Innovation Systems in Australia[1]

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1. Innovation Systems Frameworks

Countries differ in their capacity to produce, acquire and use knowledge. They differ in the level of their investment in innovation, the roles of the public and private sectors, the industries and technology fields of greatest importance and the rates of change in those patterns, the level of cooperation among organisations, the modes of financing innovation, attitudes to risk taking, the regulation of the labour market and the role of large and small firms. In short, they have different 'innovation systems'. The structure, functioning and integration of the various components of the national innovation system (NIS) have a major bearing on the level, and continuing upgrading, of a nation's innovation competencies. These competencies play a central role in economic growth and change.

Following the seminal works of Freeman (1987), Lundvall (1992) and Nelson (1993), there have been a large number of studies of national innovation systems. These studies have sought to analyse the ability of nations to generate, diffuse and use economically significant knowledge. However, there have not been any comprehensive studies that have analysed Australia from a national innovation systems perspective.

How can we analyse Australia from an innovation systems perspective? The NIS approaches do not provide any 'ready to use' frameworks. Studies that use a national innovation systems approach tend either to assume a high level of homogeneity *within* nations, or to focus on only some components of the NIS – often the R&D system. Many studies use a range of innovation-related indicators. [2].

This chapter outlines three complementary indicator-based analyses, each of which reveals important characteristics of the Australian innovation system:

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[2] While valuable in raising issues and questions to be investigated, indicator approaches rarely provide real insight and answers. There are three particular problems with indicator-based approaches: the indicators are based on relationships (eg R&D inputs drive

- A review of traditional innovation-based indicators, presented here in terms of two contrasting perspectives on Australian innovation performance;
- An analysis of patterns and trends in R&D activity at the national and state level; and
- An analysis of patterns and trends in Australia's technological and scientific specialization.

The final section identifies several characteristics of the Australian innovation system, and then to develop several more speculative interpretations of the evidence.

2. Innovation Systems: An Analytical Perspective

National innovation systems can be understood as a nation's capacity to generate, diffuse and use economically significant knowledge. Innovation systems evolve and a primary endogenous driving force is learning: "if knowledge is the most important resource, then learning is the most important process" (Lundvall, 1992). Learning is the central process not only in the generation of knowledge but also in the diffusion and use of knowledge. Learning occurs at the level of individuals and organizations but also through various forms of *interactions* between actors: eg firms, government agencies, universities, and formal or informal 'bridging organisations'. Among the more important mechanisms for interactive learning are producer-user networks, the pooled labour market, informal meeting places, etc. These patterns of interaction draw on established networks based on antecedent innovations and production links that may only slowly include new actors. For this reason these interactions may lead to path-dependencies in innovative search.

These learning processes are set by *nation specific circumstances,* including the accumulated skills and capabilities of firms, national laws and regulations, culture and the specialisation in research and education, and are derived from its history. Lundvall (1992) conceptualised a national innovation system as consisting of two main parts: the economic structure and the institutional set-up. The *economic structure* refers essentially to what a nation produces - products, services, technologies, the labour force, skills etc..[3] The economic structure largely shapes ***what*** 'nations' learn. For example, if a country has a large mining industry, then different actors are likely to learn a great deal about large

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innovation) that are themselves in question; aggregation leads to a serious loss of information; there are no indicators for many important categories.

[3] Note that even if there is not a one-to-one relation, the economic structure reflects the technological and industrial specialisation of a country. To some extent then, the economic structure can be analysed through the means of taxonomies (Pavitt, 1984, Soete 1989, Miles and Coombs 1999) simply by associating data on the economic structure to the various categories in the taxonomies.

projects and logistics. An economic structure may be more or less beneficial in terms of current market growth trends[4].

The *institutional set-up* refers to the structure of organisations and institutions, and includes the nature and processes of (product, capital, labour, equity, IP) markets and networks, strategies of firms, the type of regulation and structure of incentives shaping, reinforcing or constraining the direction of the innovative search.[5] Hence, the institutional set-up refers to ***how*** the generation, diffusion and use of economically useful knowledge takes place.

3. The Australian Innovation System: Alternative views on performance

Assessing Innovation Related Performance

Indicators derive their meaning from assumptions about what phenomena are important and how they can best be estimated. The relationships between innovation and economic activity are complex, involve interactions, lags and feedbacks, and evolve continuously. Understanding these relationships requires attention to multiple dimensions, including institutional issues Deviations from the performance of a 'model' economy (typically the USA) or from 'best practice' exemplars among OECD countries in specific dimensions do not necessarily signal a problem. Countries are not arrayed along a path of inexorable development. Nevertheless, such comparisons (Figure 1 and Figure 2) can be useful for characterising innovation-related performance if we bear in mind the structure and history of the Australian economy:

- **Diversity**. Australia's population is concentrated in several cities distant from each other. Agriculture is a major industry but is diverse – operating in temperate, tropical and semi-arid areas. Mining is a major industry, but across a continent mining is highly diverse involving coal, iron ore, gold, aluminium, silver, mineral sands, nickel, diamonds etc- each with different requirements for capital goods, services and infrastructure.
- **Historical legacy.** The legacy of import substitution industrialisation, was a range of institutions (eg labour market regulation, attitudes to entrepreneurship), innovation-related infrastructure (a well developed public education and research system, but poor research-industry links in many sectors) and competences (low management and R&D capabilities in

[4] For example, a high level of dependence on ICT exports was a 'good thing' in 1999, but far less attractive in 2002.
[5] The concept organisation here covers all types of organisations, such as firms, policy agencies, universities etc. The notion institution refers to either pervasive or persistent patterns of behaviour in the nation or rules or regulations within a country.

industry) that continued to impede innovation performance even when the incentives for innovation increased, following the opening of the economy[6].

- **Industry structure.** Primary products account for about 8% of Australian GDP (the level for about 30 years), above most OECD countries. The manufacturing share of GDP (about 12% in 2000) is lower and declining faster than in most OECD countries. The services sector is larger (79% of GDP in 2000 and has risen more rapidly than in most OECD countries. Australia has a relatively very small 'high-tech' manufacturing sector. This sector, and particularly large firms in this sector, account for the majority of BERD, and most interaction with the public sector research system in most OECD countries.
- **Firm size**. Australian industry has a relatively large proportion of small firms and small firms (less than 100 employees) account for a relatively large share (almost 30% in 1999) of BERD.[7] Such small firms account for twice the proportion of BERD in Australia as in Canada or Finland, and three times more than in the US or the UK.
- **Trade.** Australia's trade intensity (trade/GDP) is relatively low, closer to the low trade intensity of large economies like the USA, Japan and France, than to the high trade intensity of small countries like Ireland, Finland, Sweden and Canada. Australia did not participate in the strong growth of trade in manufactures of the 1970s, losing opportunities to develop economies of scale.
- **Specialisation.** Australia has a relatively low level of technological specialisation for a small economy – small advanced economies tend to be quite specialised in some fields of technology. Whereas most countries have become more specialised over the past 20 years, Australia's level of specialisation has remained more or less constant. Australian specialisation is in agriculture, primary metals, mining and oil & gas- a pattern quite similar to that of Canada and Norway.[8]
- **Foreign ownership**. The level of foreign investment in Australian industry is relatively high, and particularly high in the R&D intensive sectors. Overall, foreign affiliates account for almost half of the R&D in Australian manufacturing, a level far higher than all but a few other OECD countries[9]

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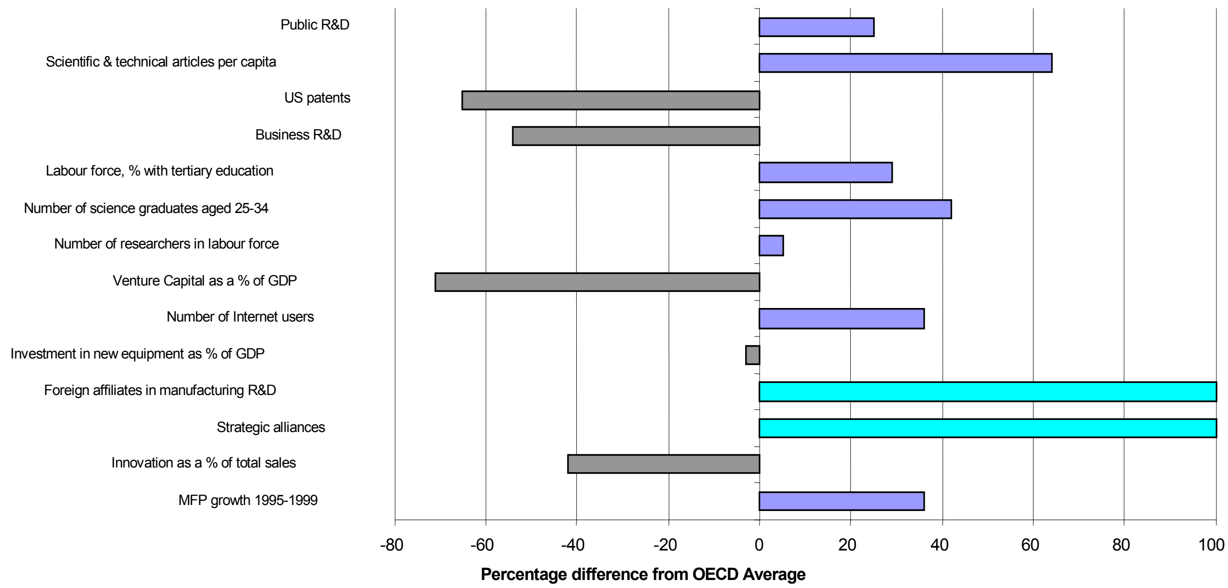
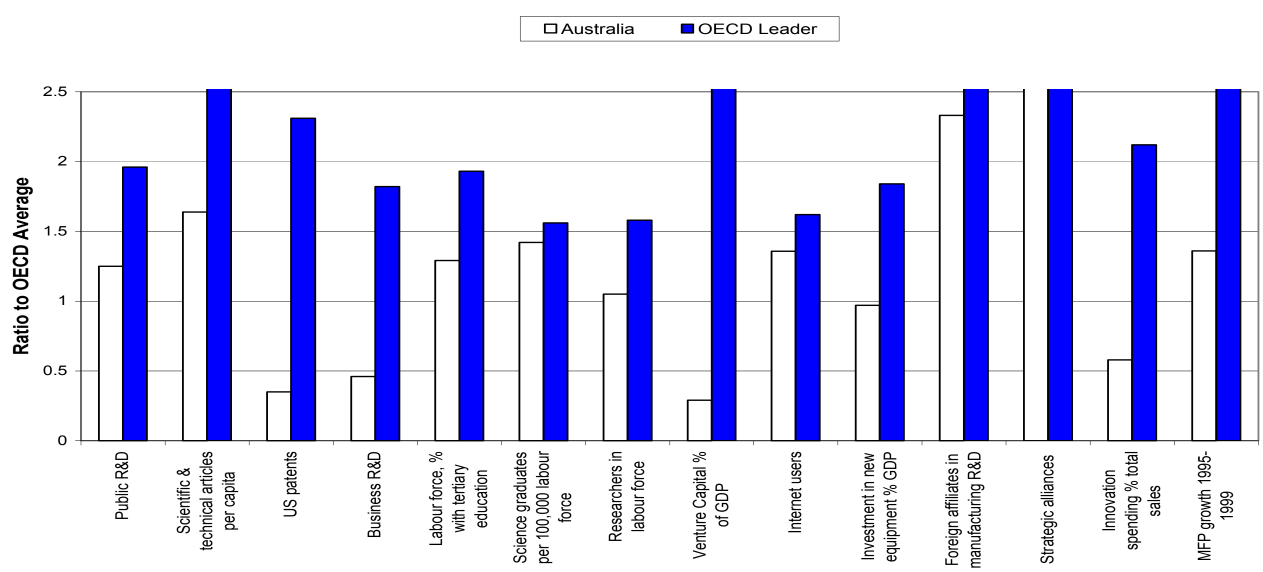
[6] See for example: Elek, Camilleri & Lester. The Role of Technological Change in Australian Economic Performance. Centre for Economic Policy Research. ANU. 1987, and Sheehan, P. and G. Messinis. Innovation in Australia.
[7] The Allen Consulting Group. Systematic Mismatches in the National Innovation System. 2000.
[8].Aggregate patent performance is a poor indicator of Australian performance, because much technological activity is in fields of low patent activity and also activity in 'high tech' fields tends to be in narrow niches rather than broad fields.
[9] DITR Australian Innovation Scoreboard. 2002. (2003)

Figure 1. Australia's Innovation Performance Compared to OECD Average*



Sources: ABS (2002a, 2002b, 2002c, 2002e), OECD (2002a, 2002d, 2002e, 2002f, 2002g, 2001a, 2001b, 2001c, 2001d, 2001e), US Patents & Trademark Office (2002) and World Competitiveness Yearbook (2002)

Figure 2. Australia's Innovation Performance Compared to OECD Leader*



Sources: ABS (2002a, 2002b, 2002c, 2002e), OECD (2002a, 2002d, 2002e, 2002f, 2002g, 2001a, 2001b, 2001c, 2001d, 2001e), US Patents & Trademark Office (2002) and World Competitiveness Yearbook (2002)

It is possible to assess a wide range of indicators of the many aspects and dimensions of Australia's innovation system, and of innovation-related performance, and reach two quite different conclusions: either that the innovation system is robust and adaptive; or alternatively that it is weak and 'locked-in' to 'old' patterns of specialisation.

