R&D INQUIRY
Submission No. 22

Business Commitment to Research and Development in Australia

A submission to the

House of Representatives Science and Innovation Committee

by

CSIRO

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Inquiry into Business Commitment to Research and Development in Australia

On 16 July 2002 the Federal Science Minister Peter McGauran announced the terms of reference for an inquiry into the Australian business community's commitment to research and development (R&D) by the House of Representatives Standing Committee on Science and Innovation. The terms of reference are:

International comparisons indicate that while the public sector in Australia supports R&D at an impressive level, business investment is less impressive.

With particular consideration of:

- *the R&D drivers in small and medium sized business;*
- *the needs of fast-growing companies; and*
- *the considerations by which major international corporations site R&D investment,*

the committee seeks to address three questions.

- *What would be the economic benefit for Australia from a greater private sector investment in R&D?;*
- *What are the impediments to business investment in R&D?; and*
- *What steps need to be taken to better demonstrate to business the benefits of higher private sector investment in R & D?*

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Executive summary

CSIRO is Australia's largest public sector research organisation. Its mandate requires it to assist Australian industry. CSIRO implements this mandate through the research and other services it provides to business, either directly on a fee for service or partnership basis; or indirectly through the business uptake of CSIRO research outputs available in the public domain.

The business sector is an essential component of Australia's national innovation system, funding, performing and using research. However, compared to other OECD countries, Australian business expenditure on R&D as a proportion of GDP is low and this might impact on the effectiveness of the overall innovation system. In 2000-01, around 3 500 Australian businesses funded research but around one quarter of these appear to have an opportunistic rather than sustained R&D strategy.

R&D expenditure varies between industry sectors and according to firm size and foreign ownership. Some of these factors help explain the apparent low commitment of Australian business to R&D. In particular, only large firms can sustain a significant research effort and Australia has few large firms. Australia has a greater proportion of its business research conducted by firms having fewer than 100 employees than any other OECD country apart from Iceland. Moreover, business commitment to R&D tends to be at the experimental development end of the research spectrum. While similar to the situation in other countries, this emphasises the dependence of business on the research carried out in CSIRO and other non-business components of the innovation system.

R&D is a major driver of technological innovation. Increased business investment in research could provide significant benefits to individual firms and to the nation as a whole. However, from the perspective of individual firms there are significant risks in research and the consequences of failure are likely to be greater for smaller firms. Major impediments to greater investment in R&D include the willingness or ability to accept risk, the financial capabilities of firms and their management attitudes.

Demonstrating the benefits of R&D has to emphasise the need to integrate R&D into a business development plan and within the context of an innovation strategy. However, there is also a need to work within the financial and risk constraints affecting Australian firms. One way to do this is to encourage and facilitate partnerships with public sector research agencies.

CSIRO has strategies to increase its engagement with Australian business and to provide the support that can make it easier for business to engage in research. Recent initiatives including a strengthening the Business Development and Commercialisation area, more flexible charging and risk sharing arrangements, flagship programs, and involvement with pre-seed funds, will provide opportunities and incentives for business investment. These initiatives require sustained support from government through appropriation funding, as well as continued government support for business R&D, including business public sector research partnerships, if they are to be fully effective.

Introduction

CSIRO is Australia's largest public sector research organisation with 75 years of sustained and significant achievements to back up its high national and international reputation. The organisation has 61 sites in Australia and over 6 300 staff, of whom sixty percent hold university degrees, including the 1 800 having doctorates.

CSIRO has an interest in business commitment to R&D for a number of reasons. Not the least of these is that the *Science and Industry Research Act* states that a primary function of CSIRO is to carry out scientific research to assist Australian industry. (Attachment 1)

CSIRO's main interactions with business flow from the business sector's roles in funding, performing and using research. Firms needing research do not necessarily have the capability to carry out the research themselves. They may lack the necessary expertise, equipment or facilities. For this reason they may contract out their research to another organisation, such as CSIRO. Businesses performing their own research may need access to specialised facilities or services such as those that CSIRO can provide. (See Attachment 2.) Moreover, firms performing their own R&D often have a higher propensity to take up research and technology developed in other organisations (including CSIRO), than do firms not involved in R&D. In part this flows from the skills, knowledge and commitment to innovation of staff conducting research. CSIRO also plays a very important role in providing informal advice to firms, especially SMEs.

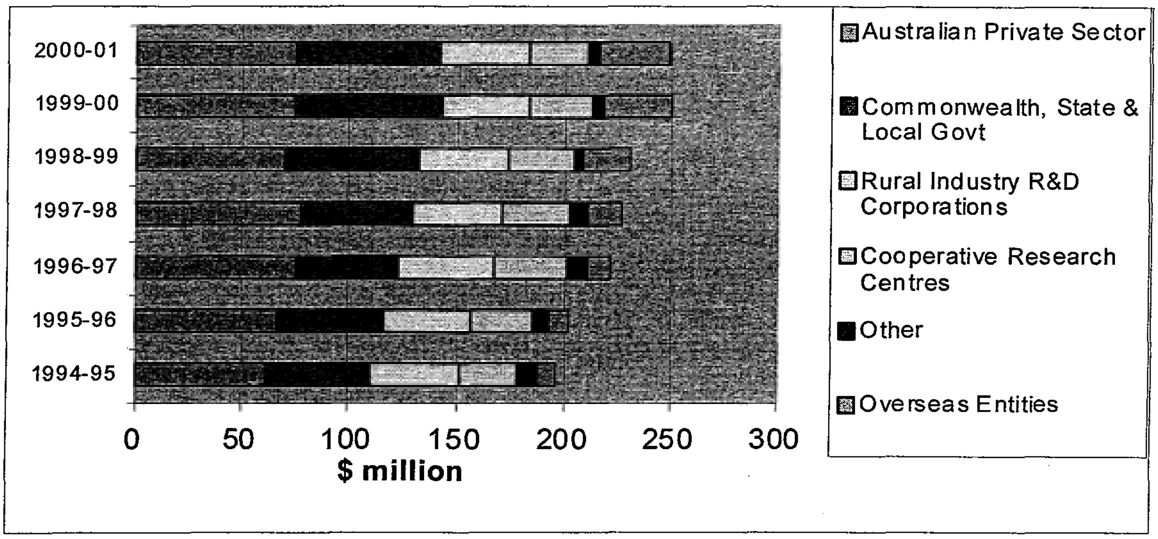
Research agencies such as CSIRO, the universities and business are all essential components of Australia's national innovation system. The effective operation of the system as a whole depends on the effective functioning of each component. CSIRO's strong commitment to working with Australian business helps individual firms innovate but also increases the contribution that business makes to Australia's total innovation system. In this latter role the CSIRO acts as a national facility that business can draw upon to complement its own activities. For example, CSIRO's size and breadth of activity allows it to monitor international developments in science in a way that would not be possible for individual Australian firms; and individual firms are able to benefit from this activity by working with CSIRO.

CSIRO works with business in many ways but some of the most important areas are:

- Clarifying the scientific expertise necessary to address a firm's problems
- Developing proposals to provide a service to the firm
- Negotiating a contract with the firm
- Conducting research or providing scientific services as specified in the contract
- Providing information and expert opinion on national and international developments in those areas of science in which CSIRO has expertise
- Providing access to specialised equipment
- Providing access to independent third party experts
- Directing a firm to other organisations that might be able to help if an inquiry falls outside CSIRO expertise.

In 2002-03, CSIRO will generate around $300 million in external earnings through research contracts, specialised consultancies and other services. This will supplement the $639.6 million CSIRO received in direct budget funding from the federal government. As a result, the organisation will have total revenue exceeding $900 million. External earnings grew by eleven per cent in 2001/02. Figure 1 shows the sources of this funding and the increasing importance of the research and other services CSIRO offers to the business sector. In interpreting Figure 1, it is important to note that the funding from the Rural Industry R&D Corporations includes an industry component.

Figure 1
Sources of CSIRO external funding



CSIRO provides services to over 3 500 customers each year and two thirds of these (by number) are from the Australian private sector. In 1999-2000, the organisation performed work on behalf of 173 of the top 500 companies in Australia and for 1 444 SMEs. There were 2 300 firms that used CSIRO testing and related services.

CSIRO uses a wide variety of mechanisms to capture the benefits of its research for Australia. As an example, research provides the foundation from which CSIRO is able to offer 50 specialised technical and analytical services to industry and other researchers. (See Attachment 3.) These scientific services form an essential part of Australia's science, technology and innovation infrastructure.

CSIRO also uses a variety of mechanisms to transfer its technology to the business sector. Every year CSIRO scientists produce over 8 000 client reports in addition to around 3 000 scientific papers. CSIRO also seconds staff to other organisations, arranges industry workshops and seminars, and prepares other, specialist publications to transfer the technology that it creates.

