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VOLUME 3 : APPENDICES

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INSTITUTIONAL

APPENDICES

APPENDIX A: PUBLIC CONSULTATION

The Commission received the reference for this inquiry in September 1993. It placed advertisements widely, and provided an *Issues Paper* to a large number of individuals and organisations. The draft report was released in December 1994; about 2200 copies of the 3-volume report and over a thousand separate printed copies of the Overview, were distributed.

A.1 Consultancies

After advertising for expressions of interest, the Commission let the following consultancies:

- Dr Steve Dowrick *(The Role of R&D in Growth: a Survey of the New Theory and Evidence)*;
- Dr Shantha Liyanage and Professor Stephen Hill *(Taxation Concessions for Research & Development in Selected Asian Countries);*
- Dr Colin Rubenstein (*Advisory Framework for Australian Science and Technology Policies)*; and
- Professor Clem Tisdell *(Economic Justification for Government Support of Research and Development: A Review of Modern Microeconomic Literature and its Policy Implications)*.

Copies of the papers resulting from these consultancies were made available on request to interested parties.

A.2 Information papers

Information papers were made available for comment by interested parties following the release of the draft report.

- *Organisation and funding of government research agencies in selected countries.*
- *Government support to R&D by benefiting industry.*
- *Provision of research to rural R&D corporations.*

A.3 Public hearings and submissions

In November and December 1993, and February and March 1994, the Commission held public hearings in Perth, Adelaide, Melbourne, Sydney, Brisbane and Canberra.

At the time of the release of the draft report, 262 submissions had been received from a wide range of participants. The Commission held public hearings on the draft report in February and March 1995 in Hobart, Perth, Adelaide, Melbourne, Sydney, Brisbane and Canberra. During the period subsequent to the release of the draft report, the Commission received a further 200 submissions, making a total of 462 submissions received. These are listed below. Those submissions which were presented at a public hearing are indicated by an asterisk (*).

Inquiry participants

Participant	*Submission number*
A F Bambach Australia	105
Academy of the Social Sciences in Australia	352
ACT Chief Minister's Department	392
ACT Government	256
Advisory Board of Agriculture (SA)	162
Aerospace Technologies of Australia*	349
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AMGEN Australia Pty Ltd	235
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Ampol Exploration Ltd*	88
AMRAD Corporation Ltd*	43
ANUTECH Pty Ltd*	353
Apple & Pear Growers Association of SA Inc*	290
ASI Technologies*	58
Association of Australian Aerospace Industries*	74
Association of Australian Medical Research Institutes	231
Australian Academy of Design*	166
Australian Academy of Science*	160, 269, 357
Australian Academy of Technological Sciences & Engineering*	40, 186, 337
Australian Academy of the Humanities	2

Australian Agricultural Machinery Manufacturers Association	209
Australian Almond Improvement Society	354
Australian Apple & Pear Growers Association*	340
Australian Avocado Growers Federation Inc	416
Australian Banana Growers Council*	288, 372
Australian Biotechnology Association	206
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Australian Centre for International Agricultural Research	400
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MITEC Ltd Australia*	107
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Trounson, Professor A*	36
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United Dairyfarmers of Victoria*	61, 216, 345

A.4 Visits within Australia

The Commission conducted an extensive round of visits within Australia and overseas. Those with whom discussions were held are as follows.

New South Wales

Australian Photonics Cooperative Research Centre
Australian Science & Technology Council
Australian Technology Group
BTR Engineering (Australia) Ltd
Centre for Research Policy, University of Wollongong
Federation of Australian Scientific & Technological Societies
Hawker De Havilland Pty Ltd
Hoover (Aust) Pty Ltd
Michael Johnson & Associates
National Health & Medical Research Council
NSW Department of Agriculture
Mr Richard Shoen (former Director of National Science Foundation)
University of New England