Chart 1: Alternative Perspectives on Australia's Innovation Performance

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The Dynamic Growth Perspective

Australia is a broadly based dynamic and flexible economy, diversified across markets, and increasingly sectors, underpinned by competitive domestic markets and flexible labour markets. High-level human resources and strong research organisations facilitate the rapid uptake of new knowledge produced anywhere. Imported knowledge and equipment combined with local knowledge and capability supports active problem solving and systems integration in a range of sectors generating relatively high levels of productivity. A 'fast-user' strategy combined with natural and human resources is a sound basis for future prosperity. A focus on R&D and patents misses the level of dynamism in technology adaptation and application. Key indicators of this performance include:

- High and increasing productivity;
- Relatively high level of public sector R&D;
- Substantial growth in niches markets in key manufacturing sectors: telecom equipment, wine, boats, automobiles and components;
- Maintaining strong competitiveness in resources sectors through the effective application of new technology, including IT;
- Increasing technological specialisation in biotech and pharmaceuticals;
- High FDI as % of GDP;
- Strong performance in international science;
- A strong ICT services sector and high growth in 'knowledge based services';
- Rapid and broadly-based uptake of ICT.

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The Laggard Perspective

The Australian economy maintains a high level of dependence on natural resources and is failing to develop sustainable new areas of specialisation and growth. Productivity growth in the 90's is the result of one-offs: micro-economic reform and the uptake of ICT. This performance masks underlying weaknesses in new firm formation and in the growth of new internationally competitive industries. The poor performance of Australian firms in R&D and patenting signals the weaknesses in management, scale and international positioning of Australian industry. Australia's declining position in 'high tech' sectors and the declining international significance of its science and patents indicates the extent to which Australia is being left behind the frontier of innovation and growth in the world economy.

- The 3rd lowest ranked in the OECD in gross expenditure in R&D and one of the lowest in business R&D;
- The lowest expenditure on innovation among OECD countries;
- A relatively very low level of investment in venture capital;
- International patenting activity (per mill. pop'n.) is one of the lowest in the OECD;
- 80% of the top fifteen export products are resource-based commodities with a low level of processing;
- A large and growing trade deficit in ICT products and services.

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Chart 3 Dynamic Growth Perspective

Innovation-Related Investment

- Australia has been a leader in pubic investment in R&D and particularly in relative investments in basic research. Government investment in R&D as a proportion of GDP is slightly greater than the OECD average[10].
- 'Knowledge-based industries' contribute 31% of GDP (in 2000) and 'knowledge workers' represent 38% of the labour force – levels similar to comparable OECD countries. The proportion of 'knowledge workers' in the labour force increased at a similar rate to most other OECD countries[11].
- Expenditure on higher education (1.6% of GDP) is comparable with the OECD average..[12]
- About 18% of the Australian workforce has tertiary qualifications, above the OECD average (14%)[13].
- About 24% of tertiary students in Australia are in 'science & technology' fields, above Canada (16%) and the US, but below Finland (38%) and many other OECD countries. [14]
- Industry investment in workforce training increased strongly through the 1990s[15].

Innovation-Related Performance

- Australian production of scientific and technical articles (about 700 per million population) is greater than the OECD average (about 450/million).16
- MPF growth (1.4-1.5% pa over 1990-99), was comparable to or better than most OECD countries.[17]
- The growth in GDP per hour worked (about 2% pa over 1990-99), was one of the highest among OECD countries.[18]
- By the early 1990s R&D intensity in some Australian manufacturing sectors (eg metal products, iron & steel, shipbuilding) was above the OECD average. The service sector in Australia was a particularly strong R&D performer[19].

Linkages

- Foreign direct investment inflows over the 1990s (1.75% of GDP) were well above the OECD average (1.0%), but outflows (0.8% of GDP) were well below the OECD average (~ 1.4%).[20]
- Australia has Australia has been estimated to have one of the highest levels of international inter-firm alliances (about 5.5 per US$ billion GDP) in the OECD. This level is similar to that of Canada.[21]
- Over the past 20 years the rate of growth of Australia's trade intensity has been among the most rapid in the OECD, similar to Canada and Finland. The growth in export performance has been increasingly broadly-based in terms both of products and markets[22].

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[10] DEST Australian Science at a Glance. 2002.
[11] DITR Australia as a Modern Economy, 2002. . Estimates based on OECD categories.
[12] Ibid p19.
[13] DITR Measuring Innovation Performance. Current Status and Future Considerations. Draft April 2003.
[14] DITR Australia as a Modern Economy, 2002; p36. Figures are for 1987-1997.
[15] AEGIS The High Road and the Low Road. Australian Business Foundation. 1997.
[16] DITR Australia as a Modern Economy, 2002; p45. Figures are for 1997.
[17] OECD STI Scoreboard, 2001.
[18] Ibid.
[19] DIST Australian Business Innovation. AGPS 1996.
[20] DITR Australia as a Modern Economy, 2002; p20 . Estimates based on OECD categories, for 1990-98
[21] OECD STI Scoreboard, 2001. Figures are for the 1990-99 period.
[22] Working Paper 4: Assessing Australia: Characteristics, Innovation, Structure and Specialisation

Exploring New Innovation-Based Opportunities

- Australia is reported as having a high proportion of the population working in new firms (17%), significantly higher than Canada (11%) and Finland (9%). [23]
- Australia has the third highest level of **expenditure on ICT** (10.5% of GDP) in the OECD[24]. The rise in ICT expenditure in the 90s has been comparable to other OECD countries.
- The share of **ICT investment** in total non-residential investment has risen steadily since the 1980s (22.5%) is the third highest in the OECD[25]
- The rate of growth over the 1990s of Australian **biotech patenting** in the US (about 18% pa) was one of the fastest in the OECD (av. 8% pa)[26]
- Australia has steadily increased its relative level of specialisation in most medical-related fields: pharmaceuticals, biotechnology, and medical instruments[27].
- Exports of knowledge based services have grown strongly over the 1990s, and as imports have declined as a proportion of GDP, net exports have grown more rapidly than for most other OECD countries[28].
- Australia's relative export specialisation in resource-based products (largely minimally processed) has increased over the past 30 years. Wine and boat building emerged in the 1990s as new areas of comparative specialisation.[29]

[23] Global Entrepreneurship Monitor 2001. Figures are for2001 and the data were developed from surveys.
[24] DITR Australia as a Modern Economy, 2002, p3. . Estimates based on OECD categories, for 2001.
[25] DITR Australia as a Modern Economy, 2002, p5. . Estimates based on OECD categories, for 2000.
[26] US Patent and Trade Mark Office. Data for 1992-99
[27] Working Paper 4: Assessing Australia: Characteristics, Innovation, Structure and Specialisation.
[28] DITR Australia as a Modern Economy, 2002. . Estimates based on OECD categories and cover the period 1990-2000,
[29] Working Paper 4:Assessing Australia: Characteristics, Innovation, Structure and Specialisation. Based on Revealed Comparative Advantage scores.

Chart 4 Laggard Perspective

Innovation-Related Investment

Business investment in **R&D** (about 0.65% of GDP) is one of the lowest in the OECD, less than half the OECD average (about 1.4%). Business R&D (BERD) grew strongly through the early 1990s, declined from 1995 to 2000 and has increased from 2000 to 2002. [30]

Overall **R&D** investment levels rose from the mid-1980s to the mid 1990s to levels (about 1.6% of GDP) significantly below the OECD average.

Expenditure on innovation by manufacturing firms (estimated at about 1.9% of sales) was one of the lowest in the OECD. [31]

A relatively low proportion of Australian managers hold tertiary qualifications[32].

Innovation-Related Performance

Australian **patenting** levels in the US (about 40 per million population) are comparatively very low, less than a third the level of Canada and Finland. Australian patenting in the US grew over the 1980 – 2000 period at a rate similar to other OECD countries, but as a consequence the 'gap' in patenting level widened. Australian patenting in the US is more widely dispersed, with fewer areas of high specialization than is the case for most other OECD countries.[33]

Medium-high technology and particularly high technology industries account for a relatively small share of Australian **exports**, about 32% compared to the OECD average of about 65%. Despite a growth in trade intensity Australia's deficit in medium and particularly high tech products has widened through the 1990s[34].

Over the 1985-95 period, employment growth in Australia was largely in sectors of low innovation-related investment (R&D, training)[35].

Broadband penetration rates at 0.57 per 100 people are significantly below the OECD average (1.96 per 100 people) and comparable countries such as Canada (6.3%)[36].

Linkages

From the early 1990s the role of FDI inflows (%GDP) increased strongly in most OECD countries – but not in Australia, where Australia's share of FDI inflows declined markedly. The relative size of the stock of FDI in Australia (FDI stock/GDP) is one of the highest in the OECD.[37]

While Australia has a relatively high number of alliances, a relatively high proportion of these are domestic and a relatively low proportion are 'technological'.[38]

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[30] DITR Australia as a Modern Economy, 2002; p34-5. Figures are for 1999.
[31] Ibid; p36. Figures are for 1997 for Australia and 1996 for other countries.
[32] Industry Task Force on Leadership and Management Skills. Enterprising Nation (Karpin Report) Canberra: AGPS; 1995)
[33] Australian Research Council & CSIRO Inventing Our Future 2000. p27 and DITR Australia as a Modern Economy, 2002; p43
[34] AEGIS (1997) The High Road and the Low Road. ABF. ;Sheehan, P. and G. Messinis. Innovation in Australia.
[35] AEGIS op cit
[36] DITR Australia as a Modern Economy, 2002; p13.. . Estimates based on OECD categories, for 2001.
[37] Ausis 2003 Working Paper 4:Assessing Australia: Characteristics, Innovation, Structure and Specialisation. Based on Revealed Comparative Advantage scores. IMPP. ANU
[38] OECD (2001 and OECD STI Scoreboard (1999). The latter trend may be a result of the former and both may be due to Australia's relative isolation.

Exploring New Innovation-Based Opportunities

Investment in Venture Capital (about 0.06% of GDP) is below the OECD average (about 0.14% of GDP).[39]

The proportion of venture capital directed to early stage funding appears to be relatively very low.

Australian firms tend to focus less on innovation in products and services than do firms in other countries, and have markedly less confidence than do firms in other countries in capturing value from innovation. [40].

Some evidence indicates that the level of entrepreneurial activity in Australia, while increasing, is lower than in many other OECD countries[41].

While ICT imports (~3% of GDP) are the average level for the OECD, ICT export levels are relatively very low (1% of GDP) less than a third of the OECD average[42].

Because Australia has a relatively very small ICT manufacturing sector, the share of ICT employment in business employment (about 4.6%) is one of the lowest in the OECD[43]

The rate of growth over the 1990s of Australian **ICT patenting** in the US (about 10% pa) was below the OECD average (13% pa). [44]

Australia has increased its relative level of patenting activity in the 'traditional' resource-based fields[45]

Overall Australian patenting tends to be in areas where technology is moving less rapidly and Australian patents tend to have a relatively high level of linkage to science but to be based on older prior knowledge[46]

Australia has increased its relative export specialisation in resource-based products. Canada and Finland also have a comparative export specialisation in resource-based products (largely wood), but these are significantly processed prior to export and both of these countries have strongly increased their relative specialisation in high VA manufactured products[47].