Another measure of CSIRO's support to industry is that it is Australia's leading patenting enterprise, averaging around 80 Patent Cooperation Treaty applications a year. CSIRO currently holds over 3 500 patents, protecting 730 inventions and in 2001-02 received $18.5 million from the exploitation of its intellectual property.

An even more direct demonstration of CSIRO's contribution to Australia's economic development is that more than 70 spin-off companies owe their origin to intellectual property and expertise developed within the organisation. These spin-off companies, by the nature of their business activities, have a high commitment to R&D.

Commitment of Australian business to R&D

Introduction

OECD-area expenditure on R&D has increased considerably over the past 20 years. In 1999 OECD countries spent US$553 billion on R&D (amounting to around 2.2 per cent of overall GDP). The business sector was the main source of this funding, providing about 60% of the total. In the USA, the business sector provided 67% of total R&D funding; in Japan business provided 72%.[1] As well as being the main source of funding for R&D, the business sector was also the major performer of R&D. In 1999 the business sector performed close to 70 per cent of the OECD's total R&D.

Table 1 compares OECD countries according to their expenditure on R&D as a proportion of GDP. The table shows that in 1998-99 Australia spent 1.5 per cent of its GDP on R&D, ranking 11 out of 16 countries.[2]

Looking only at government expenditure, Australia ranks fifth equal; and looking at higher education expenditure, Australia ranks sixth equal. Australia's low overall ranking is a result of the relatively low level of expenditure by the business sector.

Looking only at business sector expenditure, Australia ranks twelfth. Italy, Spain, Poland and Hungary are the only countries in which business expenditure on R&D amounts to a lower proportion of GDP than in Australia.

[1] OECD, STI Scoreboard 2001.
[2] In 2000-01 Australia spent 1.53 per cent of GDP on R&D. ABS 8112.0

Table 1
Expenditure on R&D as a percentage of GDP, OECD Countries - 1998-99

Country	Business %	Government %	Higher education %	Total(a) %
Japan	2.17	0.28	0.45	3.04
Finland	1.94	0.36	0.57	2.89
United States	1.94	0.21	0.37	2.60
Korea	1.79	0.45	0.28	2.55
Germany	1.57	0.34	0.40	2.31
France	1.36	0.41	0.38	2.18
Iceland	0.75	0.76	0.51	2.04
Netherlands	1.06	0.35	0.53	1.95
United Kingdom	1.20	0.24	0.36	1.83
Canada	1.03	0.22	0.45	1.71
Australia	**0.68**	**0.35**	**0.44**	**1.50**
Czech Republic	0.82	0.33	0.12	1.27
Italy	0.55	0.22	0.25	1.02
Spain	0.47	0.15	0.27	0.90
Poland	0.30	0.22	0.20	0.72
Hungary	0.26	0.21	0.17	0.68

(a) Includes private non-profit.

Perhaps surprisingly, the average annual growth rate in Australian business expenditure on R&D for the period 1991-98 was 6.46 per cent, compared to an OECD average annual growth rate for the period 1991-99 of 2.97 per cent.[3] While the performance of Australia's business in this respect was commendable, the proportion of Australian research funded and performed by the business sector remains comparatively low, although it has improved significantly since the early 1980s, as shown by Tables 2 and 3. These show changes in the percentage of Australian R&D funded and performed by business compared to the OECD average over the last 20 years.

Table 2
Percentage of R&D funded by business[4]

	1981	1989	1991	1995	1997	1999	2000-01
Australia	20.2	41.1	44	47.8	45		45.9
OECD	51.1	56.6	58.8	59.8	62.3	63.2	

[3] Figures taken from OECD, STI Scoreboard, 2001
[4] Figures taken from OECD, STI Scoreboard, 2001 except for 2000-01, calculated from ABS 8112.0

Table 3
Percentage of R&D performed by business[5]

	1981	1989	1991	1995	1997	1999	2000-01
Australia	25	40.2	44.1	48.2	45.1		47
OECD	65.7	68.8	68.8	67.4	69.1	69.9	

There are many factors that can affect the level of business investment in R&D and this can make comparisons between countries difficult. For example, the propensity to invest in research will vary between sectors. An accounting practice or hairdressing business is less likely to invest in research than a biotechnology company, or a firm operating in the defence industry. There will also be differences related to the size of firms. The larger a firm, the more likely that it will have the specialised skills, the resources and the ability to fund, perform and use research. The level of foreign ownership may also play a part with companies tending to conduct most of their research in their home country, rather than in their overseas subsidiaries. Factors such as government policies, the taxation, legal (including intellectual property) and economic frameworks, the availability of venture capital and of people with the appropriate (technical and entrepreneurial) skills can also influence the level of investment in R&D.

Australian companies funding R&D

According to the Australian Bureau of Statistics, around 3 500 Australian businesses funded research in 2000-01. Looking at this figure more closely, and comparing 1999-2000 with 2000-01:

- 2 600 businesses conducted research in both years
  - 45 per cent of these had increased expenditure by 10 per cent or more
  - 32 per cent had decreased expenditure by 10 per cent or more.
- 800 businesses that reported a total R&D expenditure of $356 million in 1999-2000 did not report any research expenditure in 2000-01.
- 900 businesses that did not report R&D expenditure in 1999-2000 reported a total expenditure of $440 million in 2000-01.[6]

These figures suggest that around 25 per cent of the firms conducting research in any one year do so to meet a particular need rather than from any ongoing or sustained commitment to research per se. This is not surprising given that research is not an end in itself and that smaller firms fund a significant proportion of Australian business research The market for research services is fluid, depending on the specific needs a business is facing at any one time and the resources it has available, taking into account on the economic and business outlook.

[5] Figures taken from OECD, STI Scoreboard, 2001 except for 2000-01, calculated from ABS 8112.0
[6] ABS Research and Experimental Development, Businesses, Australia. Cat.8104.0 (1 July 2002)

While the number of Australian firms funding research is relatively small, the number of firms investing in technological innovation is much larger. The OECD guidelines for collecting and interpreting technological innovation data include the following activities as technological innovation: design; research and development; acquisition of technology in the form of patents, licences and trademarks; acquisition of technology in the form of machinery and equipment; tooling-up and industrial engineering; manufacturing start-up and pre-production development; training; and marketing for new products. According to Australia's most recent innovation survey, 26 per cent of the estimated 55 000 manufacturing businesses in Australia had undertaken one or more technological innovation activities in the three year period from 1 July 1994 to 30 June 1997.[7]

Sector variation

The level of investment in R&D will clearly vary between different business sectors. While all sectors generate and use new technology to some extent, some have a greater dependency on technology and operate in areas in which technology is developing more quickly. It is possible that a low commitment to R&D expenditure on the part of an individual firm might represent the industry norm.

Table 4 shows how the percentage share of total manufacturing R&D varies between industries grouped as high-technology, medium-high-technology and medium-low to low- technology. Australia spends a lesser proportion of its research expenditure on high technology industries and more on medium-low to low-technology industries than the OECD mean. This could reflect the structure of Australian industry, rather than a different propensity to invest in research. If so, the solution is not necessarily to encourage firms to invest beyond the industry norm but to create or attract new firms.

Table 4
R&D expenditures in manufacturing by level of technology – 1991 –99
(Percentage share of total manufacturing R&D)

	High-technology			Medium-high technology			Medium-low and low-technology		
	1991	1995	1998	1991	1995	1998	1991	1995	1998
Australia	31.7	27.4	34.7	30.5	28.8	28.2	37.8	43.8	37.0
OECD		50.7	52.2		36.9	35.5		12.4	12.3

[7] ABS 8116.0

The European Union Fifth Framework Programme (1998-2002) provides another interesting perspective on structural differences. The program sets out the strategic research priorities of the European Union and has specific measures for SMEs. It classifies SMEs able to benefit from its research programs into three categories:

- Technology developers, having strong research capabilities. These make up less than five percent of Europe's industrial SMEs and tend to be small, young and in high-tech sectors.
- Leading technology users that do not have sufficient capabilities to meet their own technological needs, so they outsource their R&D. They make up around 10 to 15 per cent of SMEs, tend to be over 10 years old and come from both the manufacturing (medium technology intensity) and service sectors.
- Technology followers are mainly end-users of R&D. They tend to be in the less research-intensive sectors, invest little in R&D and look for short-term results.[8]

Clearly, while technology developers are more likely to occur in some sectors than others, this classification of firms can apply to any sector. While the proportions may differ, any sector will include firms whose business and technology strategies fall into these categories. A decision to adopt a particular niche in this way may be a sound commercial decision. It would not be possible for all the firms in a sector to aim at becoming technology developers and it would not be a sensible use of resources if they were to do so.