Victoria

Advanced Engineering Centre for Manufacturing
Aerospace Technologies of Australia
Australian Minerals Industry Research Association
BTR Aerospace Australia
Mr Peter Carpenter (VFF Egg Producers Group)
Professor Adrienne Clarke (CSIRO; Department of Botany, University of Melbourne)
Comalco Aluminium Ltd
Comweld Group Pty Ltd
CRA Advanced Technical Development Facility
CSIRO Institute of Industrial Technologies
Ericsson Australia Pty Ltd
Mr Philip Evans (VFF Research Committee)
Farley Cutting Systems Aust Pty Ltd
ICI Australia Ltd
Industry Research & Development Board
Kodak (Australasia) Pty Ltd
Mr Bill Kricker
Melbourne University
Montec Pty Ltd, Monash University
Monash University, Centre for Competitive Advantage
Dr Colin Rubenstein
Dr John Stocker (CSIRO)

Strategic Industry Research Foundation
Toyota Motor Corporation
Transfield Amecon
Victoria Farmers Federation
Walter & Eliza Hall Institute of Medical Research
Mr Bob Waters (Grains Council)

Queensland

Department of Business, Industry & Regional Development

Western Australia

WA Legislative Assembly Committee on Science & Technology
Department of Commerce & Trade
Professor Robert Lindner, University of Western Australia

Northern Territory

Department of Industries & Development
Integrated Technical Service Pty Ltd
Menzies School of Health Research
Northern Territory University
Office of Northern Development

Tasmania

Australian Vice-Chancellors' Committee
Critec Pty Ltd
Department of Premier & Cabinet
Tasmanian TechnoPark
University of Tasmania

Australian Capital Territory

Australian Industrial Property Office
Australian Research Council
Australian National University
Australian Science & Technology Council
Australian Vice Chancellors' Committee
ANUTECH
The Chief Scientist (Professor Michael Pitman)

CSIRO
Defence Science & Technology Organisation
Department of Community Services & Health
Department of Defence
Department of Employment, Education & Training
Department of Finance
Department of Industry, Science & Technology
Department of Primary Industries & Energy
Department of Prime Minister & Cabinet
Grains R&D Council
Industry Research & Development Board
Institution of Engineers
Metal Trades Industry Association
National Health & Medical Research Council
Professor Ralph Slatyer (ANU)
Mr Nobuo Tanaka (visitor to the Department of Industry, Science & Technology from the OECD)

A.5 Conference on R&D and economic growth

In May 1994 the Commission held a conference on *R&D and Economic Growth*, at which Dr Steve Dowrick (ANU) and Professor Paul Romer (University of California, Berkeley) made presentations, and Professor Ron Johnston (University of Sydney) was discussion opener.

A transcript was made of the discussion, and copies are available.

A.6 Roundtable discussions

The Commission also held two informal meetings at its Belconnen offices in a 'roundtable' format. The first was held on 27 April 1994, and had as its theme:

Getting better outcomes from Australia's R&D effort: is there a need for a more strategic approach?

Invited guests were:

Dr Colin Adam (CSIRO)
Professor Max Brennan (ARC)
Sir Roderick Carnegie (Business Council of Australia)
Professor Alan Gilbert (University of Tasmania)
Professor Ron Johnston (University of Sydney)

Professor Alan Lloyd (Melbourne University)
Professor Michael Pitman (Chief Scientist)
Mr John Plunkett (IR&D Board)
Professor Alan Trounson (Monash University)

The second was held on 11 May, and its theme was:

R&D and effective business performance

Invited guests were:

Dr Mathew Butlin (CRA Ltd)
Dr Peter Farrell (ResCare Ltd)
Professor Gerry Freed (University of Sydney)
Dr Steven Gumley (Critec Pty Ltd)
Dr Peter Harvey (Kodak Australasia Pty Ltd)
Mr Bob Jeal (Hawker de Havilland Pty Ltd)
Mr Peter Laver (BHP)
Mr John Riedl (Jtec Pty Ltd)
Mr Ken Windle (Glaxo Australia Pty Ltd)

A.7 Presentations

During the course of the inquiry, Commissioners and senior staff made a number of presentations on the inquiry or on the draft report. These are listed below.

