcomes?
  How is intellectual property to be protected?
  How do we learn from mistakes and what improvement processes and feedback systems are required?
  What are the criteria for project and personnel selection and evaluation?
  Who evaluates this criteria and at what frequency?
  How are budgets to be determined and expenditures agreed / controlled?
- **The structural problem of managing part-whole relationships:**
  How does one encourage a multi-disciplinary approach?
  How are synergies to be achieved?
  How do we avoid bureaucratic overheads?
  What resources are required from each party?
  What assets / facilities can be shared?
- **The strategic problem of institutional leadership:**
  What are the critical limits within which to operate?
  What should be avoided rather than what ends should be achieved?
  How is a critical mass achieved?
  If empowerment is a function of direction, support and autonomy (freedom to act), then how is it best achieved in the institutional context?
  How is conflict to be resolved?

These questions remain open for further discussion. They are important questions to resolve within universities, and between universities and business, if private sector investment in R&D is to be increased in the university sector.

Why Businesses Invest in R&D

- Companies fund research to gain proprietary advantage and to develop new products, processes and services that provide them with substantial economic returns that are sustainable over time.
- Business investment in R&D is proportional to the potential for improvement in the firm’s competitive position and, therefore, in those technologies that provide opportunities for improved product performance, lower product cost or which can be embodied into new products.
- Companies can enhance technical competency and human capital by participating in R&D collaborations. Technical capability and infrastructure, not available “in-house”, can be leveraged to solve difficult problems and to take advantage of new opportunities not previously anticipated.
- By engaging with public research institutions and universities, companies improve education and training outcomes. Flow-on effects benefit not only the companies involved but also the communities and regions in which they operate.

What are the Impediments?

Impediments to business investment in R&D can be categorised into five main themes, namely:

- Concerns relating to appropriability (the extent that a firm is able to capture and hold the benefits or profits from its investment).
- A predominant emphasis on functionality.
- Concerns that expected returns in the short or long term will not be realised.
- Uncertain technological outcomes and risk aversion.
- Technological myopia[16] or lack of technological policy and strategic planning.

Impediments relating to Appropriability:

- If appropriability is weak then there is a reduced incentive to invest because the knowledge gained from the research can be too easily imitated by competitors.
- Teece [17] provides a framework to explain why a fast second mover or even a slow third mover might outperform the innovator. The argument here is that returns from R&D investment do not necessarily accrue to the investing company because it does not possess or control complementary assets necessary to develop the technology or to market the product. When appropriability is weak then imitators can gain the economic benefits which ought to accrue to the research initiator/innovator.
- University R&D creates knowledge for the "public good". This knowledge is not appropriable to an individual firm alone. Universities have a need to safeguard the open academic environment and to protect research agendas from undue commercial influence. Freedom to publish and to discuss research results is a hallmark of the university and this is often at odds with business objectives. Publications are important for securing government funding and for promotion within universities and government research agencies. This criterion for government funding and promotion may actually be discouraging business investment in university R&D.
- Intellectual property right protection is cumbersome and costly. The cost and time required to acquire a patent is too high and too long. There is no guarantee that patents and licensing agreements, to protect property rights, will not be circumvented.
- Some overseas owned companies operating in Australia like to maintain control of resources and do their research "at home". This can be motivated by nationalistic sentiment, taxation incentives or for appropriability reasons.

Impediments relating to functionality:

- Competitive pressures and shorter product life cycles tend to focus research effort in the Edison Quadrant (low quest for fundamental understanding but high quest for pragmatic utility).
- Pragmatism and functionalism, as perceived in terms of what is known now, are not the only value drivers. Creative ideas and experimentation need to be seen as legitimate and good things.

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[16] Foster, R.N.; "Timing Technological Transitions", from *Technology in the Modern Corporation: A Strategic Perspective,* edited by Mel Horwitch, Pergamon Press Inc, 1986.
[17] David J Teece, "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy", from The Competitive Challenge: Strategies for Industrial Innovation and Renewal, edited by David J Teece, 1987, Centre for Research in Management, School of Business Administration, University of California, Berkley. This paper published in Readings in the Management of Innovation, edited by Tushman and Moore, Harper Business Publication , 2nd edition, 1988. pp621-647.