Characterising the Australian Innovation System.

Before an initial assessment of the performance of Australia's NIS it is useful to draw out three systemic characteristics of the NIS:

- **Resource-Enabled, Knowledge-Based, Competition-Driven Innovation**.

  Mining and agricultural industries have a vital role in Australia's balance of trade. A substantial part of Australia's research system is linked to these industries, as are a wide range of manufacturing and service sector suppliers. The performance of much of Australia's mining and agricultural industries is dependent on innovation based on complex technologies and high-level

[39] OECD STI Scoreboard, 2001. Figures are for the 1995-99 period.
[40] David Brown.The Innovative Company. Arthur D. Little International. 2002.
[41] OECD Economic Survey: Australia. 1998. Paris. 1998.
[42]OECD STI Scoreboard, 2001. Figures are for the 1995-99 period
[43] DITR Australia as a Modern Economy, 2002; p7. . Estimates based on OECD categories, for 1999.
[44] US Patent and Trade Mark Office. Data for 1992-99
[45] Ausis 2003 Working Paper 4: Assessing Australia: Characteristics, Innovation, Structure and Specialisation. IMPP. ANU
[46] Ausis 2002 Working Paper 2: Innovation In Australia: Characterisation of Four Themes in Australian Innovation Systems.IMPP. ANU

capabilities. These industries are resource-enabled but increasingly market and innovation-driven. In major areas of mining and agriculture Australian productivity performance is world leading. In both mining and agriculture the strong and sustained demands for innovation and problem solving have led to the emergence of specialist providers of equipment and services – although much of the core capital goods are imported. Many of these specialist suppliers are now exporting goods and services.

- **Dispersion, Fragmentation and Focussing Devices.**

Australia's innovation systems are highly dispersed: geographically, sectorally, technologically and organisationally. The scope for economies of scale in innovation and production has been more limited than the aggregate picture would suggest. The significance of barriers to focus, critical mass and effective interaction is generally underestimated.

- **Systems Integration and Problem Solving in the Innovation System.**

A great deal of innovation in Australia involves essentially systems integration - combining sub-systems and adapting systems to meet Australian needs. These processes often require high-level capabilities to solve problems and incorporate novel design elements.[48] R&D and patent statistics tell us little about these types of innovation, which are central to productivity. As organisational change is often required for effective technological innovation, managerial will have a major bearing on the effectiveness of technological innovation and the returns to investment. Managerial competencies are also vital user-producer links and supply chain development which are increasingly associated with technological innovation.

Three dimensions provide a useful starting point for assessing overall NIS performance:

- Performance in generating (and renovating) resources required by firms and other problem-solving organizations. These resources include human resources, knowledge, networks, infrastructure, trust, standards, etc.
- Performance in solving problems – ie in mobilising resources to meet performance gaps. This operates at the level of the firm, the technological 'system', the sector and, in relation particularly to the policy domain, at the national level.
- Performance in ensuring diversity and hence generating options for economic (etc) progress–ie building capacities beyond those needed for current problem solving, as in

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[47] Ausis 2003 Working Paper 4: Assessing Australia: Characteristics, Innovation, Structure and Specialisation. IMPP. ANU
[48] With implications for the role of the public sector research system and approaches to its evaluation.

developing new competencies, technological trajectories, industries, clusters, innovation systems[49]..

In relation to all three of these dimensions it is clear that Australian innovation systems are evolving in response to the opening of domestic and international markets and technological trajectories. Over the 10 years from 1988 Australia moved from having some of the highest tariff levels in the OECD to generally the lowest levels[50]. Substantial components of agriculture are shifting from commodity production by developing higher value-added activities based on differentiation in products and marketing-related services. Significant new areas of strength have developed in for example, wine, scientific and control instrumentation, and some services sectors.

In relation to the first two of these dimensions the overall evidence suggests that the innovation system is performing reasonably well, when assessed in terms of recent performance. Australia has a strong public sector research and education system and is an effective user of new knowledge and technology from domestic and international sources[51]. However, there are some critical caveats to make, including: growth off a low base (eg in some areas of patenting and trade); the drivers of export growth (including the role of the depreciation of the A$); and the sources of productivity growth (particularly the role of one off factors such as micro-economic reform), hence:

"It is beyond dispute that Australia has experienced strong economic growth for a decade or more, during the latter part of which time many standard indicators of innovation have been falling. Again these outcomes can be interpreted in different ways. One view is that these facts show that broad economic change can be more important to growth than innovation as commonly measured, because market forces will find the best growth opportunities. The other view is that Australia's recent growth spurt is unsustainable, being driven by rapid growth in borrowings by households, by a surge in net foreign debt and by a falling dollar….. On this account, these and other factors have masked Australia's declining position in the global knowledge economy." (Sheehan & Messinis, 2003)

A critical issue for such an assessment is whether there are obstacles to the evolution and upgrading of innovation systems, whether resource allocations, competencies and attitudes etc remain locked into patterns that are no longer productive. A recent comparative international survey found, as many similar surveys have found over the past 20 years, that, despite persuasive evidence to the contrary, Australian firms consider that their innovation-related performance is 'world class.'[52] There is some evidence that public sector research organisations remain focussed on traditional fields of science, while the business sector is focussing on engineering and software, limiting effective

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49 Where national economic, environmental, social (etc) performance is unsustainable and cannot meet the objectives of the society, change in the innovation system is one mechanism for achieving change in the wider economic, social and environmental system.
50 Bean, C. The Australian Economic 'Miracle': A view from the North. Australian Economy in the 1990s. Reserve Bank of Australia 2000 Conference. P 95
51 Over the past decade users have captured the greater share of the benefits from ICT innovation.
52 Brown, D. The Innovative Firm. Arthur D. Little 2002.

interaction. Bourke, drawing on data for the 1981-97 period, has shown that industry participation in scientific papers (and hence presumably also in research collaboration) is particularly low in Australia , about 2% compared with 8% in the UK and 9% in the US. [53]

In relation to the third of these dimensions, one general area that appears to be a continuing systemic weakness is that of the exploration of new industry development through new firm formation, either as start-ups or spin-offs from existing firms. The relatively low levels of venture capital, particularly of early stage finance, appear to be a continuing problem.

In relation to the third dimensions of assessment, it is vital to recognise that, despite the recent performance, the Australian economy remains vulnerable[54]. Our analysis of trade, R&D and US patent data indicates that Australia has increased its relative specialisation in 'low-tech activities'. There may well be a case for a more systemic and sustained approach to upgrading the 'accumulation of skills and knowledge' and more generally ensuring that Australia has an innovation system able to contribute substantially to the development of the economy rather than simply respond to short term market signals. In this regard it is worth quoting at some length a recent discussion on the assumptions underlying the current policy settings:

"The new growth theories point out that the growth-enhancing effect of trade is an aggregate effect; we expect it to hold on average…. but not in every case. In particular, trade can reduce growth for countries that have comparative advantage in industries with low-growth potential. Lower growth does not, however, necessarily imply lower economic welfare. Specialisation through trade may move the terms of trade in favour of the low-tech country which is enabled to import cheaper high-tech goods…….Trade is not, however, necessarily welfare enhancing in the absence of competitive markets. If there are substantial market failures in the accumulation of knowledge and skills and new goods, then trade is a double-edged sword. On the one hand, trade acts as a conduit for new ideas, stimulating growth and enhancing welfare. On the other hand, trade liberalisation and consequent specialisation in low-tech activities may relegate a country that is historically disadvantaged in the accumulation of skills and knowledge to fall further and further behind.

The pessimistic view of trade liberalisation for Australia is that it might lead us to inefficient specialisation in natural resource based activities with few incentives for enhancing skills and knowledge. For example, the current recovery in the world economy is already having the effect of improving short-term prospects for the terms of trade and raising the real exchange rate. It is possible that such movements may squeeze out the recent expansion in exports of high value-added manufacturing and lower our prospects for long-run growth and welfare by compounding failures to develop our skill and knowledge base. These are, however, second-best welfare arguments. It is not obvious that we should be using trade policy to rectify failures in the markets for the development of skill and knowledge and new goods. Rather, if we

[53] The Allen Consulting Group. Systemic Mismatches in the National Innovation System. 2000. and Bourke, P. (2000) Relative Strengths in Australian Basic Science. A Summary Bibliometric Map. Contributed Paper. National Innovation Summit. Bourke claims that in the US industry participated in one in four 'engineering and technology' compared to one in 20 in Australia.
[54] Like Sheehan and Messinis, Bean draws attention to the rising level of private and external Australian debt. Bean, C. The Australian Economic 'Miracle': A view from the North. Australian Economy in the 1990s. RBA 2000 Conference.

address these problems directly, both the new theory and the econometric evidence suggest that trade liberalisation is likely to enhance both growth and welfare.[emphasis added]"[55]

4. Australian Business R&D – Regional Diversity and Changing Knowledge Base

In 2000-01, business R&D expenditure (BERD) was $4.8 billion. BERD is almost equally distributed between manufacturing and service industries (each accounting for about 45% of BERD), while mining accounts for about 10%. In 2000-01, about 55% of all Australia's business R&D expenditure was undertaken within seven industry groups — three service industries, three manufacturing industries, and mining (Chart 5).

Australia's business R&D at the national level — major fields of technological skill.

The rising significance of ICT in Australian R&D is evident when we look at the fields of research.[56] In terms of the broad field of research, engineering and ICT account for over 80% of BERD. But within engineering the largest field of research is in communication technologies. Overall, business R&D expenditure directly focussing on R&D in information, computing and communication sciences, communications technologies, and computer hardware together comprise 38% of all BERD (Chart 6). Furthermore, half of the top eight fields of research (representing 65% of Australia's total BERD) are in ICT. Manufacturing and automotive engineering then follow, showing the traditional areas of the R&D skills base. Medical and health research skills are also significant, as is resources engineering — a field strongly associated with the mining industry.

Australian R&D expenditure at the level of States and Territories

In comparison with leading economies, Australia's gross expenditure on R&D, at 1.53% of gross domestic product (GDP), is relatively modest. Corresponding data at the State and Territory level, however, varies considerably[57]. Chart 7, comparing the trend in Australia's BERD as a proportion of GDP with corresponding trends (BERD as a proportion of Gross State Product (GSP)) for each state and territory, shows that Victoria has consistently had the highest BERD/GSP ratio (BERD intensity) of the states and territories. BERD in Queensland increased sharply in 1995-96, but then followed the national trend. After falling in 1996-97, SA's intensity has increased overall — SA is the only state to have surpassed the peak level of BERD/GSP that most states and territories

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[55] Steve Dowrick **Openness and Growth RBA 1994 Conference International Integration of the Australian Economy**
[56] The ABS requires firms to indicate the distribution of their R&D across both 'core business activity' and 'field of research'.
[57] Not all of this variation in gross R&D expenditure as %GSP (Gross State Product) is due to differences in levels of business R&D expenditure – Commonwealth and Higher Education R&D activity contributes to inter-state variation in R&D intensity.

reached in the period 1995-96 to 1997-98. While R&D intensity declined after 1995 in most states the decline was particularly market in WA.

