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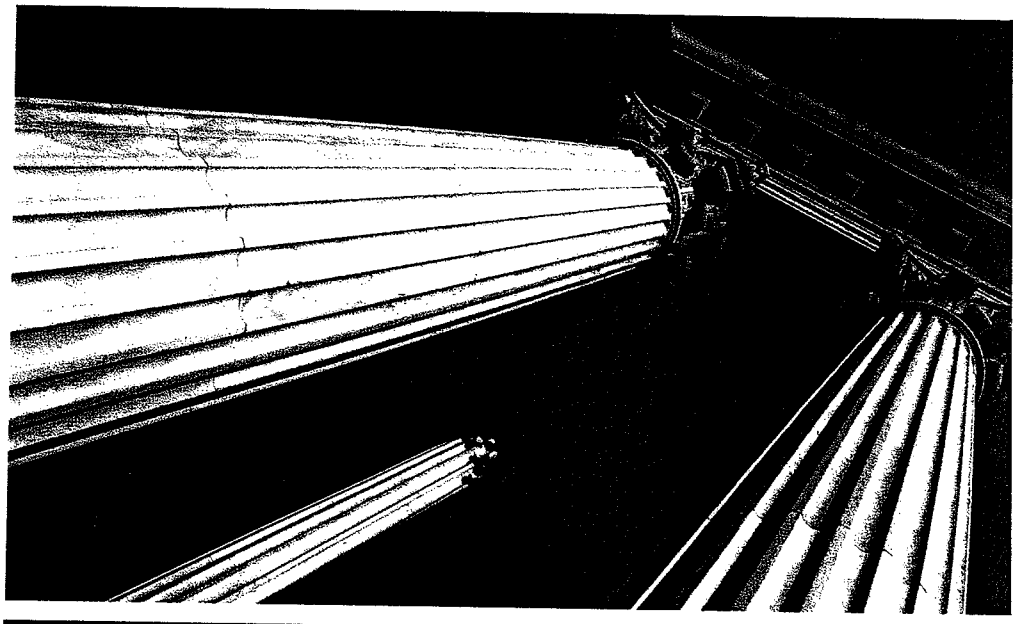

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# *features*

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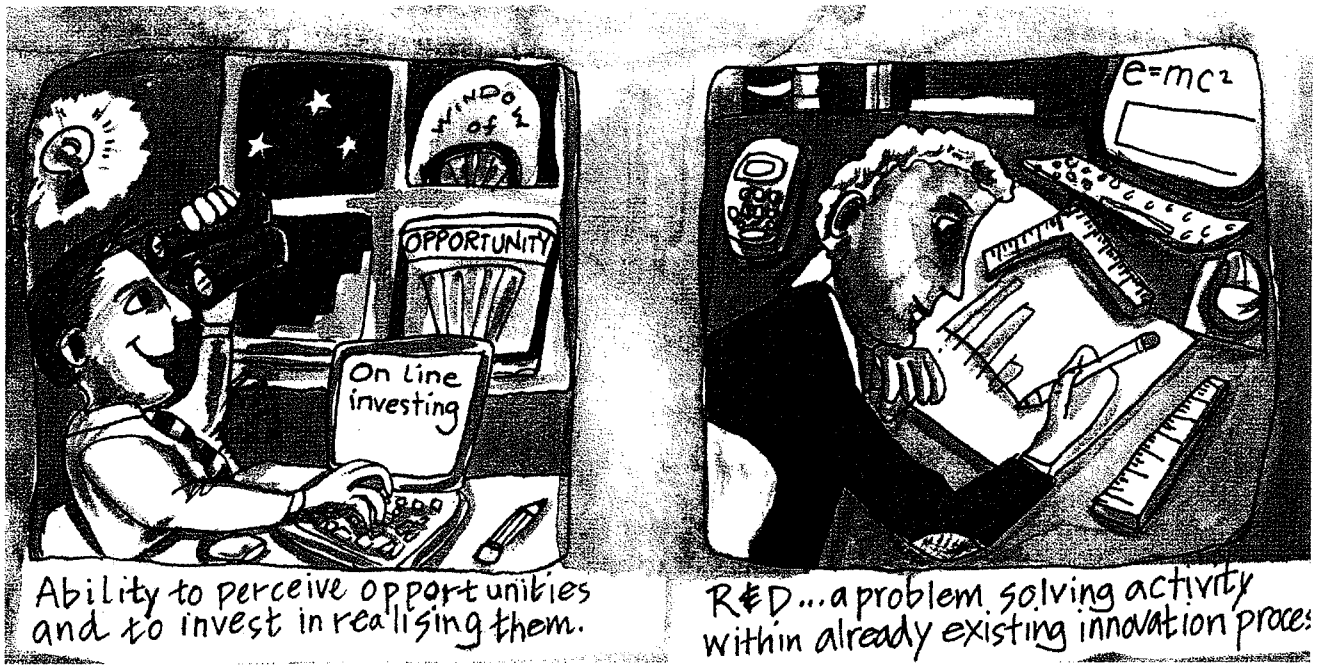
# Australia's innovation challenges: building an effective national innovation system