While there are differences between sectors, it is also important to note that each sector operates in its own operational environment. There can be significant variation from year to year in R&D funding in any one sector. For example, between 1999-2000 and 2000-01, R&D expenditure in the Australian:

- mining industry increased 57 per cent
- manufacturing industry increased 8 per cent
- finance and insurance industry increased by 91 per cent
- property and business services industry increased 12 per cent.[9]

Business size

Australia differs from many OECD countries in having a relatively small number of large businesses. For example, Australia had only 8 companies in the 2001 Financial Times list of the top 500 companies in the world.[10]

The Australian Bureau of Statistics defines small businesses as those employing fewer than 20 persons. In 1999 there were 951 000 small businesses in the private, non-agricultural sector. These employed around 47 per cent of the workforce of that sector and around 37 per cent of Australia's total public and private sector workforce.[11]

[8] www.cordis.lu/sme
[9] ABS 8104.0
[10] FT500 – 2001 edition (Financial Times, UK)
[11] Small business in Australia, 1999, ABS 1321.0

In 1999-2000, only 2 700 Australian businesses (3.6 per cent) had more than 200 employees. Australia had 3 700 businesses having between 100 and 199 employees, 33 200 having 20-99 employees and 167 100 having between 5 and 19 employees.[12]

Table 5 provides data on the proportion of a country's total research effort conducted by firms of different size. It demonstrates that a country's largest firms tend to account for the greater proportion of its business research effort.

Table 5
Total R&D broken down by size class of firms (1999)[13]

Number of employees	Fewer than 100	100 – 499	500 – 999	More than 1000
Australia	29.2	20.7	12.3	37.8
Canada	16.8	15.8	10.1	57.4
USA	10.4	8.3	3.8	77.5
Korea	4.1	8.8	8.2	78.9

Australia is unusual in the high proportion of its research conducted by firms having fewer than 100 employees. This proportion is higher than for any other OECD country, apart from Iceland. One explanation for this would be that the commitment of Australian SMEs to research is greater than that of equivalent businesses in other OECD countries. However, another explanation is that these figures do no more than reflect the small number of large firms in Australia and the increased relative importance this gives to the smaller firms.

In the USA, firms having more than 10 000 employees account for 55 per cent of industrial research. This concentration of business research effort in larger firms is not surprising. Research requires highly skilled and specialised staff, expensive equipment and facilities, and a level of financial resources sufficient to apply the research results as well as conduct the research. Moreover, research involves risk – direct technical risk but also commercial and market risk. Even if the research has a successful technical outcome, it need not result in commercial success. A competitor might get there first or the market might not have the anticipated interest. Larger firms are likely to have a greater capacity to manage the risk than smaller firms. At any one time a large firm can have a broad portfolio of projects, some of which will be successful and compensate for those that are not.

[12] Small Business in Australia Update 1999-2000, ABS 1321.0.55.001
[13] Figures taken from OECD, STI Scoreboard, 2001

Some simple calculations can show the difficulties a small firm can experience in conducting research. Consider a high R&D intensity firm that spends ten per cent of its turnover on R&D. Such a firm might have ten per cent of its employees working on R&D. Of these, 80 per cent are likely to work at the development end of the research spectrum. For a firm with 200 employees, this would mean 20 R&D staff of which 4 would be in research and 16 in development. A firm operating in a low R&D intensity industry, spending 1 per cent of turnover on research and development, would need 2 000 employees to maintain 4 research personnel and 16 employed in development. Yet having fewer than 4 employees working in research is unlikely to be viable.

Foreign ownership

The Australian Bureau of Statistics has recently released a paper: *Foreign ownership characteristics of businesses undertaking research and experimental development activity in Australia.*[14] The paper uses data from 1999-2000. In that year, foreign-owned businesses were responsible for 42 per cent of total business expenditure on R&D, 45 per cent of total manufacturing R&D and 70 per cent of the 'motor vehicle and parts and other transport equipment' sector R&D. Foreign-owned businesses also dominated R&D expenditure in the wholesale and retail industries (at 79 per cent) but were responsible for only 8 per cent of total expenditure in the scientific research industry.

The ABS study provides some interesting data on the source of funds foreign-owned companies use for research. 'Own funds' are the funds the business itself sets aside for R&D; 'other Australian funds' are sourced from other Australian businesses, government grants and other funds; and 'overseas funds' are those that flow into Australia for R&D purposes.

As shown in Table 6, Australian-owned businesses provided 58 per cent of 'own funds' but took up 84 per cent of 'other Australian funds and only 17 per cent of overseas funds. However, overseas funds made up only 4.7 per cent of total business expenditure on R&D in that year.

Table 6
Source of R&D funds for Australian and foreign-owned businesses

	Own funds		Other Australian funds		Overseas funds	
	$M	%	$M	%	$M	%
Australian-owned	2 062.5	58	259.6	84	32.8	17
Foreign-owned	1483.5	42	49.5	16	157.4	83

[14] www.abs.gov.au/ausstats/abs@.nsf

Registration data from the R&D tax concession scheme show that over the late 1990s the average number of foreign owned companies claiming the tax concession was around 500. This was less than one third of the foreign owned manufacturing enterprises in Australia (although far fewer than one third of Australian owned manufacturing enterprises conduct research). Moreover, data in the tax concession management information system show that foreign companies' share of Australian expenditure on R&D by business increased from 9.8 per cent in 1985-86 to 31.3 per cent in 1996-97.[15]

A 1999 survey of around 400 firms that together account for nearly 80 per cent of R&D expenditures in Europe, North America and Japan looked at changes in the proportion of the R&D budget firms were spending outside their home region. Consistent with the move towards globalisation, the trend was from 15 per cent in 1995, to 18.7 per cent in 1998, to a forecast 22 per cent in 2001. Overall, and especially for European firms, there was a high correlation been the percentage of sales revenues from non-domestic operations and the non-domestic R&D spending percentage.[16]

Type of research activity

Not all research has the same purpose. Basic research aims at acquiring new knowledge. While basic research does not have any specific application in view, the fruits of such research provide a broad base that serves as the foundation for solving many practical problems. Applied research has specific applications in view, while experimental development has the purpose of creating new or improved products and processes.

Sixty nine percent of Australian business expenditure on R&D is on experimental development, while only six per cent goes on basic research. Business commitment to research is for research that will produce short-term gains. This serves to emphasise that business research builds on the foundation of knowledge created by other parts of the innovation system – particularly universities and government research agencies, such as CSIRO.

Table 7 shows how the share of funding going to different parts of the research spectrum varies between broad industry sectors, while Box 1 presents data on the automotive industry as a case study.

[15] Dr Alan A Jones, *Innovation in Australian Small and Medium Sized Enterprises*. 2nd Arab forum on small and medium industries. May 2001. Kuwait.
[16] Edward B Roberts *Benchmarking global strategic management of technology*. Research Technology Management. March-April 2001.

Table 7
Business expenditure on R&D by type of activity[17]

	Basic research	Applied research	Experimental development
Mining	5.1%	23.1%	71.6%
Manufacturing	4.8%	23.0%	72.1%
Other industries	7.9%	26.5%	65.5%

It is interesting to compare these figures for Australia with some data presented by Charles F Larson, the former Executive Director of the Industrial Research Institute (IRI). This institute is a non-profit organisation of some 235 leading companies and members of the IRI carry out over 75 per cent of the industrial research effort in the United States manufacturing sector. Table 8 presents data on the proportion of the IRI's members' research effort going into different research effort in 1998 and projections for 2008.

Table 8
IRI members' expenditure on R&D by activity[18]

	Longer term research	Shorter term research	Development
1998	5%	22%	73%
2008	4%	18%	78%

Even if the definitions used by the IRI do not match up exactly with those of the OECD, these figures suggest that the commitment of Australian business to the longer term and basic research is at least as good as that of some of the biggest firms and performers of R&D in the world.

As already mentioned, business R&D takes place in the context of a global innovation system and draws upon the (publicly funded) work of research agencies and universities through various forms of collaboration and alliance. The strength and relevance of public sector research has a direct influence on the ability of business to conduct its own research and to improve its performance. Indeed, public expenditure on R&D can lead to greater private sector investment. This is because firms that build on the outputs of public sector research face reduced levels of technical risk. In addition, firms are able to use using public sector facilities that they would not be able to justify constructing for themselves.

[17] ABS 8104.0
[18] Charles F Larson, *Industrial R&D in 2008 http://www.iriinc.org/webiri/publications/cfl-industrial2008.cfm*

A case study – R&D in the Australian automotive industry

The Automotive Competitiveness and Investment Scheme (ACIS) has admirable objectives in encouraging R&D within carmakers and component manufacturers. Recent Australian Bureau of Statistics data shows that less than one percent of R&D in the automotive industry is pure research ($4.5m of the total $473m) (ABS 8104.0, June 2002). The overwhelming majority of claimed expenditure ($399m) was engineering development, a category that can include new-model expenditure or even expense associated with implementing a new production technique adopted from an overseas parent. The balance of $69million is categorized as Applied Research, generally meaning expense associated with implementing a new technology.