Chart 5 BERD (2000-01) - Industry of Core Business Activity

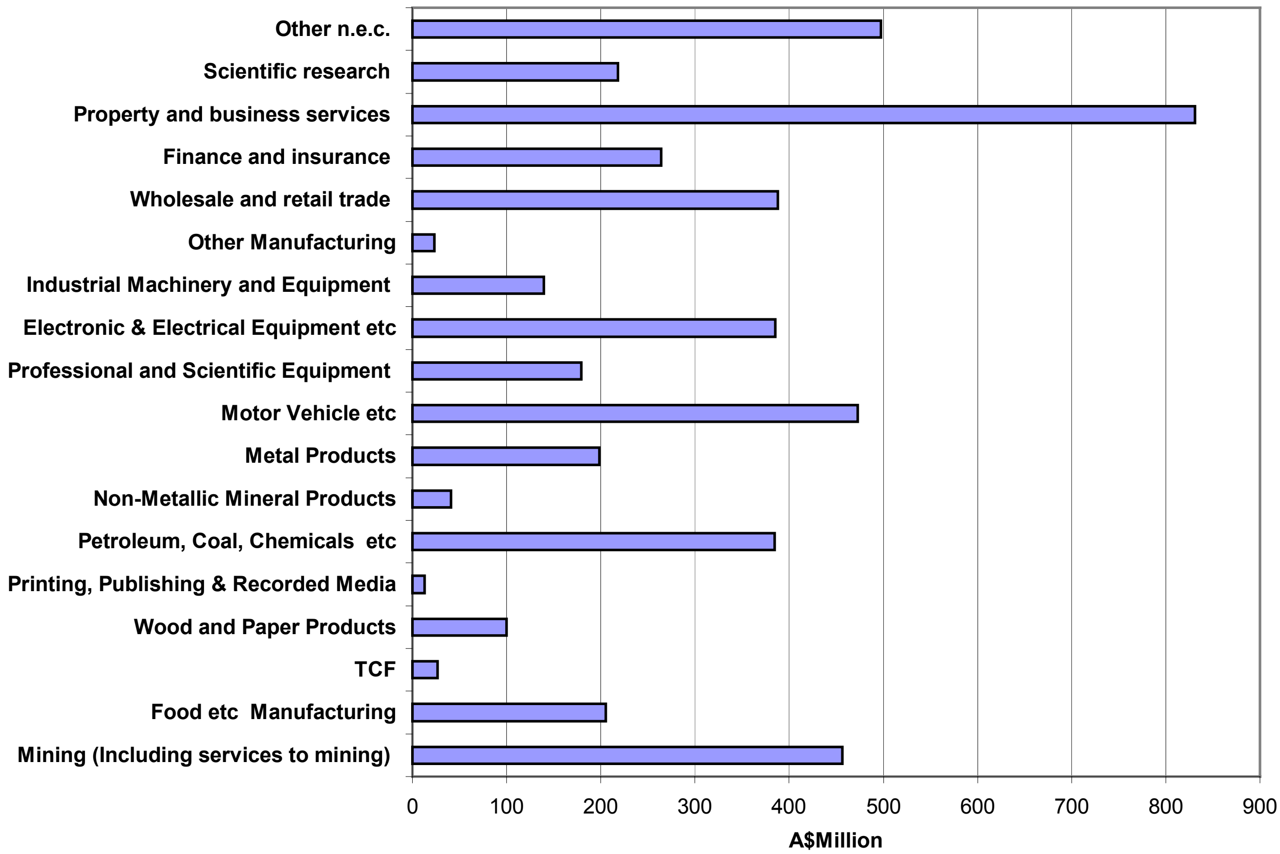


Chart 6: Australia — Major R&D fields of technological skills (RF), 2000-01 (%GDP)

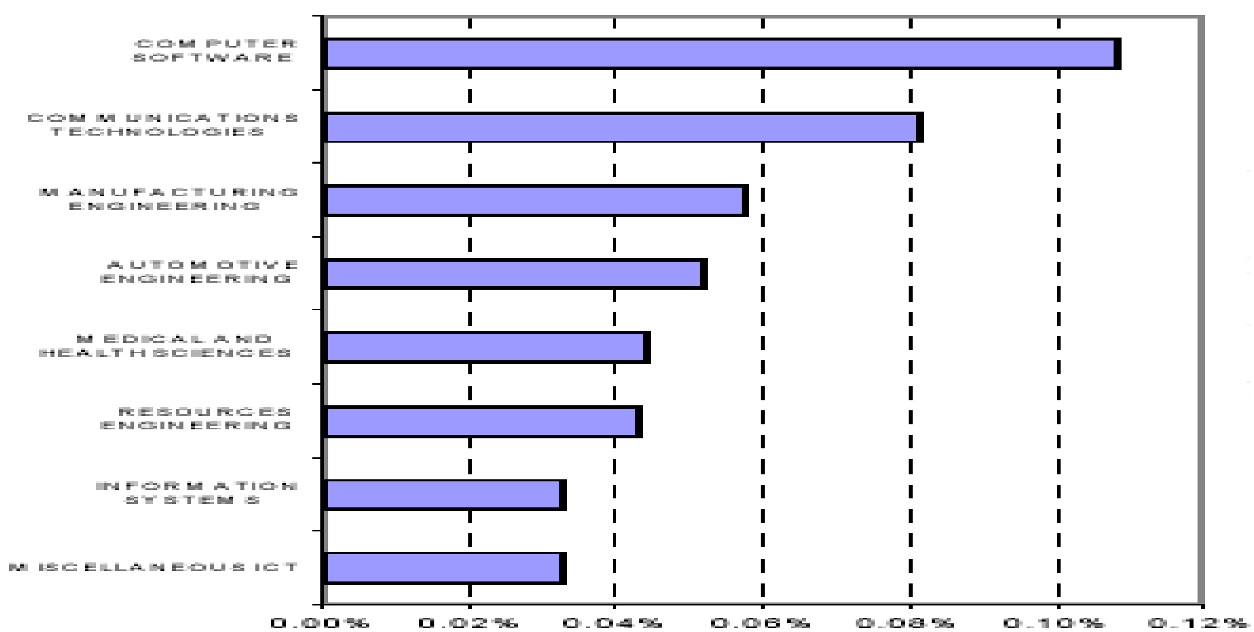


Chart 7: Change in National and State-level BERD (as %GDP or % GSP)

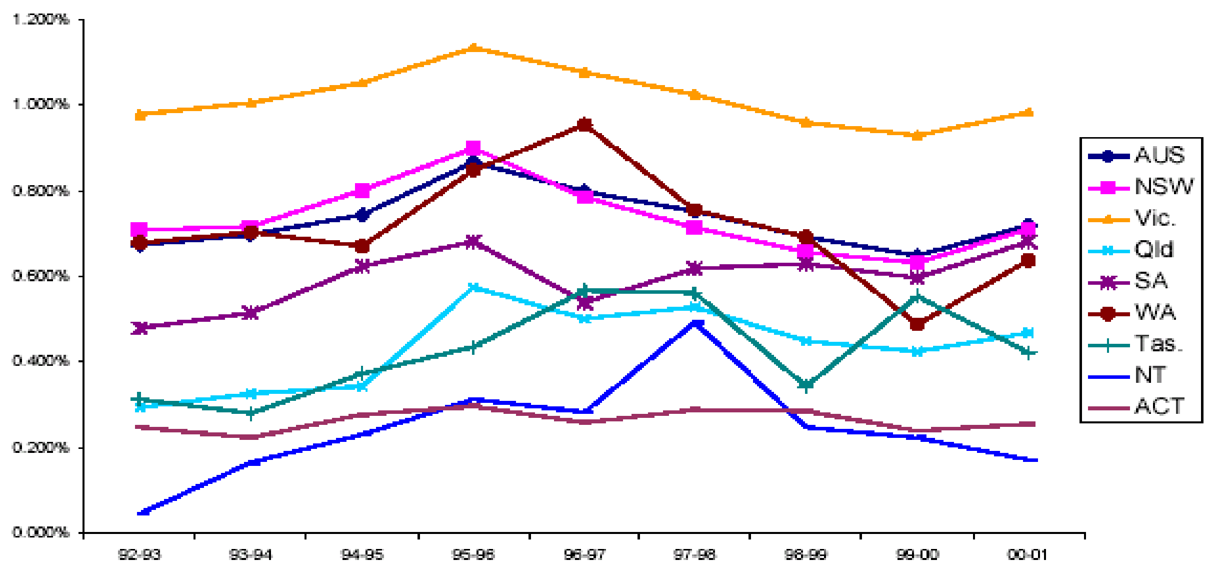


Chart 8 summarises a range of data on R&D performance and on patenting in Australia by organisations based the major states. It indicates the important sectors in each state in terms of R&D investment, R&D increase over the 1990s, the major fields of research, and relative patenting activity. On the basis of these patterns the characteristic strengths of each state are identified. In the following analysis of R&D patterns and trends at the state level we will discuss two States: New South Wales and Queensland[58].

New South Wales

NSW's gross expenditure on R&D (GERD) as a proportion of GSP ranks below the national GERD intensity average of 1.53%. This level results primarily from lower levels of R&D expenditure in Commonwealth agencies and in universities. However, NSW has Australia's second highest intensity of business R&D expenditure (0.71% of GSP), though it is significantly below the corresponding level in Victoria (0.98%).

Chart 9 shows the major R&D performing industries in NSW: computer services; electronic equipment; finance and insurance; metal products; photographic and scientific equipment, and food processing. NSW's R&D skills base is dominated by computer software — where it has the strongest research capability, both in scale and in R&D intensity. Communications technologies are also relatively strong — being at approximately the same scale as in Victoria, but behind that State in R&D intensity in that field of research.

[58] For a more detailed discussion of State and Territory patterns see Working Paper 3: Regional Aspects of Australia's R&D Activities

Chart 8: Patterns of R&D Activity and Strength at State Level[59].

	New South Wales	Victoria	Queensland	South Australia	Western Australia
Major R&D Performing Sectors	ICT services; ICT equipment; finance and insurance; metal products; photographic and scientific equipment, and food processing.	ICT services; ICT equipment Chemicals; Auto. Instruments and parts; Medical & pharmaceuticals; Finance & insurance.	Mining; ICT services; Metal products; Petroleum, coal and chemicals.	Petroleum, coal & chem.; Machinery & Equipment wholesaling; ICT equipment; Auto engineering; photographic & scientific equipment; ICT services.	Metal ore mining; Property & business. Services; ICT equipment; ICT services.
Sectors with strong Growth in R&D	ICT services; Photographic & scientific equipment.	ICT services; ICT equipment; finance & insurance	ICT services	Machinery & Equipment ; Wholesaling; ICT services; ICT equipment	Metal ore mining
Major Fields of Research	Computer Software; Communication Technology; Medical;	Automotive, mechanical & industrial engineering; Communication tech.; Software; other ICT.	Software, Metallurgy; Resource engineering; Auto., mech. & Industrial engineering.	ICT; Manufacturing engineering; Automotive engineering; Software	Resource engineering; communication technology.; chemical engineering; metallurgy
Patent Strength & growth	Electronics Processed food, instruments.	Consumer goods & equipment; Mechanical engineering; Chemistry & life sciences	Civil engineering Mechanical engineering. consumer goods & equipment	Process engineering; instruments; Mechanical engineering	None
Apparent Overall Strengths	ICT services & equipment; Instruments & devices	Communication services & equipment; Automotive engineering, Biotech.	Resources, Software	Instruments; Auto. Engineering	Resources

Overall, NSW is growing above the Australian average in most patent areas (Chart 11). Patent data points to relative strengths in Electronic equipment, instruments and processed food. These areas show strength in fine measurement and control of devices.