- Many businesses see R&D expenditures as a cost rather than an investment. Many large corporations when they decentralised to form Strategic Business Units in the mid 1980's devolved many "Corporate Centre" funding responsibilities to SBUs. Corporate research funding suffered as a consequence when particular SBUs withdrew financial support for Corporate R&D Centres. Often this was done for parochial reasons, or because high hurdle rates were set on investment returns in the short term. Some also saw previous expenditures as "taxation without representation".
- "Town and Gown Prejudices". Many business managers believe that researchers at universities do not understand business imperatives. They consider that academics are more interested in knowledge and in philosophical pursuits than in practical and financial outcomes. Many academics believe that business managers lack imagination or are too narrowly and pragmatically focussed.

Impediments relating to timeliness of outcomes and returns on investment:

- Industry focus is too short-term. Many small companies have a "today" focus.
- Results from research (basic and applied) are not immediate enough and are too widely distributed, or there is too high a risk for individual companies to justify the costs.
- Universities have a reputation for not meeting the milestones and deliverables of the original project proposal. This discourages investment and causes a lack of trust.
- Industries see the "full recovery of costs" approach by universities for contract research as non-economic.

Impediments relating to uncertainties / risk:

- Industry research tends to be directed into areas where there are fewer market and technological uncertainties. This tends to favour investment in more applied research and in incremental process and product improvements.
- No guarantee that research commitment can be sustained over the medium to longer term because of funding uncertainty and high mobility of researchers and technical managers. Longer term research requires continuity of employment and stable interactions.

Impediments relating to technological myopia, technological policy and strategic planning:

- Business organisational structures and systems often focus on routine, non-innovative activities. Standardisation within mature industries focuses on maintenance of current practices and loses sight of technological and external environmental changes. This stifles innovation.
- Organisational processes in technology management are not integrated or are poorly defined. R&D investment is delayed until it is too late in the product life cycle. Foster[18] argues that technological myopia contributes to the loss of competitiveness in business. In his estimation there are four possible reasons for losing a competitive position, namely: incorrect perceptions of technical limits; an inability to measure

[18] Foster, op cit

technical progress; faulty interpretation of market signals; and an unrealistic faith in "understanding customer needs". These, he maintains, are fundamental cultural weaknesses that undermine effective technology management.
- Demand "push" from industry researchers in academia rather than a demand "pull" from industry.
- Research funding is considered to be a public responsibility and business has already paid for it through its taxes.
- Many companies are not convinced of the value of research investments and prefer to lobby for concessions rather than address causal realities.
- Some academics view industry research as "second class". There are too few incentives for academics to engage in industrial research. Traditional academic performance measures do not encourage or motivate staff to pursue collaborations with industry.
- Ignorance of current support mechanisms (eg Australian Research Council (ARC) Linkage Programme, AusIndustry Programmes).
- Processes at more formal levels can be cumbersome and overly bureaucratic.

What are the Policy Implications?

Policies relating to Appropriability:

- When appropriability is weak then there is a need to develop policies that promote more generic research and encourage businesses to pool their contributions (eg: through industry bodies such as the Australian Chamber of Commerce and Industry, the Australian Industry Group, Business Council of Australia, AMIRA, Australian Institute of Engineers and other professional bodies).
- Issues around appropriability and complementary assets have implications for government R&D and capital investment policies. To enhance innovation and new product development, R&D policy initiatives need to be matched by policies that simultaneously remove barriers that impede development of complementary assets specific to the technology. This is particularly appropriate in industries where there is already a high degree of market power.
- Policy considerations that enhance access to knowledge, expertise and information flows and support multi-disciplined approaches in generic R&D programmes that have identifiable and quantifiable social outcomes should be a focus.
- There is a role for government in establishing clear intellectual property right guidelines / principles for tied public funding. Currently there is a power imbalance between business and university researchers when negotiating IP rights. University researchers are at a significant disadvantage because they often have little option but to accept industry terms if they are to access limited research funding.

Policies relating to functionality:

- Need to develop mechanisms of cooperation between universities and business that reconcile different outlooks, objectives and time horizons if we are to bring about expanded industry support for university research consistent with core values of academe.

- Government policy should not provide conditions and incentives for firms to upgrade and invest in R&D and product innovation without regard for the common good and longer term environmental sustainability. Industrial activities which contribute negatively in this respect could be taxed or industries forced to invest funds in remediation and/or research directed at minimising harm or the negative consequences associated with their particular activity. This would encourage business R&D investment in more fundamental studies directed at alleviating adverse social and/or environmental consequences and/or encourage state of the art technologies in existing processes.