**Keith Smith and Jonathan West**




*Australia needs to upgrade its national innovation system to address the risk and finance problems faced by business, and to develop a knowledge infrastructure oriented towards the knowledge bases that underpin the economy.*

Australia faces two distinct but related strategic challenges with respect to innovation: the need to create essentially new industries based on radical technological changes; and the pervasive technological upgrade required to retain competitiveness in existing industries.

In order to meet these challenges, current policy tools and approaches will need to be modified to ensure the appropriate role of:

- Australia's 'knowledge infrastructure', such as universities and research institutes, in creating and maintaining knowledge and capabilities for innovation; and
- business in the commercialisation of innovations, particularly in relation to innovation finance and risk management in business creation and development.

Unfortunately, in terms of innovation, the division of labour between the knowledge infrastructure and business, both new and existing, has often been oversimplified and misunderstood.

The problem is not to incentivise the knowledge infrastructure to provide commercialisable knowledge. Rather, it is necessary to separate out the infrastructure problems and the

business development issues. The task of the knowledge infrastructure is to create, maintain and diffuse generic and scientific knowledge bases that support innovation problem-solving across Australia's industrial structure. This requires a long-term, integrated approach to funding and governance.

Commercialising innovations is the task of business, for which new financial mechanisms are needed to create incentives and control risk. We argue that tax incentives and innovation finance both need to be re-thought; we suggest several possibilities, including a system of income-contingent pooled loans for innovation finance.

Our approach is based on research results from a new field, 'Innovation Studies', which focuses on the structure and operations of learning, including science and research and development (R&D) as well as diverse non-R&D learning processes, and on the array of corporate activities involved in bringing innovations to the market. Although persistent innovation is one of the few genuinely defining features of modern society, serious innovation research only began in the mid-1970s. Innovation Studies is now a significant field both in Europe and the United States; it is emerging in Australia.[1]

## Innovation processes and the innovating firm: research results

Innovation cannot be understood in terms of a discovery phase followed by a commercialisation phase. Recent innovation research has recognised that the innovation process varies considerably across industries, and follows different sequences in different technologies.

Robust conclusions from Innovation Studies, relevant to the Australian situation, include:

- Innovation involves continuous interaction and feedback between perceptions of market opportunities, technological capabilities and learning processes within firms. An innovating firm is characterised by the ability to perceive opportunities and to invest in realising them. These strategic capabilities are very unevenly distributed among firms.
- Often, R&D is not a source of innovation but an effect of innovation decisions. R&D should be seen not as a process of discovery that initiates innovation but as a problem-solving activity within already existing innovation processes.
- Solving innovation-related problems often requires recourse to knowledge and skills outside the firm. So cooperation and collaboration between innovating firms and suppliers, customers, design or engineering consultants, universities or research institutes are frequent characteristics of modern innovation processes. In this context, the role of universities and research institutes is not to generate innovations but to solve background problems relevant to innovation processes.
- Innovation requires sustained investment, under conditions of uncertainty, in a range of innovation-related assets — human skills, new capital equipment, design capabilities, strategic marketing, engineering development programs and more. So innovation requires corporate governance systems that encourage such investment and can manage the risks involved.
- A key characteristic of innovation capabilities, at the levels of both firms and countries, is that they are cumulative. They often depend heavily on past investments and sustained investment over long periods.

*Innovation cannot be understood in terms of a discovery phase followed by a commercialisation phase. Recent innovation research has recognised that the innovation process varies considerably across industries, and follows different sequences in different technologies.*

In summary, the capacity to innovate is capability based, cumulative, collaborative in character, and highly uncertain. So any successful innovating economy needs mechanisms and institutions to provide sustained investment in capabilities to manage collaboration and cope with risk and uncertainty and their implications for business development. The 'national innovation system' is the totality of these mechanisms and institutions: it is the overall context within which innovation occurs.