59 Based on the analyses in Working Paper 3: Regional Aspects of Australia's R&D

Chart 11: NSW — Major R&D industries (ANZSIC), 1992-92 to 2000-01 (%GSP)

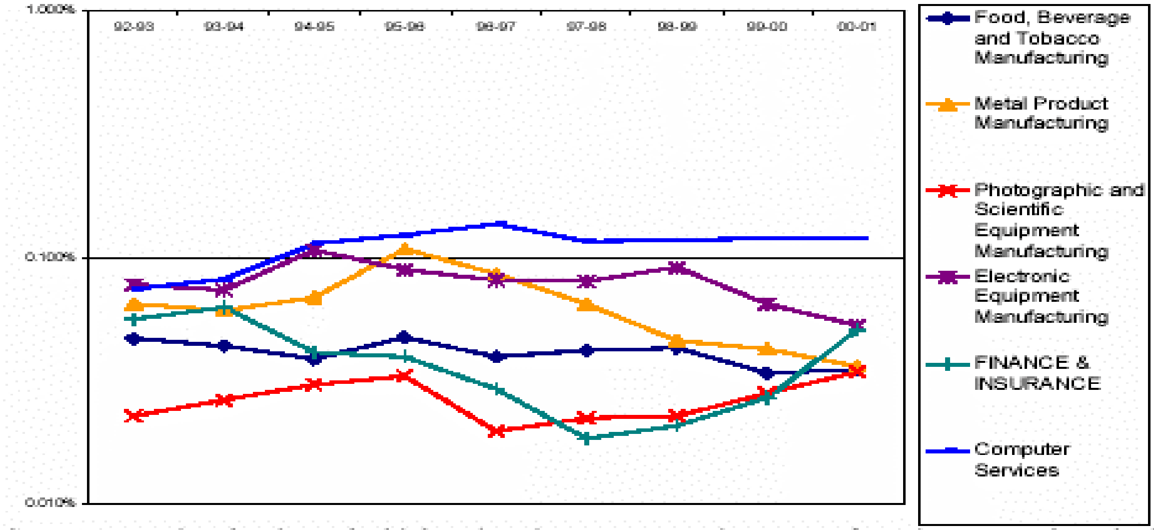


Chart 12: NSW business — Major R&D technological skills base (RF), 2000-01 (%GDP)

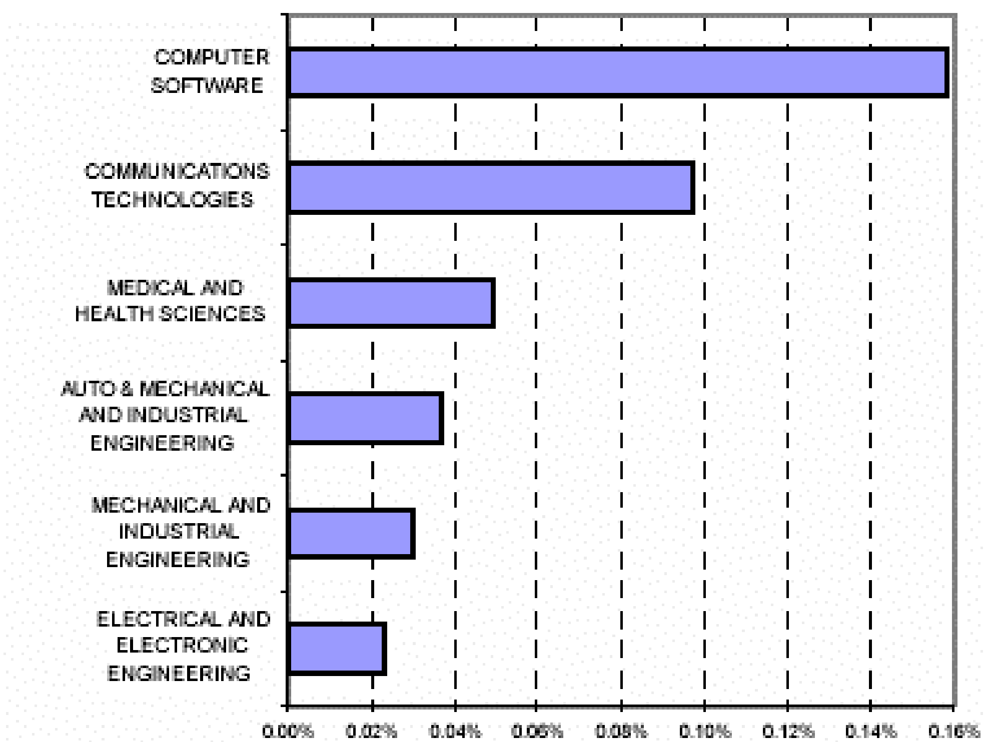
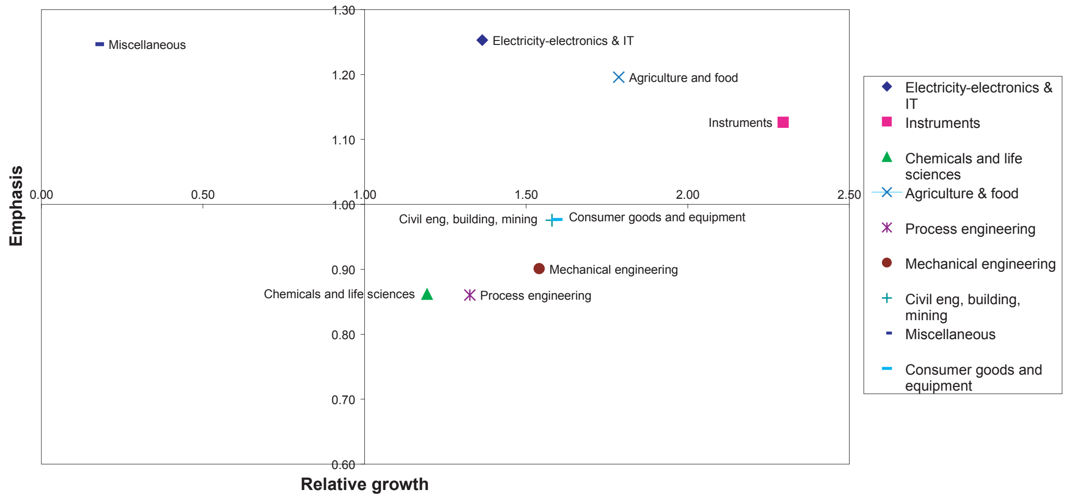


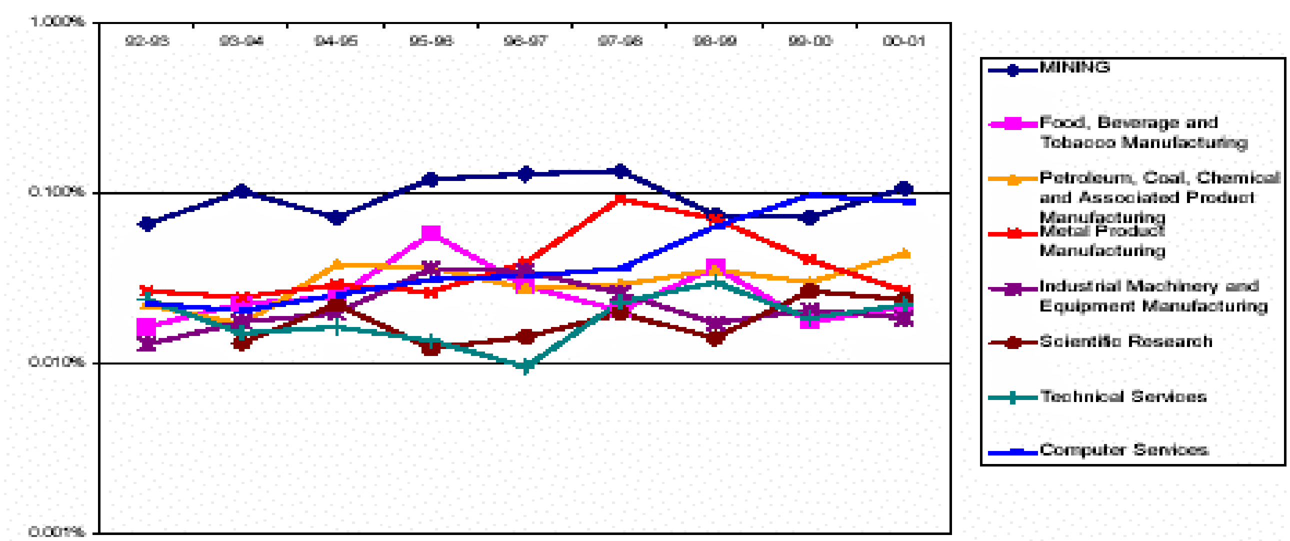
Chart 13: NSW — Broad patent R&D fields, by relative emphasis and growth



Queensland

Queensland's R&D intensity (1.23% in 2000-01) is lower than other states. Queensland's BERD/GSP peaked at 0.57% in 1995-96 and stood at 0.47% in 2000. The mining industry has consistently been Queensland's largest R&D spender, but has recently been challenged by computer services (Chart 12).

Chart 12: Qld — Major R&D industries (ANZSIC), 1992-92 to 2000-01 (%GSP)



Queensland's leading business research fields in 2000-01 were a close reflection of the two industries spending most on R&D, computer software was the leading research field followed by metallurgy and resources engineering (Chart 13). Queensland has a strong and growing emphasis on patenting in civil engineering and mining. There is also some emphasis and relative growth in the areas of mechanical engineering and consumer goods (Chart 14).

Chart 13: Qld business — Major R&D technological skills base (RF), 2000-01 (%GDP)

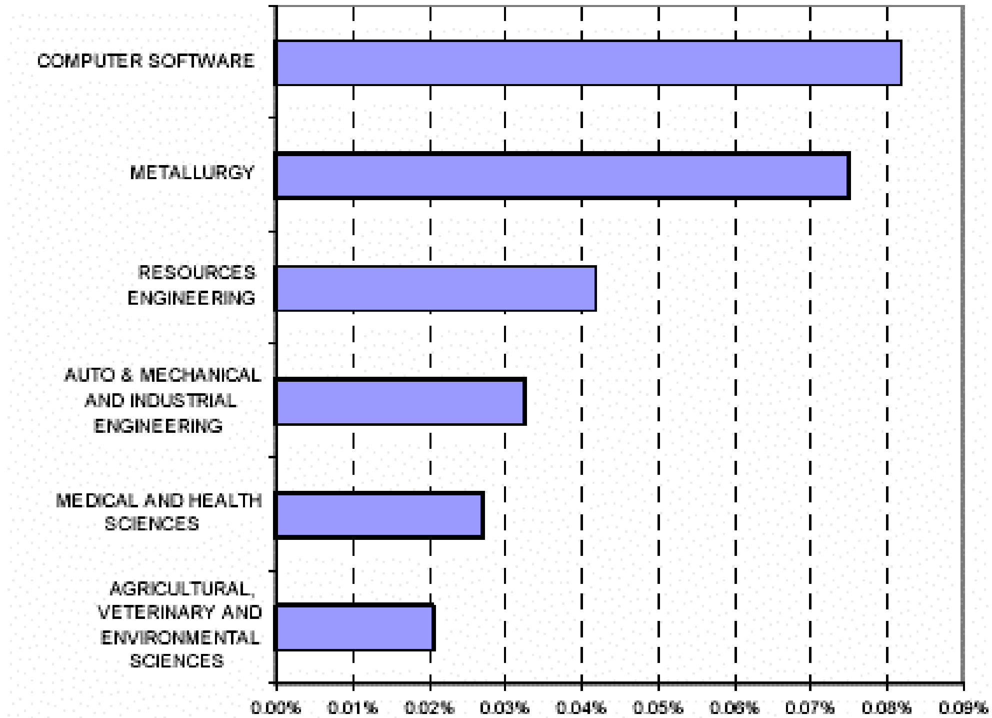
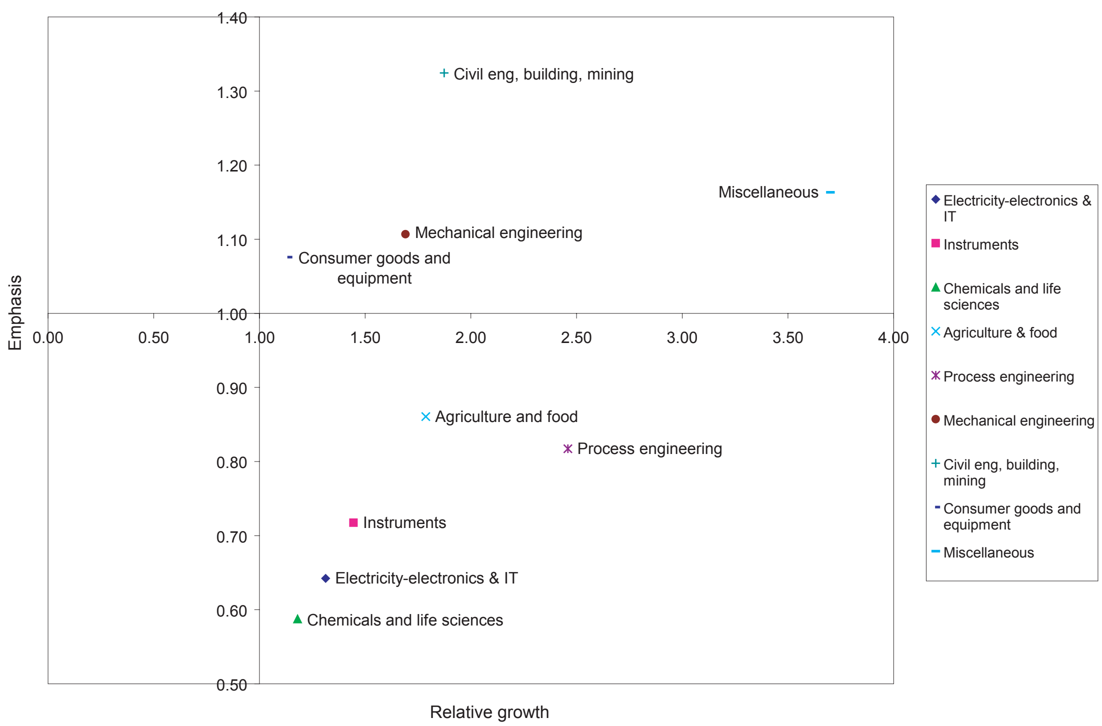