These data show that the Australian industry has not been investing in sustained research and that the ACIS Scheme has not provided sufficient incentive to change the situation at this time. This is reflected in CSIRO experience in its relations with the industry inasmuch as the profile of R&D work has not moved towards basic research. Indeed, it is of growing concern that the majority of CSIRO work performed at the request of industry is short-term, problem-solving work. The concern for CSIRO is that such work distracts from longer-term research projects without adding to the body of scientific knowledge. Anecdotal evidence from an internal CSIRO assessment is that commitment for R&D from the automotive industry and their suppliers is harder to achieve, more difficult to profile because they do not have time to assess their future needs, and that there is less corporate funding available for R&D.

CSIRO has been spending more than $10 million per year on automotive-related research. Some of this work is at the leading edge of automotive technology, particularly in low-emission vehicle and light metals technologies. CSIRO has research activities in all the major sciences used in hybrid and hydrogen-powered vehicles. This includes energy storage, energy-system management, modelling, electric drive motors and low-mass componentry. CSIRO provided the electric power train, storage technologies and control algorithms for two hybrid demonstration cars in 2000, the ECOmmmodore and the aXcessaustralia car. Both vehicles deliver exceptional fuel efficiency

CSIRO regards this and its other automotive work as vital to sustaining automotive manufacturing in Australia but local companies are not moving quickly enough to maintain their place in a world that is taking up the technologies. Unless this situation changes, Australian-made cars and components will become irrelevant. The business commitment to R&D has also suffered from a short-term approach in some CRC activities. Here we have basic CRC funds consumed in short-term problem solving or product development, activities that should rightly be called technical consulting. The CRCs see this work as a means of getting closer to the industry, ever hopeful of self-sustainability, while the companies are happy to receive subsidised assistance, especially with the significant leverage component of CRC funds. The provision of a clearly defined pathway for the spending of government assistance, with a balance between experimental development, basic research and applied research would ultimately pay longer-term dividends for all Australians.

A further way to enhance business commitment and to entertain a higher proportion of basic research would be to fund CSIRO through an automotive Research Centre. This body could develop industry alliances and generate approved basic research projects for the industry. Furthermore, it would be possible to introduce a mechanisms that gives better recognition of basic research through greater taxation incentives or through such schemes as a modified ACIS.

Benefits of research

The inquiry's terms of reference ask: what would be the economic benefit for Australia from a greater private sector investment in research?

In addressing this issue, it is important to note first that research is not an end in itself. Research is the process of systematic investigation or experimentation to discover new knowledge. Particularly in the case of the research funded by business, this knowledge might relate to the development of new or improved products, processes, materials or services. The benefit to the firms conducting or funding research comes from the increased competitiveness that results from applying the research findings. In other words, the benefits come from innovation, not research. The exception to this, and it is an important one, is where the purpose of the firm is to conduct research, either on a contract basis, or with a view to seeling the research outputs to another (often much larger) business. Some biotechnology companies operating in the pharmaceutical sector, for example, apply this kind of business model.

In a world of rapid change, it seems axiomatic that firms must have a process of continual innovation to maintain their position, let alone improve their performance. There is no doubt that research is a major driver of technological innovation, both directly and indirectly. Not only does research lead to new and improved products and processes, it develops a knowledge and skills base, and an openness to new ideas, that facilitates other forms of innovation. The returns on investment in research can be considerable but are not always direct, as shown by the case study in the box. This describes some results from a Centre of International Economics benefit –cost study of some CSIRO research projects.

Given that individual firms benefit directly from the research they carry out because it can lead to increases in their productivity and profitability, and helps in developing new markets, this will result in economic benefit for Australia as a whole. However, there are broader benefits to the economy that go beyond those from the benefits to individual firms. These come in part from the benefits that flow to consumers from using new and improved products. For example, a firm developing a new and more effective pesticide might increase its market share and profitability. The farmers using the new product might benefit from increased crop production, lower costs of application and having a better product at a lower price. The general community might benefit from lower levels of environmental damage and better quality, or cheaper, produce.

The economic benefits to Australia also arise from more subtle spillover effects. These can include the skills that employees develop through performing the research and can take elsewhere, or the availability to other firms of information coming from the research, even if patents restrict their use of the information.

In considering these results, it is important to recognise that research and innovation provide most benefit to the firm when they are successful. If research is unsuccessful, the benefits that still accrue to the firm in terms of better skills and increased knowledge may not be valued, particularly if the net benefits are negative.

There are many empirical studies demonstrating that increased innovation improves firm competitiveness and performance. For example, a recent study in Australia identified positive links between R&D investment, patent activity and market value, defined as the sum of the shares issued plus debt (i.e. the theoretical amount needed to own the firm outright). There are also studies that show positive links to R&D expenditure and profits.[19] More generally, a major Industry Commission report into R&D noted the significant role R&D play in driving technological progress. The report noted that economic theory and empirical analysis both suggest that technological progress has the potential to be a major contributor to economic growth.[20]

The cost of converting a research output to an innovation is usually much more than the cost of the research. Moreover, the risks involved in innovation are greater than the risk of the research having an unsuccessful technical outcome. This is particularly the case given that business R&D tends to be at the experimental development end of the research spectrum and, in the case of smaller firms, will normally aim at incremental improvements rather than great leaps forward. The technical outcome is often more certain than the commercial outcome; and the consequences of commercial failure are often more severe than the consequences of technical failure, because the necessary investment is greater.

General data on the probability of research leading to a successful innovation do not seem to be available. In any case, the success rate will vary considerably from sector to sector. An obvious example comes from the pharmaceutical industry, which is notorious for the small proportion of the prospective chemicals it develops that ever reaches the market. The venture capital industry finds that despite a very stringent screening process, such that only a very small proportion of the possibilities put forward for funding receives support, perhaps only one in ten investments becomes a significant commercial success. The box on page 22 presents some empirical data on commercialisation success rates.

[19] Simon Feeney and Mark Rogers. *Innovation and Performance: benchmarking Australian firms.* Melbourne Institute Working Paper No.7/01

[20] Industry Commission. *Research and Development. Report No. 44.* 15 May 1995

A case study from CSIRO – the benefits of research

CSIRO commissioned the Centre for International Economics to identify the scope and scale of benefits that flow from the organisation's research. The study noted that CSIRO research delivers a range of public and private benefits. These are:

- Lower unit production costs
- Improved quality of goods and services
- New products
- Reduced business risk
- Development of skills
- Improved human health
- Informing policy
- Reduced pollution
- Improved environmental health

The study reviewed more than 60 previous benefit-cost studies; provided an initial qualitative assessment of the returns on current investments; and reported the results of four, new, detailed, benefit-cost studies of projects funded in the current triennium.

Some of the results were as follows:

Benefit-cost evaluations of CSIRO projects show significant returns:

- 17 manufacturing projects had benefit cost ratios ranging from 0.5 to 72
- 7 minerals and energy projects had benefit-cost ratios between 3 and 39
- 12 environment projects had benefit cost ratios from 0.3 to 29
- 29 agri-business projects had benefit cost ratios of 0.4 to 236

Results for the four more recent projects were that: Robotic mining had a benefit cost ratio of 96 and an internal rate of return of 720%; the RoadCrack project had a benefit cost ratio of 91 and an internal rate of return of 45%; the aXcess Australia low emission vehicle project had a benefit cost ratio of 130 and an internal rate of return of 51%; the Vesta bushfire control project had a benefit cost ratio of 81 and an internal rate of return of 70%

The report concluded that the present value of anticipated benefits from just four successful current triennium projects will be many times CSIRO's total triennium funding.[21]

[21] Centre for International Economics. *Assessing the contribution of CSIRO*. November 2001

Evaluations of programs supporting business R&D can provide some proxy data for the success of research projects. For example, the European Union has special measures to foster and facilitate the participation of SMEs (fewer than 250 employees) in its research programs. Over the period 1994 to 1998, almost 15 000 SMEs took advantage of these special programs. Reviews have shown that five years after completing their project, 43 per cent of participating SMEs had increased their turnover, 53 per cent had accessed new markets and 42 per cent had created new jobs. These research projects were likely to be aiming at more incremental improvements than the major developments leading to a new business that would interest venture capital companies.

One set of EU programs has the acronym CRAFT. This covers projects in which groups of SMEs work together to define the objectives of research projects and collectively control the work of the organisation they chose to carry out the research. Reviews of this program have found that a year after their completion, 82 per cent of the projects anticipate the commercialisation of a new product and 73 per cent an internal use that will boost their competitiveness.[22]

The data that are available on the likely commercial success of research suggest that while there is a risk for individual firms in conducting more research, the benefits to the economy as a whole are likely to be positive. This may help explain why large firms are responsible for most business research. A large firm is not only in a better position to have specialised facilities and the staff able to recognise opportunities and perform the research, it is also more likely to survive a failed research project.