Policies relating to timeliness of outcomes and returns on investment:

- Need to address performance measures and rewards for academic staff involved in industrial research.
- Universities need to more strategically develop and market specific areas of competency and improve timeliness of outcomes to meet the shorter time frames of business.
- Industry could enhance funding provisions for industrial chairs and centres within faculties. This could significantly enhance the university-industry interface and provide more timely outcomes and knowledge transfers. The interaction between universities and industry is often initiated and sustained through a personal linkage. It is often not legitimised in a formal "organisational" sense. While this may be expedient it can hardly ever be strategic in nature. It could be made so through more direct funding of industrial chairs or centres within the university sector.
- Government could better facilitate research through increased funding of the teaching load allowing more time for academic research and networking.
- Tax rebates and other incentives could be provided to encourage industry to employ science and engineering graduates in auditable R&D activities in-house.

Policies relating to uncertainties / risk:

- Government could provide greater incentives for business to invest in R&D venture capital consortia.
- Government could enhance tax deductibility and provide accelerated depreciation schedules for high risk, private venture projects that are focussed on national priority areas.
- Develop Public Private Partnering arrangements for high risk, long lead time scientific projects considered to be in the national interest.

Policies relating to technological myopia, technological policy and strategic planning:

- Good policies are likely to be industry specific but governments need to focus on those policies that have worked across rather than within industries. Government policy should not try to pick winners. An exception to this may be when new technologies are emerging or where government and business demands or requirements are not specialised or fully specified [19]. R&D investment in generic technologies, where the technology / knowledge is a step or two removed from commercial application and where there is a tension between pure and applied interests should be encouraged. These are programmes in the Pasteur Quadrant. Here desires for more fundamental understandings, simultaneously inspired by considerations of use, tend to satisfy academic and business priorities. These programmes tend to favour more collaborative rather than competitive funding models.

- Encourage collaborative models that allow businesses and universities to access scientific and technological talent. For example, funding to support sabbatical exchanges between academics and industry professionals is suggested. This support would enhance knowledge transfer and stimulate new avenues for industry-university interaction.
- Need to address ambiguities in policies that encourage collaboration but reward competition. If Australia is to avoid being left behind in many new technologies we need to provide greater incentives for collaboration between businesses, research agencies and Australian universities both domestically and abroad.
- While "picking winners" is considered to be risky this largely depends on the level at which strategic initiatives are being targeted. Like corporate business, the nation's R&D portfolio should not be so narrow as to confine itself to a given technology because other technologies may end up being superior. Rather, the nation's Science and Technology R&D strategy needs to be both contemporary and anticipatory. It needs to stimulate current and to initiate new activities to sustain and build up nation-wide competencies that meet present and future priorities. It needs to make explicit those linkages, mechanisms, priorities and processes that the nation uses, or will use, to coordinate resources within and external to it. This is too important a task to leave to the free market or serendipity.
- The government could consider paying the expenses of industry funded research organisations to develop and broker research project opportunities for client companies. This would obviate the need for these organisations to recover their costs via a levy on the research funds raised.
- Various initiatives through AusIndustry assist in the commercialisation of R&D and help bridge the gap between promising scientific discoveries and commercialisation and the adoption of new technologies and best practice. Demand for the R&D Start scheme demonstrated the willingness of business to take advantage of incentives offered by government. Such policies are appropriate. It would seem that R&D Start should be further funded.
- The government should continue to maintain a number of different initiatives and programmes which encourage research collaborations between industry, universities and other research providers. The Australian Research Council (ARC) Linkage Programme encourages industry-university interactions that are important both as a mechanism for researching and solving real world problems and for providing industry-oriented research training. The Cooperative Research Centre (CRC) Programme promotes and supports collaboration between industry, universities and agencies such as the CSIRO. There is a greater need to communicate the benefits of these initiatives and programmes.

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[19] Richard. R. Nelson and Richard. N. Langlois, "Industrial Innovation Policy: Lessons from American History", *Science*, Vol 219, 1983, pp 814-818. Also printed in Readings in the Management of Innovation, edited by Tushman and Moore, 2nd Edition, Harper Business, 1988, pp661-669.

- A significant challenge for academics is to communicate the relevance of research to industry. Many businesses are not aware of the ARC Linkage programme for example, and engagement in them is often initiated through a "hard-sell" by individual academics. Similarly, the President of the Australian Academy of Science in 1997, Sir Gustav Nossal, wrote in *The Australian*, that the CRC Programme is one of Australia's best kept secrets[20]. Arguably little has changed since 1997.

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[20] Article by Sir Gustav Nossal in response to the Mortimer Report published in The Australian, 12 August, 1997.