Chart 14: Qld — Broad patent R&D fields, by relative emphasis and growth



Assessing BERD Performance in Australian States

Taken overall, this analysis illustrates several points:

- Service sectors account for almost 50% of Australian BERD, and through the 1990s their share of BERD grew more rapidly than manufacturing, mining or agriculture. R&D in some manufacturing sectors (eg metal products in NSW and WA) declined sharply in the late 1990s.
- The role of ICT as a sector of industry (largely in services) and as a field of research is highly significant and pervasive. The top two fields of research in business are ICT and overall 65% of BERD is allocated to ICT-related research. In 2000-01 Computer services was the sector with the greatest level of investment in R&D and Communication services was the fifth largest R&D spending sector. The computer services industry showed the fastest (and by far the most consistent) rate of growth in R&D expenditure over the 1990s in NSW Queensland and SA.
- The second, third, fourth and sixth most important fields of research in industry in Australia in 200-01 were all in engineering: communication engineering, manufacturing engineering, automotive engineering, and resource engineering.
- R&D in software and engineering account for the majority of R&D industry but a minor share of R&D in the public sector. The possibility of a mismatch in research allocation and in human resource development needs to be assessed.
- Mining was the second most important sector in terms of BERD expenditure in 2000-01, the most important sector in Queensland and the NT, and dominated all R&D effort in WA.
- Patterns of R&D activity and directions of change in that activity vary significantly among the states.

5. Australian Innovation: Patterns of Specialisation and Evolution.

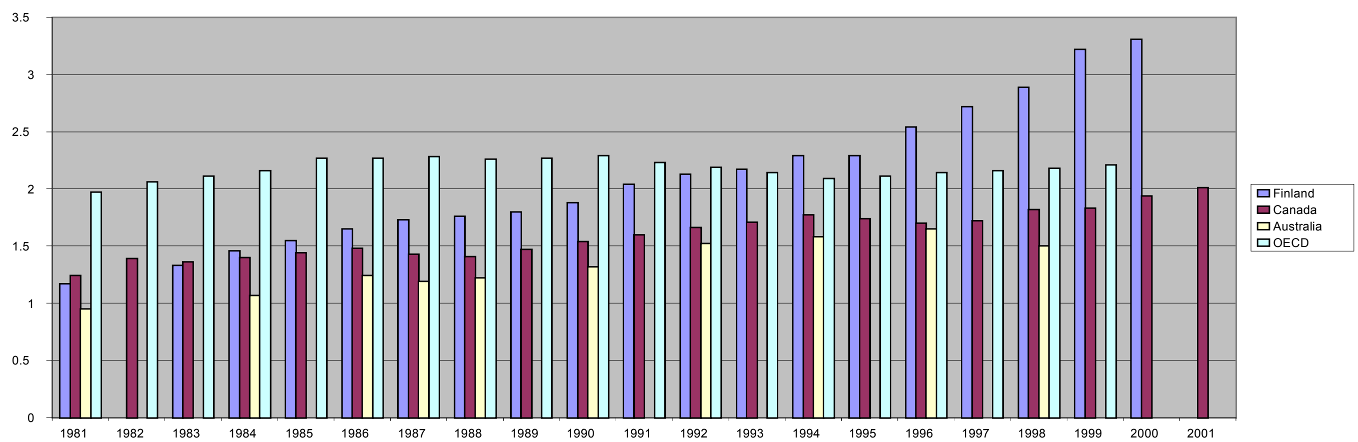
Much of the comparative analysis of national innovation systems has focused on the research system (Nelson, 1993). This focus characterises a nation's technological specialization by assessing the level and direction of innovative effort. Since such approaches focus on only some dimensions of the innovation system they provide a 'narrow view' on the overall innovation system (Lundvall, 1992).

The following analysis of the recent (20 year) evolution of Australia's technological specialization uses indicators based on R&D, patenting and scientific publications[60]. We compare Australia's performance with that of several OECD countries and in particular with Canada and Finland, as these two countries share a similarly long history of specialisation in natural resource-based sectors.

The Evolution of the Pattern of the Innovative Effort as indicated by R&D Expenditure

Australia's R&D expenditure pattern is characterised as low in GERD and BERD, but high in the government share of total R&D expenditure (Gregory, 1993; Australia Science & Technology at Glance, DEST, 2002). Chart 15 shows total R&D intensity levels (GERD/GDP) over 1981– 2001 for Australia, Canada, Finland and the overall OECD average. Total R&D intensity levels in Australia remained below the OECD average. In the early 1980s Canada, Finland and Australia had roughly comparable R&D intensities. While levels in Canada and Australia have remained similar, by the late 1990s Finland's R&D intensity was more than double that of Australia.

Chart 15 R&D Intensity 1981-2001: Australia, Canada, Finland & the OECD



Source: Ausis

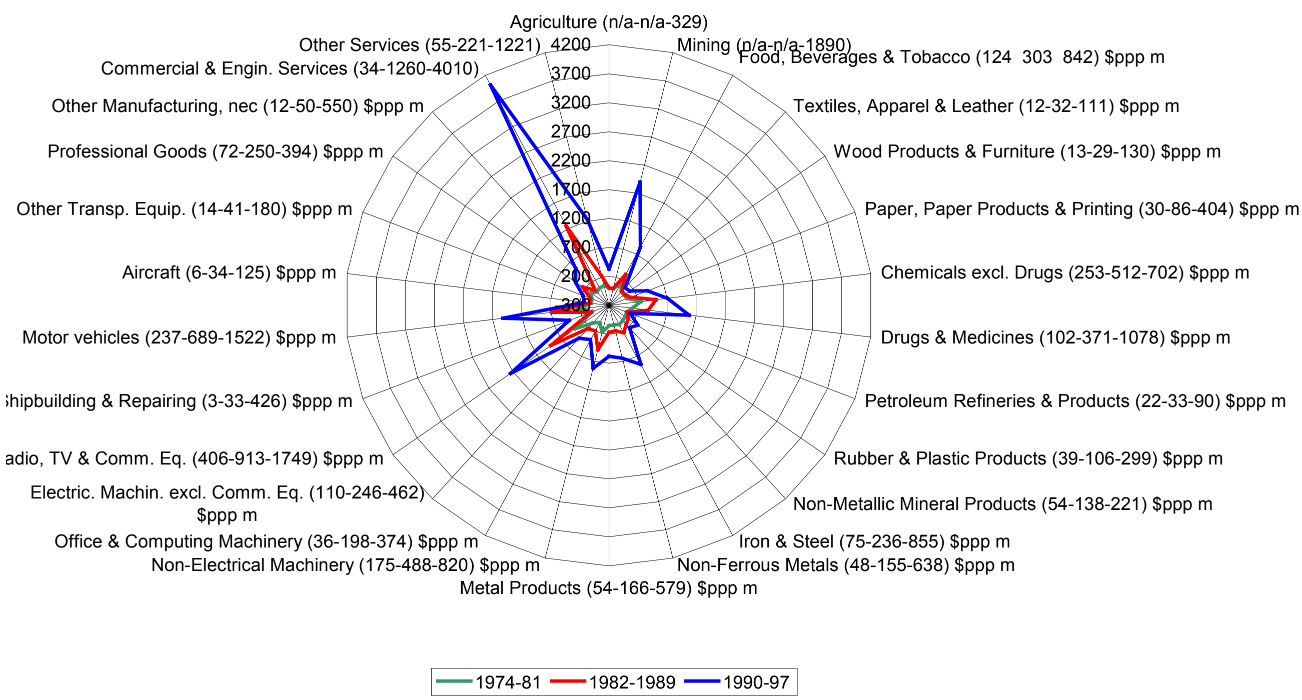
Patterns of Sectoral Distribution of Business Funding for R&D

In all three countries over period 1974 to 1997 R&D has grown particularly strongly in some sectors, (eg Electronics in Finland, Communications Services and Pharmaceuticals in Canada, and Commercial & Engineering Services in Australia). But only in Australia has it grown in all sectors. In both Canada and Finland some significant sectors showed very slow growth or a decline in real

[60] These indicators have significant limitations and need to be interpreted with caution. See Ausis (2003) Working Paper 4. Assessing

R&D expenditure. In terms of BERD Australia has not developed the level of specialisation of either Canada or Finland[61]. However, the commercial and engineering service sector has emerged as a strong R&D performer. R&D expenditure by this sector already reached more than US $1.2 billion in the period 1982-89 and increased to US$ 4 billion in the period 1990-97. A large part of this expenditure is in software development in such sectors as finance and insurance, wholesale and retail and property and business services.

Chart 16 Australian BERD: Expenditure by Sector and Period. (million 1995 $ ppp)



Source: Ausis

Technological specialization: Patenting

Small countries tend to be more specialised than large countries, and open trade regimes tend to lead to increased specialization. National patterns of specialisation tend to persist over long period of time.

Australia has been characterised in three different ways in previous studies:

- A follower country with high specialization (Pianta & Melliciani, 1996)

Australia. IMPP. ANU

61 These raise questions for further analysis, for example: Why is Australian BERD in motor vehicles almost double that of Canada, which has a much larger industry and exports many (period 1995-2000) more motor vehicles than Australia? Why does Australia show

- Specialized in low growth sectors (Archibugi & Pianta, 1992)
- Specialised in natural resources-based sectors (Amable & Boyer, 2001)

Pianta and Melliciani grouped OECD countries into four groups (Chart 17) based on patent, R&D, investment and trade data. They comment that Group 3, 'follower' countries, caught up to Group 1 and 2 countries in terms of GDP per capita by concentrating their efforts in investment activity (rather than R&D) and a few selected fields of technology.

Chart 17. Taxonomy of OECD countries

Group	Group	Countries
GROUP 1:	Large advanced countries with low specialisation	US, France, UK, Japan, Germany
GROUP 2:	Smaller advanced countries with average specialisation	Netherlands, Switzerland, Sweden.
GROUP 3:	Follower countries with high specialization	Italy, Canada, Denmark, Belgium, Norway, Australia, Finland
GROUP 4:	Small, laggard countries with very high specialisation	Spain, Ireland Portugal Greece

Source: Pianta and Melliciani (1996)

Archibugi and Pianta (1992) relate the technological specialization at the country level to patterns of change in global patenting activity. A high correlation between national technological specialization and global patenting trends indicates that a country is positively specialized in those patent classes in which global patenting is growing most quickly and negatively specialized in those patent classes where global patenting has been stagnant or declining. Japan showed the strongest positive correlation. Australia's technological specialization, like that of Canada, Sweden, Germany, Spain and Portugal, was relatively concentrated in areas of low global patent growth.

We have reviewed these analyses using the most recent data on patenting in the United States, to calculateRTA[62] for Australia and other OECD countries. Chart 18 shows the RTAs for Australia, the two comparator countries, Canada and Finland.