Large firms can run with a diverse portfolio of projects and have the confidence that those that are successful will more than repay the costs of those that fail. In this context, it is interesting to note that innovating small firms spend more per capita on innovation than do innovating large firms. (See Table 9.) [23]

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[22] www.cordis.lu/sme

[23] These data refer to technological innovation which can comprise any of the following activities: design; R&D; acquisition of technology in the form of patents, licences and trademarks; acquisition of technology in the form of manchinery and equipment; tooling-up and industrial engineering; manufacturing start-up and pre-production development; training; marketing for new products.

Table 9
Costs of undertaking technological innovation - 1996-97[24]

Business size	Turnover per employee	Innovation costs per employee	Innovation costs as a proportion of turnover
Fewer than 20 employees	132 000	9 000	7%
20-199 employees	185 000	7 000	4%
200 or more employees	266 000	6 000	2%
All	238 000	6 000	3%

The total amount spent by Australian manufacturing businesses on technological innovation during 1996-97 was around $3.9b. About half of this was spent on R&D ($2.0b). A further $1.1b was spent on tooling up, industrial engineering and start up. On average, businesses with expenditure on innovation activities spent $296 100 on innovation, or $6 300 per employee. Not surprisingly, expenditure on innovation increased with the size of business. Expenditure ranged from an average of $61 000 for small businesses to $4.1m for large businesses. The average innovation expenditure per employee showed the reverse trend, ranging from $8 900 for small businesses to $5 600 for large businesses. Similarly, the ratio of innovation expenditure to the total turnover of the business fell as size of business increased. Small businesses undertaking innovation expenditure, spent an average of 7% of their total turnover on innovative activities, while large businesses spent only 2% of their total turnover on such activities.[25]

Impediments to business investment in R&D

Feeney and Rogers offer two explanations as to why, given that innovation leads to increases in firm performance, firms do not undertake more innovation. One is that the high returns are compensation for the high levels of risk. The second is that firms face financial constraints.[26] A third impediment might be management skills, management attitudes and the particular business models that companies chose to use.

[24] Innovation in Manufacturing, Australia, ABS 8116.0. Data relate to businesses having innovation expenditure.
[25] Australia Now – ABS web site
[26] Simon Feeney and Mark Rogers. *Innovation and Performance: benchmarking Australian firms.* Melbourne Institute Working Paper No.7/01

A case study – raw ideas to commercial success

Greg A Stevens and James Burley[27] have analysed data from project literature, patent literature and experience, and venture capitalists to prepare success curves for industrial innovation. These curves provide data on the number of ideas it takes to come up with a successful innovation. The authors found that the different sources of information provided remarkably similar results.

There are clearly differences between sectors. Drug companies, for example, typically require 6 000 to 8 000 starting ideas for every successful new commercial product. Across most industries, however, the authors found that it typically takes 3 000 raw ideas to produce one, substantially new, commercially successful, industrial product.

According to Stevens and Burley, it takes about 3 000 raw ideas to identify 300 on which the generator is willing to take minimal action, such as performing a few simple experiments, or discussing the idea with management.

Of the 300 ideas that emerge from this initial self-screening process, 125 will advance to the stage that they become a small project. These projects will have a high probability of producing a research output that will lead to a patent.

Only 9 of the 125 projects will develop into significant projects with large development efforts.

Four of the large projects advance to the next stage of major development efforts.

Less than half of the major development efforts (1.7 projects) reach the commercial launch stage.

On average only 59 per cent of commercial launches provides economic profit to the parent company – i.e. a success rate of 1 project out of 3000 ideas.

While these data have most relevance to the research strategies of large firms, in that many SMEs do not attempt to produce 'substantially new' industrial products, the data help illustrate some of the problems SMEs face given the risks involved in any one project.

[27] Greg A Stevens and James Burley. *3,000 Raw Ideas = 1 Commercial Success*. Research.Technology Management 1997.

A further factor that can mean business investment is less than might be in the national interest is the difficulty a firm has in appropriating all the benefits of its research – the spillovers mentioned in the previous section. However, while spillovers certainly exist and a certain level of freeloading is possible, it is not clear that this is an issue firms, especially SMEs, explicitly take into account in making their decisions. Recent developments in the intellectual property area, including the introduction of the innovation patent, are in any case making it easier for firms to capture for themselves the benefits of their more incremental inventions.

In considering impediments to business investment in R&D, it is important to recognise that, around the world, it is only a minority of firms that conduct R&D. However, the firms that do invest in research are crucial to a nation's economic development and sustained future.

Research is risky but for firms operating in sectors characterised by rapid technological development, there are also risks in not conducting research. It is possible to lessen these risks by developing a culture that promotes the monitoring of technology developments and the rapid uptake of technology developed elsewhere. Moreover, because the success of technological innovation depends on a wide range of factors other than research, it is important that all firms strive to innovate across all areas of their operations.

New technology cannot provide its full performance outcomes unless the firms introducing it pay proper attention to matters such as managing for change, training, financial control, marketing, intellectual property management, and so on. If firms do not strive to outperform in areas in which non-technological innovation is important, they can have difficulties in capturing the benefits of their research. Just as research is not an end in itself, it not something that can occur separately from a firm's other activities.

Research has to form an integral part of a firm's growth, competitiveness and business development strategy. This means that management structures and attitudes can be major impediments to business investment in R&D. Using the outputs of research can accelerate growth and improved performance but only if it takes place within a well thought out business strategy.

Research has to be relevant to a business strategy and cannot compensate for one. This applies across all areas but is perhaps most obvious in the case of large research projects. For example, developments in the mining and metals industry can involve hundreds of millions spent on research over 10 or 15 years followed by a billion dollar investment to put the research into practice. This requires much more than laboratory skills.

The predominantly small size of Australian firms compared to their overseas counterparts might subject them to greater financial constraints in funding research. This is especially so given that the trend towards shorter product cycles means that a more concentrated research effort is necessary to keep ahead of competitors. A more concentrated research effort requires a greater number of people and better access to more sophisticated facilities and equipment.

Apart from anything else, small size will often mean greater exposure to risk and more significant consequences should the research itself, or the overall innovation process, fail. Moreover, small size limits the degree of specialisation in a firm's staff and can influence the kinds of facilities they have available. Business can overcome these kinds of impediments by using the services of public sector research agencies. However, firms may lack the expertise that would allow them to identify which of their problems might be susceptible to a research solution. This again relates to the management and other cultures within the firm.

Another factor associated with firm small size is small market size. Those SMEs that do not export have a relatively small domestic market from which to gain a return on their investment in R&D. Firms operating in a larger market clearly have the advantage and this again relates to the business development strategies of individual firms. However, it is important to recognise that moving into overseas markets itself requires significant investment and that developing new export markets has risks.

A well-developed venture capital industry can help address some of the financial and management limitations that can impede investment in research. However, the main interest of venture capitalists is in the later commercialisation stages and in start-up companies. They have little involvement or interest in the relatively small research projects aimed at incremental, but still significant, improvements that are likely to be of greatest interest to smaller firms.

Steps to demonstrate to business the benefits of higher business investment in R&D

There is no doubt that Australia would benefit if Australian businesses were to invest more in research and were to capture the full benefits of that investment. However, it is important to recognise that firms do not make their decisions according to what is in the national interest but according to what will promote their own survival and growth. This means that the promotion of R&D has to take place in the context of business development plans and improved management processes. It has to become part of encouraging firms to pay more attention to their external environment – of making them sensitive to the significance of technological and market change and to their need to respond to the increasing competitive pressures coming from globalisation.

A key part of the growth strategy of important firms around the world is to allocate funds to R&D to develop new business. Global expenditure on R&D is increasing and every day the world sees around 5 000 scientific papers published and 2 000 patents issued. According to projections by the Industrial Research Institute, US industry funding of R&D could reach US$280 billion by 2008.

One consequence of this ever-increasing investment in research is that the value of goods comes more from their information content than from their material content. Peter Drucker once remarked that a pill is simply the packaging for the information it contains but a similar comment can be made about most areas of industry – it is the intangibles that provide value.

Charles Larson, the former Executive director of the Industrial Research Institute, has suggested that as business intensifies its emphasis on innovation, the R&D function will more closely integrate with marketing. R&D managers will become business managers (because it will be too difficult for business managers to become competent technical leaders). Mr Larson has noted that IBM researchers now spend around 25 per cent of their time with customers. He has also predicted that personnel exchanges between business and national laboratories will become more common as the interdependencies between public and private sector research become even more manifest.[28] Many studies of innovation have identified customers and suppliers as the most important stimulants of innovation and these moves simply reflect this.

The Industrial Research Institute has noted the increasing dependency of industrial research on public sector research. Confirmation that this is the case for Australia has come from studying the citations in patents. These demonstrate that technological developments depend very highly on research carried out in the public sector.