## Innovating industries and their knowledge bases

Much recent innovation policy has focused on 'knowledge intensive' industries, and the so-called 'frontier' technologies that support these industries. In Australia, as in virtually all other advanced countries, this leads to priority research policy areas placing a strong emphasis on information and communications technology (ICT), biotechnology, and nanotechnology.[2] These fields and the industries based on them are R&D-intensive, science-based and closely linked to university research. Industries such as ICT hardware and software, pharmaceuticals (including biopharma), and semi-conducting materials have shown rapid growth in output and trade, although not in Australia.

It is important to foster business growth within these industries: they appear to be areas of major technological opportunities, with unpredictable possibilities for future development; and they have generic applicability as inputs across many other activities, with potentially significant productivity enhancing effects.

It is also very important to keep the industry dimension in perspective. High-tech industries, usually defined as industries with R&D/sales ratios of more than 4 per cent, make up only a small component of manufacturing, and an even smaller component of GDP. There is no OECD economy in which high-tech manufactures make up more than 3 per cent of GDP. All OECD economies, including Australia, are comprised of a combination of large medium-technology and low-technology manufacturing industries (such as food and beverages or fabricated metal products), and large-scale service activities (such as education and health).

Innovation surveys carried out in Australia and many other countries show that these industries contain significant proportions of innovating firms, that they develop new products, and generate significant amounts of sales from new and technologically changed products.[3]

This suggests that it is important to challenge the oversimplified view that high-tech industries are 'leading' sectors, and that growth rests on their technologies in some simple way. Rather, innovation and hence growth impulses are pervasive across the economic system, which would explain why many so-called 'low-tech' sectors and low-tech economies have been growing rapidly. Growth impulses a dispersed across the system becaus innovation also is widely dispersed. Growing sectors innovate in differer ways, with a great deal of variety in methods, approaches and results. This diversity among industries is particularly important with respect knowledge creation.

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## The relationship between knowledge creation and use and distributed innovatio and growth

There are two key modes of knowledge creation and use: R&D-based knowledge and non-R&D forms of knowledge creation. Non-R&D inputs to innovation include, for example, market research, design skills, trial production and testing, prototyping and engineering experimentation, and software development. These non-R&D inputs are essential to innovation across all industries, but they are often a large component of low-tech activities. Non-R&D expenditures on innovatio are usually significantly larger than R&D expenditures, and should not be neglected by innovation policy makers.[4]

Turning to R&D, we can distinguish between internal R&D and R&D that flows into firms and industries from external sources. Internal R&D is a major characteristic of high-technology industries. Indirect knowledge creation, in which industries use knowledge created by R&D elsewhere and deploy it in

ways suitable to their own needs, happens across medium-tech and low-tech industries. It is also a prime form of knowledge creation. This type of indirect, externally created knowledge is of particular importance for the Australian economy.

## How is such knowledge created and how does it flow?

Innovation often happens through an interactive process with other firms, universities, research institutes, etc. Empirical research in a number of countries under the auspices of the OECD has shown that innovating firms are invariably collaborating firms, that collaboration persists over long periods, and that the publicly supported infrastructure (such as universities and research institutes) provides important collaboration partners. The implication is that innovation policy should have a focus that is wider than the individual firm: the focus should be on the 'knowledge infrastructure' within which firms operate.

A striking empirical feature of innovation in the modern era is the vital role of infrastructural organisations in developing and diffusing major technologies. It is surprising how often the fundamentals of major technologies — such as computing, biotechnology, mobile telephony, the GPS system and container transport — have been developed in government labs, publicly owned companies, universities, military R&D programs, etc.[5] Given the prevalence of such infrastructural inputs to modern technology, however, it seems unlikely that their role is merely

## How does knowledge flow between the infrastructure and firms and other organisations?

Knowledge can:

- be embodied in intermediate products and capital goods;
- flow via scientific principles used in engineering design;
- flow via patents and licences;
- flow via technical and engineering consultancy services;
- be exchanged via joint ventures;
- be created through scientific and technological collaboration (informal or formal);
- flow via the education system and movement of skilled personnel; and
- be created via extra-mural R&D and contract research.