A relatively high proportion of Australian and Canadian patenting is in fields related to natural resources: agriculture, oil & gas, mining, primary metals and wood and paper products although both countries have recently developed a level of specialisation in pharmaceuticals and biotechnology. Australia showed a significant specialization in medical electronics, but this declined

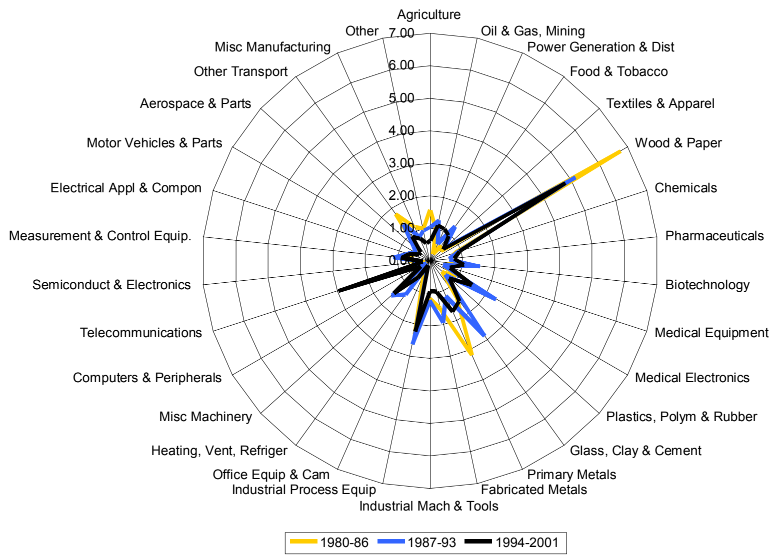
a high growth rate in BERD in metals and metal products when Canada, a major Australian competitor in these sectors, has much lower rates? Why has the food & beverages industry become much more R&D intensive in Australia than in Canada?

[62] This terminology, although commonly used in the literature, can be misleading. It does not mean that a country necessarily has an 'advantage' in a technology. In fact, RTA is a measure of a country's current technology specialisation, or the emphasis it places on a particular technology, relative to other countries. The definition of RTA for nations is the ratio of relative share of patents in technological field M in country N over the relative share of patents in technology M for the world. An RTA above 1 for a given technology implies that the country is specialised in this technology.

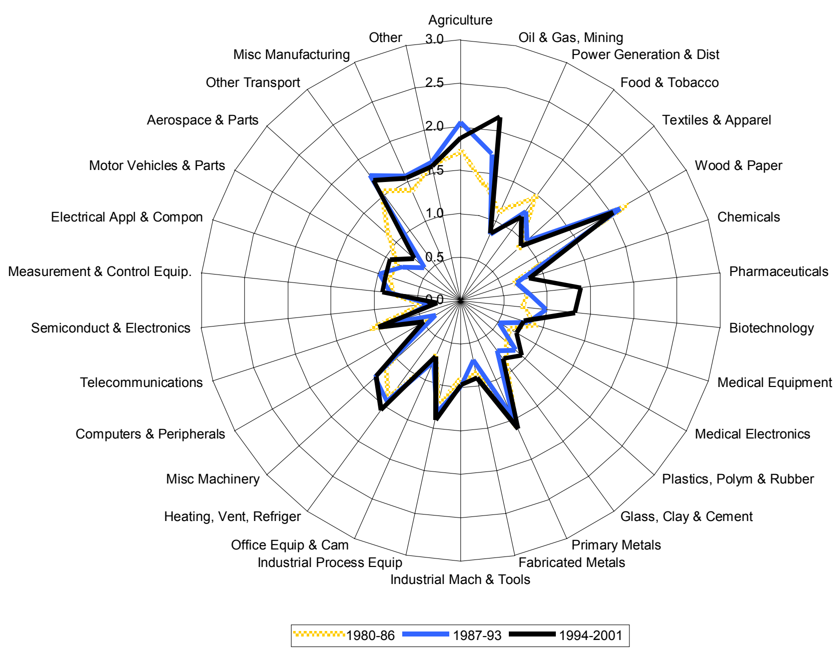
over the 1990s. Australia and Canada changed far less than Finland, indeed the former two countries have deepened their specialisation in natural resource-based sectors.

Chart 18 Patterns of Revealed Technological Advantages, 1980-2001, in: Finland, Canada and Australia

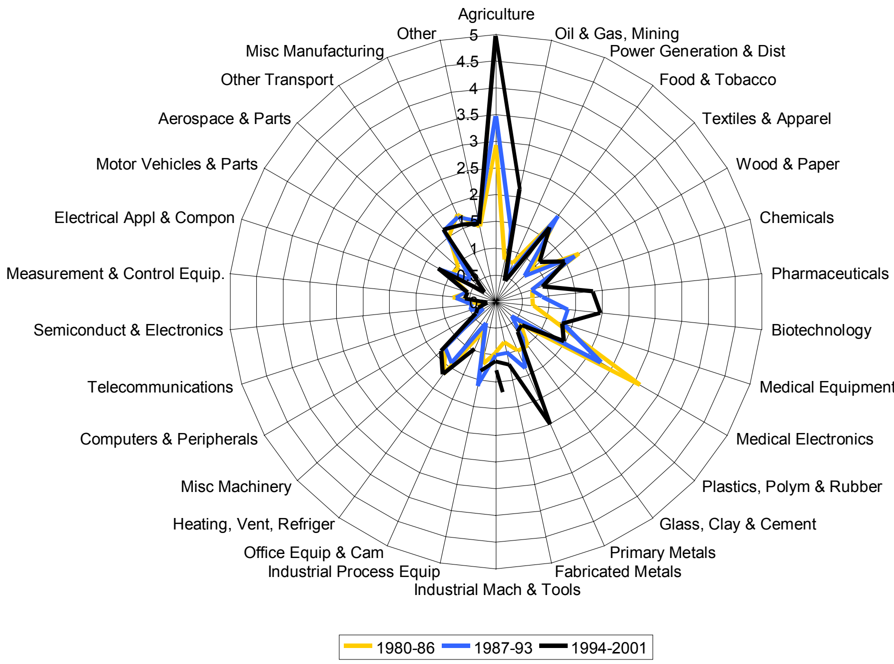
Finland's RTA



Canada's RTA



Australia's RTA



Source: Ausis

Patenting Characteristics: Maturity of technologies and links to science

Australian patenting in the US is relatively concentrated in fields of low patent growth. In the following section we look at the nature of patenting activity in terms of the technology cycle time (TCT) and level of science linkage (SL)[63].

Chart 19 shows, for a range of OECD countries and Taiwan, aggregate TCT levels for all technological fields covering the period 1980 - 2001 and aggregate SL levels for all technological fields covering the period 1985– 2001. Three groups of countries can be identified:

- A fast moving technology developer group with low SL levels - Japan, South Korea and Taiwan;
- A fast moving science based group – US, UK, Sweden, Finland, Italy, France, Germany; and
- A slow moving science-based group – Canada, Australia and Norway.

In the first group patenting activity is concentrated in fields of rapid technological change - such as semiconductors, telecommunications and computers. But even in areas of slow technological change, these countries focus on the most rapidly changing sub-fields.

In the 'slow moving science-based group', the high TCT suggests that these countries are involved in activities where the rate of technological change is relatively slow[64]. However, on average

[63] The TCT indicator is the median age of the references (i.e. 'prior art' citations to publications and patents) cited on the patent. The lower the TCT value the more recent the antecedent knowledge and thus it is assumed the more rapid the technological change. The science linkage (SL) is a measure of the number of these citations that are to the scientific literature. This measure provides an indicator of the link between a technological field and the scientific research base.

Australian patenting in almost all fields exhibits a high TCT. Hence, even in fields where the rate of technological change is high (eg electronics) the TCT of Australian patents is below the average. Australian patenting in pharmaceuticals and biotechnology (See Chart 20) are exceptions.

Chart 19: Science Linkage vs. Technology Cycle Time (1980-2001)

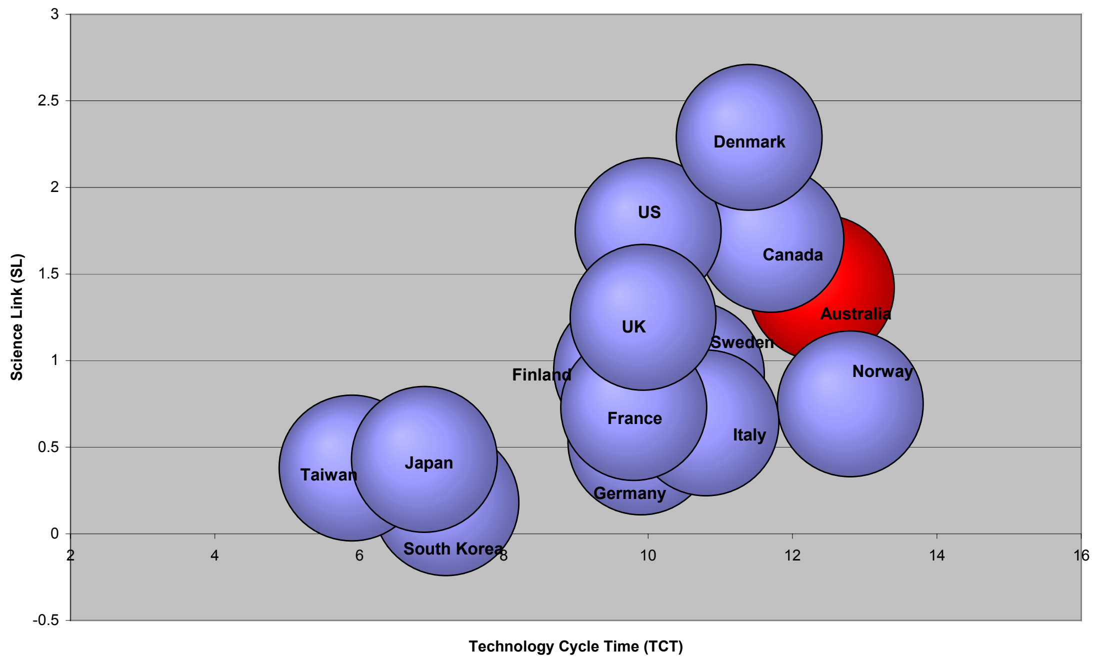
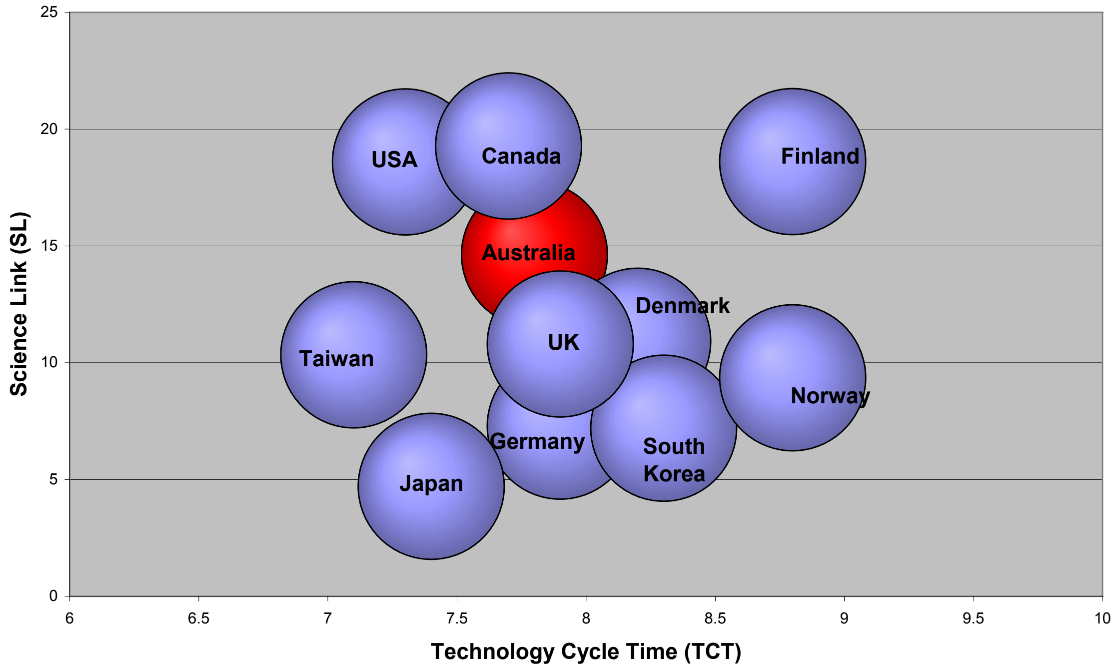


Chart 20 Biotechnology Patenting (Science Linkage and Technology Cycle Time of Patenting activity 1980-2001)

[64] This was also shown in ARC (2000) "Inventing Our Future" ARC. .