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[28] Charles F Larson, *Industrial R&D in 2008 http://www.iriinc.org/webiri/publications/cfl-industrial2008.cfm*

A recent study showed that 90 per cent of the scientific research papers cited in Australian-invented US patents issued to private companies had authors from publicly funded organisations in Australia or elsewhere. Moreover, 97 per cent of all Australian scientific research cited in all Australian-invented US patents came from publicly funded institutions. The same study demonstrated that Australian technology has a very high dependence on Australian science, much above what one might expect from the relative contribution of Australian science to the world store of science.[29]

A recent review of international studies of the links between government and private sector investment in research found good evidence that increased public sector investment leads to an increase in private sector funding.[30] Together with the patent dependency studies, this suggests that a strong and effective public sector research effort provides a necessary support for business commitment to R&D.

Role of CSIRO

CSIRO is already positioning itself to make an even greater contribution to business R&D in Australia and is directing its activities at both large and small businesses. Our 'Go for Growth' strategy is setting internal targets to significantly increase and enhance the level of service we provide to business. An important part of this strategy is to develop closer, longer relationships with customers. This will help us to better understand their business and enhance the way we can support its development.

We have strengthened and refocused our business development and commercialisation activities by increasing the number of people working in these areas and further developing our skills base. This will help bridge the gap between science and industry, as will the restructuring of our advisory committee mechanisms to help industry make more strategic inputs into the planning process. Our marketing and communication activities emphasise research outcomes and the contribution of research to business (and national) performance. As part of our focus on strengthening relationships with customers, we have introduced a quarterly customer value survey, which, among other things, will enable us to identify the drivers of value from a customer perspective.

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[29] F Narin, M Albert, P Kroll, D Hicks. (CHI Research Inc.) *Inventing our future. The link between Australian patenting and basic science.* http://www.arc.gov.au/publications/arc_pubs/00_02.pdf

[30] Centre for International Economics. *The role of public R&D spending in building Australia's innovation base: CSIRO BHAGs.* January 2002

CSIRO has a particular interest in working better with SMEs to increase their success rate in developing and adopting technology. We have been examining how similar organisations around the world address these issues and are considering options such as:

- Enhancing the use of the CSIRO 1800 contact number
- Enhancing the effectiveness of our referral service
- Raising awareness of the extensive range of CSIRO- managed plant and equipment that business might use
- Working with other Commonwealth and State bodies to consider a one-stop shop providing assistance to SMEs
- Facilitating the involvement of late-career, experienced researchers with SMEs
- Developing a joint proposal with the Australian Industry Group to set up and manage a technical advisory service.

One of the major impediments to business investment in R&D is the financial capacity of firms, especially of SMEs. CSIRO supports SMEs through its research services (and by providing access to national facilities at marginal cost). However, in many cases the limited ability of SMEs to pay for the work they require has meant that CSIRO has had to subsidise its services. For this reason, and as part of our own business development strategy, we are starting to experiment with more flexible arrangements to help SMEs use our services. For example, we will consider alternative fee arrangements for some of the services we deliver. These might include mechanisms (such as the use of royalty streams, revenue/profit sharing or success bonuses) that share the risk and rewards of the research. These mechanisms are possible given the scale and diversity of our operations and the large portfolio of projects that we manage at any one time. We are able to spread the risk in a way that individual SMEs would find impossible. In effect, these mechanisms transform our relationship with SMEs from one of customer/supplier to a partnership.

Another important way in which CSIRO is helping increase business commitment to R&D is by facilitating and promoting the establishment of spin-off companies. There are already more than 70 spin-off companies based on CSIRO-generated intellectual property and expertise, with 13 formed in 2000-01 alone. These companies, by their very nature, are technology developers with a high commitment of R&D.[31] Spin-off companies from research agencies are particularly important in Australia because our relative lack of large firms means that we are likely to have fewer spin-offs from business than in many other countries.

[31] Studies of the early stage of university and other public research agency spin-off companies show very high levels of ongoing investment in R&D. John Yencken and Murray Gillin, *Australian university spin-off companies: attitudes, policies and companies.* Australian Graduate School of Entrepreneurship at Swinburne University of Technology. Research Paper. March 2002

The flagship programs that CSIRO is developing with other partners provide another example of our work to make us more receptive to business needs. Flagships will focus significant resources in areas of national importance. The flagship programs emphasise partnerships and cooperation. The outcomes they will strive to achieve require all parts of the innovation system to work together to capture and apply the research outputs. The scale and intensity of the effort we will put into these programs will help reduce the risk to the businesses that become partners, as will the considerable background work and market intelligence that has led to the identification of the priority areas.

CSIRO's ability to provide this support to business through flagship programs stems from our unique role in Australia's innovation system. In particular, we are able to devote significant resources over an extended period to identifying and analysing issues so that we can plan a research strategy to deal them. We can then assemble the large, multidisciplinary teams necessary to implement the plan. This capacity stems from our size, internal diversity and the certainty of our appropriation funding, along with our international reputation that flows from the excellence of our science and people. It is this reputation that enables us to attract the local and international partners best able to contribute to the overall objectives of the program.

Government support

There are many government programs that help business partner with CSIRO and other organisations, in part by reducing the financial risks that firms take in investing in R&D. These are all useful and important. We would like to draw attention in particular to the significance of the *Backing Australia's Ability* initiatives. Within the context of the committee's inquiry, the initiatives to provide additional funding for the R&D Start program, to provide significant extra funds for the Commercialising Emerging Technologies (COMET) program and to establish a Pre Seed Fund for commercialising research from public sector universities and public sector research agencies were especially significant.

While these programs are important, they need continuity and to provide a degree of certainty if they are to be fully effective. As an example, the recent suspension of the R&D Start program because of cash flow problems is impeding industry investment in research projects that were ready to start. This sends mixed signals about the government's commitment to business research. It also raises the possibility that a delayed research project might be overtaken by the work of a competitor. As a result, the firm having to delay its project might face commercial difficulties.

There are changes in the innovation policy environment that would serve to encourage business to enter in partnerships that build on Australia's public research base. For example, SMEs might receive a higher level of tax concession for collaborative projects with public sector research agencies and universities. Focusing more on outcomes, it might be possible to subject earnings from activities involving such joint R&D to a reduced marginal tax rate or a tax holiday for the first few years.

While these approaches would help lift the level of SME expenditure on R&D, it is important to recognise that many SMEs have a greater need for technical problem solving, consultancy and advice, than they do for research. Technological innovation in most SMEs takes place through transfer, not development.

In considering its terms of reference, it is important that the committee recognise that business R&D does not take place in isolation and that it depends upon and draws upon the activities of organisations such as CSIRO in many ways. In providing the basic science and technology infrastructure of the nation, the research agencies (together with the universities) provide the foundation for business R&D. While this is true around the world, it is particularly significant in Australia given that we have few large companies that have the resources necessary to develop their own laboratories on a scale and level of sophistication that will allow them to operate independently.

Even in the USA, the largest companies depend on the research outputs of public sector research and will often use public sector facilities that it would be uneconomic for them to develop for their own use.

ATTACHMENT 1

CSIRO's functions as stated in the Science and Industry Research Act 1949

(1) The functions of the Organisation are:

(a) to carry out scientific research for any of the following purposes:

(i) assisting Australian industry;

(ii)furthering the interests of the Australian community;

(iii)contributing to the achievement of Australian national objectives or the performance of the national and international responsibilities of the Commonwealth;

(iv)any other purpose determined by the Minister;

(b) to encourage or facilitate the application or utilization of the results of such research;

(ba)to encourage or facilitate the application or utilisation of the results of any other scientific research;

(bb)to carry out services, and make available facilities, in relation to science;

(c) to act as a means of liaison between Australia and other countries in matters connected with scientific research;

(d) to train, and to assist in the training of, research workers in the field of science and to co-operate with tertiary-education institutions in relation to education in that field;

(e) to establish and award fellowships and studentships for research, and to make grants in aid of research, for a purpose referred to in paragraph (a);

(f) to recognize associations of persons engaged in industry for the purpose of carrying out industrial scientific research and to co-operate with, and make grants to, such associations;

(g)to establish, develop and maintain standards of measurement of physical quantities and, in relation to those standards:

(i) to promote their use;

(ii)to promote, and participate in, the development of calibration with respect to them; and

(iii)to take any other action with respect to them that the Chief Executive determines;

(h) to collect, interpret and disseminate information relating to scientific and technical matters; and

(j) to publish scientific and technical reports, periodicals and papers.

(2)The Organisation shall:

(a)treat the functions referred to in paragraphs (1)(a) and (b) as its primary functions; and

(b)treat the other functions referred to in subsection (1) as its secondary functions.

ATTACHMENT 2

CSIRO Research Facilities Important to Business

CSIRO is responsible for hosting four Major National Research Facilities and maintains a range of other major research facilities.