All industries engage in most of these activities, most of the time. The cumulative impact, in terms of evolving knowledge complexity, can be significant. For example, the food processing industry performs very little internal R&D, yet it uses complex processing and sensory technologies involving functions related to hygiene and safety, preservation, nutritional quality and logistics. These functions rest on such scientific fields as informatics, biochemistry, and microbiology. This is clearly an innovative, knowledge-based industry with deep links to the science system.

This case can be generalised. Industries such as wine, fabricated metal products, or textiles involve complex underlying knowledge related to the performance properties of processes or products.

maintained and diffused by a netwo of infrastructural institutions. The technological knowledge of the Australian wine industry rests on universities (whose oenology course were arguably the first in the world to put winemaking on a scientific basis), research institutes, producer associations, R&D funding program and an active equipment supply sector.

We can therefore speak of 'distributed' knowledge bases — distributed across many producer and users. So, apparently traditional mature and low-technology industries, as measured by R&D-to-sales ratios, may be users and repositories of high-grade scientific knowledge and thus important loci for innovation. This suggests a need for attention to the nature, characteristics, creation and diffusion of knowledge from the infrastructure

## What is the appropriate role of the knowledge infrastructure in the commercialisation of technologies?

It is helpful to distinguish between three basic levels of knowledge in production and innovation.

First, there is the technological knowledge base of the firm — which is focused on particular products, and therefore highly specific to the particular markets within which a firm operates. A firm's knowledge bases involve localised expertise relevant to skills that have been developed over time, and that offer the firm a competitive advantage in its markets. Firms that are 'bounded' by their existing areas of expertise and vision often have limited long-term strategic capabilities and must frequently look outside the firm to solve innovation-related problems.

A second level of knowledge refers to the generic industry-specific knowledge of firms, i.e. core areas of knowledge capability that are essential to any firm seeking to operate within that industry.

Finally, there is a much wider knowledge base in society as a whole, relating to the broader understanding of properties of nature. This is largely the domain of fundamental sciences, whose extremely wide knowledge set may, in principle, be applied across many industries and activities, and which are important supports across industries.

Our argument is that the knowledge infrastructure should not be involved in the specifics of innovation at the firm level. What is needed from the knowledge infrastructure is problem-solving capabilities related to the generic knowledge of specific industries and broader scientific knowledge bases. The task of the knowledge infrastructure is to maintain the wider knowledge bases to support and develop the actual or prospective industrial structure. This does not necessarily mean an exclusive emphasis on new industries.

In most advanced economies, the largest industrial cluster today is the same as it was 200 years ago: the food sector. But the characteristics of this sector have been massively changed via innovation, and this has been a source of growth. Indeed, no other industry comes close to matching the sustained productivity improvement of agriculture over this period. So, the infrastructure has two major tasks: upgrading what exists, and fostering the new where that can feasibly be created.

This perspective suggests that direct commercialisation of innovations should not be a function or task of the knowledge infrastructure. Commercialisation was defined in a recent Department of Education, Science and Training (DEST) report as 'the process of converting science and technology, new research or an invention into a marketable product or industrial process'. It is very much in focus in Australian policy, which concentrates on the financial and other incentives to promote it.[6]

By contrast, we argue that the challenge for the infrastructure is not to produce commercialisable results, but to create the knowledge conditions that enable new firms to emerge, and existing firms to innovate. The knowledge infrastructure—especially universities and research institutes — cannot substitute for or replace firms as the originators and bearers of innovation. Evidence from international debates suggests that attempts to transform universities and other elements of the knowledge infrastructure into commercial enterprises themselves may limit these institutions' ability to play their most important roles.

An integrated policy approach is needed, resting in the first instance on an appropriate public–private forum or agency that can discuss and debate the knowledge infrastructure as a whole, and its appropriate funding levels and methods, composition and governance. The knowledge infrastructure is a whole-of-government issue. The challenges of thinking through its emphases and priorities, and its areas of continuity and change, should no longer be left to fragmented agencies.

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## Innovation and business creation

If government policy is to promote innovation effectively, it must be based on a realistic understanding of the reasons businesses choose to innovate and the challenges they face in doing so.

*The key to promoting innovation is to tilt the playing field in favor of higher risk-adjusted returns to innovators.*

Firms do not innovate in order to raise productivity or solve economic problems for the country as a whole. They innovate to increase profit and growth, on a risk-adjusted basis, for themselves. Businesses will confront the risk inherent in innovation only if two conditions prevail: the return from innovation is sufficiently greater than that from 'routine', non-innovative, alternatives, and the risk is sufficiently manageable.