Source: Ausis

Hence, not only is Australian patenting conservative in that the pattern of specialization has changed little over 20 years – a period that saw major changes in many countries – but it is also conservative in that patenting tends to be based on older knowledge than is patenting in other countries. A part of the explanation for these observations may be that Australian invention focuses less on generic technologies of wide application and more on application and location-specific niches.

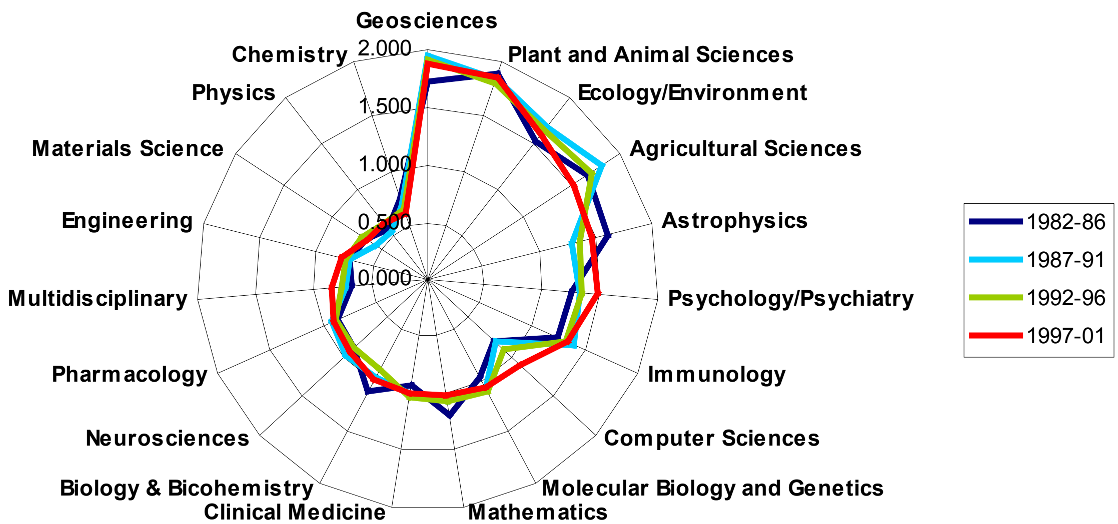
Specialization in Science

There has been little change in the pattern of specialisation of Australia science over the last 20 years. Australia's strengths at the end of the 90's continue to be in Agricultural Sciences, Earth Sciences, Biological Sciences and Medical and Health Sciences and to be relatively weaker in Physical Sciences, Chemical Sciences and Mathematical Sciences and in the more applied fields embraced by Engineering and Information and Computing Sciences (Bourke and Butler, 1999). Chart 21 shows the pattern of Australia's Revealed Comparative Advantage (RCA) in fields of science[65] over four time periods. These confirm Australia's consistent specialisation and the overall conservative nature of the pattern of scientific output[66].

[65] This is defined in an analogous way to RTA (footnote 73). As for RTA, the terminology may be misleading. A high RCA does not necessarily mean that a country has an 'advantage' in a particular science. RCA is a measure of a country's current scientific specialisation, or the emphasis it places on particular science, relative to other countries.

[66]. This characteristic was discussed in BIE (1996) Australian Science Performance from Published Papers

Chart 21 Changes in revealed comparative advantage in Australia scientific publications output in four periods



Source: Ausis

The Perspective from the Narrow View

This analysis from the 'narrow view' points to the enduring significance of Australia's resource-based history for innovative activity. It shows that:

- Australia is specialised *technologically* towards agriculture, mining, primary metals but has recently increased its activities in biotechnology and pharmaceuticals.[67]
- These patterns of specialisation in technological invention are likely to both reflect and reinforce the Australia's *industrial* specialisation.
- There is little evidence of major changes in Australia's technological specialisation, unlike some OECD countries.
- Australian inventions are focused on areas where technological change is relatively slow. Furthermore, within most technological fields, regardless of how fast they are changing, Australia is a slow mover. Again pharmaceuticals and biotechnology are exceptions.
- The strengths of the Australian science system have not changed in the past two decades and reinforce the importance of Australian unique natural resources and its path dependence.

[67] Note that technological specialisation (revealed technological advantage) is distinct from industrial specialisation.

The fields of strengths are geo-science, agricultural science and animal and plant biology, while fields of relative weakness are engineering and computing.

- Recently, there have been some signs of significant change. An emerging specialisation has appeared in the fields of biotechnology and pharmaceuticals. The engineering and commercial services sector has emerged as a major R&D performer. Australian patenting has become more rapid (i.e. has shorter TCTs) in several technological fields -both fields of slow and rapid technological change.

6. Interpreting National Characteristics

Four broad features of the Australian NIS emerge from these and related studies:[68]

The Role of Resource-Enabled, Knowledge-Based, Competition-Driven Innovation.
The performance of much of Australia's mining and agricultural industries is dependent on innovation based on complex technologies and high-level capabilities. These industries are resource-enabled but increasingly knowledge based. In major areas of mining and agriculture Australian productivity performance is world leading. In both mining and agriculture the strong and sustained demands for innovation and problem solving have led to the emergence of specialist providers of equipment and services– although much of the core capital goods are imported[69]. Increasingly, these specialist suppliers are now exporting goods and services. In some industries (eg mining and wine) the 'knowledge infrastructure', including research and training organisations and a range of intermediary organisations and mechanisms, is well developed and plays a key role in the continuous upgrading of technologies and firm level capabilities.

Conservative Patterns of Evolution

Nations develop particular economic and industrial structures and specialise in particular types of technologies; these patterns tend to prevail for long periods of time and such *path-dependence* affects processes of technological change.

Australia has a high and sustained level of specialisation in mining and agriculture and a concentration of patenting in areas of relatively slow technological change. Among OECD countries Australia has had one of the lowest levels of change in technological specialisation over the last 20 years. While patenting in biotechnology and pharmaceuticals has grown rapidly over the past decade there is little evidence of significant emerging areas of technological specialisation.

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[68] This discussion draws on a number of exploratory studies carried out in the Ausis project.
[69] Competent (leading edge?) and demanding users play a key role in the development of specialist suppliers.

Specialisation data also shows that Australia has not registered the emergence of any new major sector or field of considerable strength such as telecom in Finland and Sweden; oil in Norway; semiconductors in Korea and Taiwan, and motor vehicles in Germany. While Australia has diversified export markets and products, it's relative level of specialisation in natural resource based commodities has increased. Overall the picture that emerges is one of a conservative 'innovation system' that is only slowly (perhaps too slowly) generating sustainable new paths of technological accumulation.

The phenomena of increasing returns can have a major role in the competitive dynamics of firms, sectors and regions. Through positive feedback mechanisms (such as economies of scale, experience or learning curves) firms, sectors or regions that have a slight lead over competitors can move even further ahead. By benefiting prime movers rather than latecomers, increasing returns reinforces path-dependency. For a nation, increasing returns influences both the types of activities or sectors in which the nation is 'competitive' and the rate of economic growth. The phenomena of increasing returns are likely to be one of the reasons why the level of value adding to Australian primary exports has developed slowly.

While changes in national sectoral specialisations are slow, they may still come about, especially if the 'rules of the game' are altered. Such rule changes can result from technological disruption that makes the knowledge base of a sector obsolete, or from transformation of the business logic. For example in the wine industry, a transformation occurred when the mass market was reached by cheap, high quality standard wines. This transformation required and led to a shift in knowledge base, further consolidating the competitive position of the new leaders, but also requiring complementary shifts in the education and training organisations.

Technology Integration and Adaptation

Australian firms are largely users and adapters of core technologies and as such could be termed 'systems integrators'. This is a particular capability to add value by integrating or "assembling" systems, resources and technologies rather than involvement in their development. The core competences of 'systems integrators' are related more to activities such as project management, the integration of heterogeneous sub-systems, risk and financial assessment, logistics, and particularly problem solving and adaptation to particular applications. The significance of adaptation, and the knowledge of the constituent technologies and of the users application environment that will be required, varies widely. Innovation activity that begins as systems integration can over time involve growing novelty and a progressive shift in the make/buy pattern as firm specific knowledge and the market demand for specialised systems grows.

There is no evidence of systemic weaknesses in the capacities of Australian industrial or research organisations to acquire, apply and modify embodied or disembodied knowledge from local and international sources. The available evidence suggests that many Australian firms actively search the global stock of knowledge/technology, and that Australians are among the world's most intensive and rapid users of new ICT technology. On the basis of econometric analysis, Dowrick and Day (2003) estimate that international technology transfer accounts for approximately half of the productivity growth in the market sector of the Australian economy over the 1990s[70].

While not diminishing the importance of breakthrough innovation or of local discovery, the majority of innovation is incremental involving improvement in products, processes, methods, etc, and is based on knowledge sourced from outside Australia. Hence, broadly distributed capabilities are vital and investment in human resources is the essential foundation for innovation.

Diversification and Evolution: Emerging New Firms and Niches

While the overall story is one of strong 'path dependency' there are nevertheless signs of change. The increasing 'speed' of Australian patenting and the recent strong growth in pharmaceuticals and biotechnology patenting are one dimension of this change. In sectors such as these, access to marketing channels, and other complementary assets, will require various forms of collaboration with international firms. The management of these international relationships, and the strength of the positioning of Australian firms in global supply chains and collaborations, will shape the level of benefit from innovation captured by Australian firms[71]. There is a rich constellation of emerging new firms, often in specialised niches, although few appear to be major new trajectories. Such firms are in a diverse range of sectors and include particularly firms bringing new technology solutions to growing markets in health, environmental management, renewable energy technologies and ICT applications in services and resource sectors. Such firms emerge both from the technology supply side (eg research organisations, technology suppliers), from the demand side (the commercialisation of a solution developed within or for a user organisation) or from entrepreneurs identifying market opportunities. Services sectors accounted for 77% of Australian GDP and over 82% of

[70] Dowrick, S & C.Day. Australian Economic Growth. Why Bill Gates and the Ageing Pessimists are Wrong. National Institute of Economics and Business Public Lecture. May 2003.
[71] The history of ICT development in Australia and many other countries suggests that new technology-based industrial development is most likely to be sustainable where there is a strong nexus between technology development and local patterns of demand.

employment in 2001-02 and some services sectors (eg engineering and commercial service) have a sharply growing role in R&D.

However, developing new innovation-based enterprises in Australia remains a challenge:

- The domestic market is a small base from which to finance R&D and other innovation inputs;
- There is a small pool of experienced entrepreneurial managers;
- Under these circumstances capital providers are conservative ;
- There are few large innovation-based domestic companies that nurture and spin-off new ventures;
- Accessing export markets is a major challenge for a small company.

The Pervasive Role of the Public Sector

The public sector research and training system in particular and the public sector in general has a large role in the Australian 'innovation system'. A relatively high proportion of Australian GDP is allocated to research carried out in the public sector, and such research accounts for a high share of Australia's GERD. Public sector research continues to play a major role in the agricultural and health sectors and at least in the more generic and indivisible areas of the mining industry (eg geology, exploration and environmental management). A relatively high proportion of Australian firms are small enterprises and with very few major high-R&D-intensity firms there are few poles of major capability accumulation shaped by corporate decisions about the costs and benefits of innovation.

As Australian managers are relatively inexperienced in managing innovation-based business development and hence are risk averse in this domain, the policies and programs of government (and of institutional investors) will have a major bearing on corporate behaviour in this regard.

Public expenditure, and to varying degrees public agencies and enterprises, continue to have central roles in the provision of much physical infrastructure and in services such as health and education, and powerful regulatory role in the provision of other infrastructure and services, recently in the public domain.

As a consequence, public sector research and training organisations will be important actors in many Australian innovation systems, and, at a higher level, government (State and Federal) policy and regulatory regimes are likely to be important influences on the evolution of Australia's innovation systems.

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