Australian Animal Health Laboratory Geelong	A Major National Research Facility. Biocontainment facility for safe handling and containment of pathogenic microorganisms and for experimentation in animals with high risk animal and human infectious agents.
Australian National Fish Collection Hobart	Unique collection of Indo-Pacific fishes (220,000 specimens) with most diverse collection of sharks, rays and deepwater fishes in Southern Hemisphere; radiographs, tissue samples and more than 30,000 fish photographs.
Australian National Herbarium Canberra	Large research collection of herbarium specimens (1.3m specimens) covering Australia's plant biodiversity and that of adjacent regions.
Australian National Insect Collection Canberra	Large research collection of Australian insects (11m curated specimens with 100,000 added pa).
Australian National Wildlife Collection Canberra	A large and comprehensive collection (83,000 specimens) of Australian land vertebrates covering over 95% of Australia's birds, 75% of its mammals, 70% of its amphibians and 60% of its reptiles.
Australia Telescope National Facility NSW	A Major National Research Facility. Research in radio-astronomy, includes: the 6 km Compact Array at Narrabri; the 64m telescope at Parkes; the 22m telescope at Mopra; laboratories in Sydney.
CSIRO Collection of Living Microalgae Hobart	Culture collection of over 700 strains of marine and freshwater microalgae with the majority of the strains isolated from Australian waters.
CSIRO Entomology Quarantine Network	Containment facilities at levels PC2-PC4, in the tropics (Brisbane), the temperate zone (Canberra), and the Mediterranean zone (Perth), for risk assessment and screening of imported organisms.
Controlled Environment Facility Canberra	Facility for biology contains 14 growth rooms (about 100 sqm of floor space) that provide unique control of environmental parameters such as temperature, humidity, light intensity and carbon dioxide concentrations.

FRV Southern Surveyor	A Major National Research Facility. A 66m fisheries and oceanography research vessel with well equipped wet and dry laboratories, scientific and trawl winches, heavy lifting capacity and A-frame for profiling and sampling instruments.
High Performance Computing and Communications Centre Melbourne	Joint facility with Bureau of Meteorology provides large-scale computing and storage facilities for scientific research and the Bureau's operations.
National Measurement Laboratory Sydney	A Major National Research Facility. Responsible for maintaining the nation's primary physical standards.
Scientific Marine Data Collection Hobart	Collection of marine scientific data over last 50 years.

Other research facilities include:

- Air Quality Monitoring and Assessment Facility, Sydney
- Antenna Measurement Facilities, Sydney
- Australian Centre for Precision Optics, Sydney
- Australian Microscopy Virtual Laboratory
- Centre for Advanced Analytical Chemistry, Sydney
- Coal Preparation and Dewatering Pilot Scale Facilities, linked facilities at Sydney, Newcastle and Brisbane
- Entomology European Laboratory, Montpellier, France
- Fire and Combustion Laboratories, Melbourne and Sydney
- Fluid Mechanics Laboratory, Canberra
- Fully Integrated Textile Mill, Geelong
- Gallium Arsenide Processing Facility, Sydney
- Infrastructure Systems Engineering Facility, Melbourne and Sydney
- Marine laboratories with circulating seawater system, Hobart
- Molecular Science Pilot Plant and Scale-Up Facility, Melbourne
- Monolithic Microwave Integrated Circuit (MMIC) Design Test and Packaging Facility, Sydney
- Petroleum Core Repository, Perth
- Sustainable Materials Engineering Facility, Melbourne and Sydney

- Tidbinbilla Deep-Space Tracking Station (managed under contract with NASA), ACT
- Tropical Agriculture Controlled Environmental Facility, Brisbane

ATTACHMENT 3

CSIRO Technical and Analytical Services Important to Business

Division	Service	Description
Animal Health Australian Animal Health Laboratory, Geelong	Testing for disease agents	Testing for disease agents in aquatic and terrestrial animals, mostly for export/import certification of products or animals.
	Innocuity testing	Innocuity testing of vaccines for pharmaceutical companies.
Animal Production Sydney	Veterinary Pharmaceutical Analytical Service	Analysis of anthelmintics and other drugs in tissues and body fluids to GLP and ISO 9002 standards for pharmaceutical companies.
	Gene microinjection	Produce transgenic mice for universities and medical research organisations.
	DNA pedigreeing	Ascertain parentage of sheep for breeders using DNA from tissue samples.
Animal Production Armidale	Ovine Semen Collection Centre	Collect and process semen for ram breeders.
	Select Breeding Services	Undertake genetic analyses and advise ram breeders.
	Nemesis	Provide faecal worm egg counts for ram breeders.
	Histology service	Sheep skin follicle measurements for R&D organisations.
Atmospheric Research Melbourne	NATA certified Anemometer Calibration	Calibration of a wide range of anemometers and air-flow meters for industry. Client base includes a wide range of small to large companies.
	Flowhood Calibrations	Calibration of flowhoods used widely in the air conditioning industry to measure and adjust the airflow from vents. Client base mainly SMEs.

Ion Chromatograph Analysis for Air Pollutants	Service analyses passive samplers for in situ gaseous air pollution exposure. The range of pollutants is growing and includes: sulfur dioxide, ozone, nitrogen oxides, formaldehyde. Technology is also able to perform rainwater analysis for air pollutants, and chemical analysis of aerosol particles. Clients include health authorities, industry (particularly energy and mineral processing), as well as other air quality researchers.
Particle Characterisation	Analyse air pollution (through sampling) for particle size as well as particle source. Particle characterisation is a major issue in air quality and health assessments, particularly where small particle size of less than 2.5 micron is involved. Clients are Environment Protection Authorities, as well as major air quality consultants and industry.
Satellite Imaging of Natural Resources	Remote sensing capabilities available to add value to satellite imaging products that characterise the state of natural resources. A typical example is CSIRO's vegetation imaging to assess bushfire risk with bushfire authorities as the major client.

Building Construction and Engineering Sydney, Melbourne	Industrial Research Services	A range of testing and evaluation services for building products and systems including: - Acoustics - such as sound insulation of wall systems - Hydraulics - testing plumbing components or systems - Structural timber and masonry - evaluation of products - Structural engineering - such as load tests on materials - Facade engineering - design and prototype testing and remediation - Indoor air quality - measurement and advice - Concrete and cement - durability tests and remediation advice - Industrial flow technology - tests to improve plant efficiency - Thermal technologies and energy efficient design including ventilation systems.
	Fire-testing and safety	Fire testing of building elements and materials to Australian, British, American and international (ISO, IMO) standards. Also performance-based design for fire safety, fire modelling, hot smoke tests.
	CSIRO Appraisals	Building product and systems appraisal.
Food Science Australia Brisbane, Sydney and Melbourne	Laboratory, pilot plant and advisory services to the processed food industry	Services are provided to all sectors of the industry through our five major technical groups - Food Safety and Quality, Food Packaging and Technology, Ingredient Innovation, Consumer Science, Food Engineering. Skills include food technology, microbiology, organic and inorganic chemistry, sensory science, engineering and transportation.
Energy Technology Brisbane, Sydney and Melbourne	Process Pilot Plants	Beneficiation and dewatering testing and scale-up for the coal, minerals and sewage/waste industries.
	Air pollution	Assessment and control of particulates, air toxics, trace elements, noxious gases

	Water quality	Organic and inorganic contaminant and ecotoxicology assessments
	Analytical services	Comprehensive and specialised instrumentation supporting air, water, solid waste activities.
Forestry and Forest Products Canberra	Tree-seed Advisory and Supply Service	National tree seed bank providing authenticated and representative samples of seed, and advice on species selection, silviculture and tree improvement strategies.
Forestry and Forest Products Canberra, Melbourne	Analytical Services	Limited commercial services in chemical analysis of organic nutrients and wood preservative chemicals.
Forestry and Forest Products Melbourne	SilviScan and Near-infrared Spectroscopy	Uses a combination of scanning x-ray micro-densitometry, x-ray diffractometry and image analysis to measure wood properties such as density, fibre diameter, coarseness, and fibre orientation. Main clients include research institutions and forestry, timber and pulp and paper companies.
	Wood Identification	Identification of Australian and most imported woods for timber companies and timber merchants, antique dealers, archaeologists and forensic scientists.
	Scanning Electron Microscope, Digital Analysis and Imaging Facility	Provides information about the microstructure and chemistry of samples. Technology can be applied to all areas of research, quality control, manufacturing processes, health issues and general characterization of materials. Main clients include pulp and paper industry, research institutions and consultancy agencies.
	Wood Protection and Termite Screening	Evaluation, in the laboratory and field, of the effectiveness of insecticides, preservatives and barriers for the protection of wood products from termites, borers and fungi. Main clients include preservation companies and the forest products industry.