Policy makers can substantially influence both these parameters. But it is essential to recognise that the best policy to encourage innovative economic activity might be quite different from that to encourage other economic goals, such as greater investment in infrastructure, more housing, or broader social equity. The key to promoting innovation is to tilt the playing field in favor of higher risk-adjusted returns to innovators.

All nations with successful innovation policies have introduced ways to raise the returns from innovation and to reduce the impact of failure, usually in specified sectors. To define which policy initiatives will realise these goals, it is necessary first to identify accurately what those barriers are. Unfortunately, several pervasive myths exist in Australia about the nature of these barriers.

The first is that Australia needs a more entrepreneurial business culture. *Per capita,* Australians create at least as many new businesses as comparable developed nations. What Australia lacks is not start-up companies but successful growth of these companies into medium and then large-scale enterprises of the type that alone can adequately manage the complex problem-solving and innovation-generating processes. For an economy of its size, Australia has one of the world's lowest populations of multinational innovating companies, especially in the biotechnology sector. Australia enjoys one of the highest rates of new biotech company formation in the world, perhaps the highest, yet suffers one of the lowest average firm sizes and smallest total market capitalisation.

The second myth is that Australian businesses are excessively risk averse. Australia is a world leader in sponsoring and financing raw material exploration, one of the most risky forms of business enterprise known. Why the difference with biotechnology, for example? This needs further exploration, but an answer is likely to be found in the accumulated knowledge base of Australian management, along with the structure and incentive investment managers themselve both of which appear to militate against technology risk.

The third myth is that Australia lacks the financial resources to experiment with new technologi and that its domestic market is insufficient, and too remote, to support innovation. Compared w other successful nations, howeve Australia's economy is of ample Sweden, for example, possesses least 20 multinational enterpris that are industry leaders on a gl scale — yet its population is 8 m Australia has more than twice tl Swedish population, and has the fourth-largest pool of privately managed investment capital in t world — in the shape, primarily, its superannuation funds.

The key challenge of business innovation in Australia is that w often fail to construct sustainabl complex, growth-oriented busine enterprises necessary to bring a stream of innovations to market

The wine industry provides an instructive example of what Australia's innovation system dc well, and at what it fails. Over the past two decades, Australian have been responsible for a strea of world-beating innovations in viticulture and viniculture, and

*The key challenge of business innovation in Australia is that we too often fail to construct sustainable, complex, growth-oriented business enterprises necessary to bring a stream of innovations to market.*

have been successfully brought to market. The industry has been an exemplary example of invention plus commercialisation driving dramatic growth. Universities and research institutes have cooperated with growers and winemakers to produce new varieties and techniques, and create a vital, sustained, export industry.

Importantly, however, Australia has failed in the *business dimension* essential to capture value from this innovation. In spite of its success in growing tonnes of grapes and shipping litres of wine, and even in creating global brands, Australia's wine industry has manifestly failed to build world-class companies that can independently market and distribute their product. With one faltering exception, all major wine export, marketing, and distribution out of Australia is now foreign owned. The lion's share of value created by Australia's wine innovators thus flows to overseas equity holders.

By allowing higher returns for innovators and helping innovators bear risk, policy makers can create more favourable conditions for entrepreneurs to build the kind of business enterprises that will sponsor innovation, take ideas through to commercialisation and capture value from it.

The first aim can be achieved by discriminating between innovative and 'routine' business activity in pricing and taxes. In essence, all governments that have successfully promoted innovation allow innovators to charge more for these products or services, for a specified period of time, and provide them with some form of tax benefit, the most effective being related specifically to the needs of particular technologies.

The second aim can be achieved by supporting the diversification of risk. Innovation is much more risky than 'routine' economic activity because it intensifies each of the major forms of business risk: technical — 'will the product work as hoped'; market — 'will customers buy this previously unknown item'; and managerial — 'can this team work together under unexplored conditions to bring this successfully to market'. After firms and investors make the necessary attempts to reduce the risk to which they are exposed, the only known way to manage risk is to diversify it, in the hope that in a pool of 'bets' winners will more than offset losers.

As a pooler of risk, government enjoys three potential advantages over the private sector: it can diversify across a wider base, i.e. the entire population; it can take its returns in non-financial forms such as increased productivity, improved health and more jobs; and it can invest more for the long term. These advantages potentially allow government to act as a risk-bearing partner with private firms, and to enhance their own risk-bearing capabilities.