	Papermaking Systems	Routine testing and analysis of wood, fibre, pulp and paper, and associated products. Laboratory-scale (in some cases pilot scale) pulping and bleaching trials. Main clients are pulp and paper industry.
Health Science and Nutrition Adelaide	Analytical services	A range of analytical services for medical and nutrition research institutions, food companies and the pharmaceutical industry including: - Dietary and dietary fibre analysis - Testing of glycemic index of foods - Testing of the potential of foods to elevate blood - Franz cell testing (absorption of compounds through skin) - Plasma fatty acid and plasma sterol analysis - Proximate analysis of foods - Protein quality evaluation of foods and dietary supplements.
Health Science and Nutrition Melbourne	Analytical Services	A range of analytical services for large and small pharmaceutical companies and research institutions including: - Amino acid analysis - Oligonucleotide synthesis - Peptide synthesis - Amino acid sequence determination of proteins and peptides - Polyacrylamide gel electrophoresis of peptides and proteins including electrotransfer - In-Gel digestion for internal protein sequence determination - Peptide purification
Land and Water Adelaide	X-Ray Fluorescence (XRF) Laboratory	Analysis of soils, ores, mineral sands, and plant materials for major and trace elements for Universities, mining companies and consultant geologists.
	X-Ray Powder Diffraction (XRD) Laboratory	Analysis of soils, rocks, ores, industrial products and chemicals for mineralogical identification and characterisation for Universities, mining companies and consultant geologists

	Isotope Analysis Service	14C analysis of hydrological samples and stable isotope analysis of environmental samples for Government departments, Universities and groundwater consultants.
	Scanning Electron Microscope	Morphological and compositional analysis of inorganic and organic materials (from 0.1µm to 10mm sample size) for Government departments, Universities and independent consultants.
Land and Water Adelaide and Townsville	Analytical Services	Limited commercial service in chemical analysis of environmental samples for major and trace elements, inorganic nutrients and soil characterisation for Universities, Government departments and private industry.
Livestock Industries	Analytical Services (ASF)	The ASF undertakes a wide range of routine and non-routine type analysis and method development in specific target areas such as inorganic (e.g. trace elements, nitrogen analysis, ADF/NDF, gross energy, oil content – NMR, etc) and organic/bio-molecular type analysis (e.g. amino acids, phytosterols, isoflavins, sugars, pesticides, etc) in environmental, biological and agricultural systems. A wide range of analysis is conducted on samples such as soils, water, plant tissue, plasma and animal tissues. Clients include affiliated CSIRO divisions, universities and government departments in addition to consultants and veterinary researchers.
Manufacturing Science and Technology Melbourne	Chemical Analysis Service	Problem solving services and method development for a range of manufacturing industries. Low volume routine analyses for specialist problem solving where particular expertise is unavailable elsewhere.

	Materials Characterisation Service (including Scanning and Transmission Electron Microscopy, X-Ray Diffraction, Solid State NMR, Positron Annihilation Lifetime Spectroscopy)	Analysis of phase, structure and micro-structural properties for the manufacturing industry. Low volume routine analyses for specialist problem solving where particular expertise is unavailable elsewhere.
Marine Research Hobart	Remote Sensing Facility	The provision of SST (seas surface temperature) images to a variety of clients including government, private companies and the public.
	Microalgae Supply Service	The supply of microalgal starter cultures to the aquaculture industry. These cultures are used to mass produce food for juvenile forms of farmed species such as prawns, oysters and mussels.
Minerals Brisbane	QemSCAN Consulting Service	Automated mineralogical analyses to the mining industry.
Minerals Melbourne	Chemical Analysis Service	Method development and problem solving services to mining and related industries. (Low volume routine analyses for specialist problem solving support to industry).
	X Ray Diffraction & Electron Microscopy Services	Mineral phase, structure, and surface microanalysis determinations for mining and related companies. (Only low volume routine analyses for specialist problem solving support to industry).
Minerals Perth	Particle Analysis Service	Particle analysis services to mining and related industries.
Petroleum Resources Melbourne	Rock Mechanics Testing for the Petroleum Industry	Accurate determination of mechanical and ultrasonic properties of rock in support of exploration, drilling and completion design and reservoir management.
Petroleum Resources Perth	Nuclear Magnetic Resonance Core Analysis (NMR)	Laboratory NMR measurements of reservoir rocks and formation fluids to provide information on producibility of reservoir intervals.

Petroleum Resources Sydney	Fluorescence Alteration of Multiple Macerals (FAMM)	Improved source rock maturity assessment for the oil industry.
	Strontium Isotope Chronostratigraphy	More effective Petroleum Exploration and field appraisal for the oil industry.
	Grains for Oil Inclusions (GOI)	Advanced evaluation of oil charge risk; used in appraisal of oil wells.
	Fluid History Analysis for oil charge investigations (FHA)	Innovative core and cuttings analysis techniques in oil exploration and appraisal.
Telecommunications and Industrial Physics Sydney	Antenna Test Facility	Antenna radiation pattern measurement and related services in the frequency range 1 to 100 GHz for telecommunications equipment suppliers and defence industry.
	Gallium Arsenide (GaAs) Fabrication Facility	Design and fabrication of microwave and millimetre-wave integrated circuits for telecommunications and defence companies.
Telecommunications and Industrial Physics National Measurement Laboratory, Sydney	Ultrasound Measurements	Measurements of ultrasound devices used in medical therapy and diagnostic services and design advice to equipment manufacturers and suppliers.
	Calibration of standards and instruments for measuring Mass and Related Quantities	Calibration of measurement standards and instruments in the areas of mass, force, pressure, volume, flow (gas), relative humidity, and density metrology. Clients include State Weights and Measures authorities, balance, force machine and pressure calibrators serving the chemical, food, pharmaceutical, construction materials and metals industries, also energy utilities, equipment distributors, aviation industry, and national metrology institutes in the Asia-Pacific.

Calibration of standards and instrument for measuring acoustic and vibration quantities	Calibration of instruments such as standard microphones, sound level meters and vibration measuring transducers for a range of clients including OH&S regulators, noise monitoring services (eg: aircraft noise), equipment manufacturers, calibration and testing laboratories (eg: crash helmet testing) and mining companies.
Calibration of standards and instruments for measuring electrical parameters at dc and low frequencies	Calibration of devices such as reference resistors, electronic voltage standards and electrical power and energy metres for defence calibration laboratories, aviation industry, electrical distribution companies and electrical testing laboratories.
Services in the Time and Frequency area	Calibration of frequency devices such as electronic distance and interval measuring equipment. Also dissemination of time of day via Internet, TV, radio, GPS and telephone signals. Clients include time dissemination services, telecommunications services, GPS surveying services and the Department of Industry, Science and Resources [for defining the time scale for Universal Coordinated Time (Australia)]
Calibration of standards and instruments for measuring length	Calibration of instruments such as lasers, scales, survey tapes and electronic distance measuring machines. Measurement of complex 3D forms (eg: gear box components) and testing of measuring equipment. Clients include State Weights and Measures laboratories, Surveyors-General and precision engineering services (eg: for automotive industry).

	Calibration and testing of instruments and materials used in optical radiometry measurements	Calibration and testing of detectors and sources of electromagnetic radiation in the ultraviolet, visible and infra-red regions for manufacturers of lighting equipment and windscreens, calibration and testing laboratories requiring optical measurement, manufacturing and process industries relying on optical measurement (eg: paper, paint, food), safety applications (crack detection, medical, fire standards).
	Calibration of standards and instruments for measuring temperature	Calibration of reference thermometers, radiation pyrometers and like instruments for calibration and testing laboratories, manufacturing industries (eg: metal smelting), process industries (eg: food, pharmaceuticals, chemicals, petroleum, minerals), retail industries (eg: petrol stations), service industries (eg: environmental monitoring).
	Calibration of standards and instruments for measuring electrical parameters at radio and microwave frequencies	Calibration of instruments such as antennae and radiation hazard meters and of electromagnetic compatibility testing equipment for defence calibration laboratories, aviation industry and electrical testing laboratories.
	Power Systems Technology	Impulse testing and tests on high voltage generation and transmission components and calibration of current transformers and similar equipment for electrical generation and distribution companies and electrical testing laboratories.
Telecommunications and Industrial Physics National Measurement Laboratory, Melbourne Branch, Melbourne	Services in dimensional, electrical, pressure, volume and time and frequency metrology	Calibration services for dimensional and electrical measurement for clients in southern Australia such as defence and civil calibration laboratories, precision engineering services, manufacturers (eg: laser speed measuring systems), police services, energy utilities and State trade measurement services.

Textile and Fibre Technology Geelong	Textile testing services	Physical and chemical testing of fibres, yarns and fabrics for quality management by, early and late stage processors.
	Microscopy / materials characterisation	Materials identification and specification, problem solving and process optimisation for all industry sectors.
	Environmental Testing	Environmental management systems and strategies. Solutions to waste effluent management problems in textile processing. Analysis and benchmarking, including analysis of pesticide residues in raw wool and textile products.
	Leather and Sheepskin Product Testing	Physical and chemical testing of hides, skins and leathers.
	Education and training	Training and technology transfer services in fibre, textile and leather processing via seminars and interactive activities.

J McMahon
Cttee Secretary
2 Sept 2002