Three distinct forms of economic vehicle have been employed by governments around the world to assist private firms diversify innovation risk. The first is subsidised loans from commercial banks, in which default risk is borne partially by government and partially by the banks themselves. Such subsidies increase the willingness of commercial banks to lend to innovators, but do not substitute government officials for the due diligence process of private investors.

The second is greater support for venture capital, especially through reduced capital gains tax for technology innovators. It is worth noting that even at half the marginal tax rate, Australia's capital gains tax is close to double that of the United States. Many governments also form joint-ventures with private investment firms to increase venture-capital funds under management.

The third avenue for government is a system of pooled income-related loans. The European Union employs this approach to finance the highly successful Airbus enterprise. European Union Member States provide government loans at commercial rates to cover 33 per cent of development costs for each aircraft project. These are not repayable if the project fails but are fully repayable with additional royalties if the project succeeds. European taxpayers have made substantial profits from these royalties.[7] Australia has pioneered pooled income-related loans to finance higher education but it has not yet deployed this instrument in support of innovation.

For any of these vehicles to support diversification of risk successfully without inducing undesirable economic behavior, however, certain conditions would need to be met. The first is that private investors, not government officials, select investments, and that they do so based on commercial criteria, not on, for example, the basis of political ideals, or worse, 'who is a mate of the Minister'. This proviso is essential to ensure that innovation does not

become a game of government-relations prowess or corruption.

The second criterion should be that private investors themselves bear at least some of the risk. This is necessary to guard against behavior in which entrepreneurs deliberately take the greatest risks, which when borne by someone else (the taxpayer) can encourage adventurism in the hope of occasional major pay-offs.

The final criterion should be that government-subsided investments gain a return that can replenish the pool, even if not a venture-capital-level return. In all cases, innovators should be required to return taxpayers' money when successful, not be simply the passive recipients of non-repayable grants.

Our argument therefore is that Australia has two fundamental needs concerning innovation. The first is for a modified knowledge infrastructure policy, less focused on direct commercialisation, and more oriented towards the generic and scientific knowledge bases that underpin the Australian economy. The second is a modified business development system, addressing the real characteristics of the innovation problems faced by business. ■

## ENDNOTES

[1] The most comprehensive overview of the field is Jan Fagerberg, David Mowery and Richard Nelson (eds) 2004, *The Oxford Handbook of Innovation* (Oxford: OUP).

[2] See http://www.dest.gov.au/priorities/transforming_industries.htm#1 for an overview of Australia's research priorities in economic fields.

[3] In all sectors of the Australian economy at least 30 per cent of firms are innovating over any 3-year time period. In manufacturing, the most intensively innovating sectors are machinery and equipment and chemicals, each with about 50 per cent of firms innovating. Nevertheless in such 'traditional' industries as food products, textiles and metal products between 30 and 35 per cent of firms are innovating: see Australian Bureau of Statistics 2005, *Innovation in Australian Business 2003,* 8158.0, Canberra, pp.7, 10.

[4] In 2003, Australian innovating firms spent $A5.8 billion on R&D, and $A13.1 billion on non-R&D innovation inputs: see ABS 2005, *Innovation in Australian Business 2003,* p.8.

[5] There are numerous examples, of which the most spectacular is the US success in computing, which had its roots in major infrastructure investment by government. For an overview, see Computer Science and Telecommunications Board 1999, *Funding a Revolution. Government Support for Computing Research* (Washington USA: National Academy Press).

[6] DEST 2005, *Evaluation of Incentives for Commercialisation of Research in Australian Universities,* March.

[7] 'Let us go back to 1970 for one minute. Imagine if I had gone then to a bank and said, 'I have just started a management team from various European countries. I intend to make large aircraft to compete with Boeing. Will you lend me $1 billion? You may lose all of it. Or you may start to make some money 20 years from now. I leave to your imagination the welcome I would have had. No financial institution would have taken on such a risk, or if it had, the interest rates would have been simply prohibitive. It was therefore up to the governments of each of the countries participating in Airbus Industrie to substitute themselves for the bankers and assume such risks', Jean Pierson, Managing Director, Airbus Industrie, April 1991, at a lecture at Cranfield Management School, quoted in: Lynn 1995, *Birds of Prey,* p.150.


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