Date	**Organisation/event**	**Presented by**
12 November 1993	Pro Vice-Chancellors (Research) meeting (held at the ANU)	Gary Banks
1 December 1993	AIC Conference on R&D and innovation	Robert Jones
12 April 1994	IR&D Board meeting	Gary Banks Peter Hall Robert Phillips
28 April 1994	Australian Institute of Agricultural Science National Conference	Gary Banks
9 December 1994	State consultative group meeting at Industry Commission	Helen Owens

12 December 1994	Bureau of Industry Economics seminar	Peter Hall
7 February 1995	ABARE Outlook Conference	Robert Jones
10 February 1995	National Investment Council meeting	Gary Banks
17 February 1995	Institution of Engineers/Science and Technology Faculty of Deakin University	Peter Hall
22 February 1995	Australian Industrial Research Group Annual General Meeting	Robert Jones
24 February 1995	Coordination Committee on Science and Technology Meeting	Gary Banks
17 March 1995	Strategic Industry Research Foundation forum	Gary Banks
24 March 1995	Research policy forum at Adelaide University	Gary Banks
3 April 1995	Australian Institute of Agricultural Science Research Forum	Gary Banks

A.8 Other visitors to the Commission

The Commission also discussed aspects of the inquiry with a number of individuals who visited the Commission. They included:

Professor Max Brennan (ARC)
Professor Mark Dodgson (ANU)
Professor Henry Ergas (Trade Practices Commission)
Dr George Fane (ANU)
Professor Gerry Freed (University of Sydney)
Professor Paul Geroski (London Business School)
Mr Bob Hamilton (Canadian Department of Finance)
Dr Laurie Hammond and Peter Winsley (Foundation for Research, Science & Technology, New Zealand)
Mr Keith Hyde (Rural Industries R&D Corporation)
Professor Ron Johnston (ASTEC and University of Sydney)
Dr Ralph Lattimore and John Howe (Bureau of Industry Economics)
Dr Hartmut Lautenschlager (McKinsey & Co)
Dr Shantha Liyanage (University of Wollongong)
Mr John Mullarvey (Australian Vice-Chancellors Committee)
Mr John Plunkett and Mr Phil Kelly (IR&D Board)
Professor Paul Romer (University of California, Berkeley)

Dr Colin Rubenstein (Monash University)
Mr James Ruscoe (consultant to the European Community)
Dr John Stocker (CSIRO)
Professor Clem Tisdell (University of Queensland)

A.9 Overseas visits

New Zealand

Foundation for Research, Science & Technology
Landcare Research New Zealand Ltd
The Minister of Research, Science & Technology
Ministry of Research, Science & Technology
New Zealand Association of Crown Research Institutes
New Zealand Institute for Crop & Food Research Ltd
New Zealand Institute for Industrial R&D
New Zealand Institute of Agricultural Science
New Zealand Pastoral Agriculture Research Institute
Office of the Crown Company Monitoring Advisory Unit
PSA National Committee
Victoria University

France

Professor Robert Boyer (CEPREMAP)
Centre National De La Recherche Scientifique
M Robert Chaball
Professor Jacques Mairesse (Ecole Nationale De La Statistique Et De L'Administration Economique)
Organisation for Economic Cooperation and Development

Belgium

Commission of the European Communities (Directorate-General III)
Commission of the European Communities (Directorate-General XII)
Commission of the European Communities (Directorate-General XIII)
Professor Luc Soete (Maastricht Economic Research Institute on Innovation and Technology)

Germany

Alexander-von-Humboldt Society

Deutsche Aerospace
Deutsche Forschungsgemeinschaft (DFG)
Federation of German Industries
Forschungszentrum Julich GmbH (KFA)
Fraunhofer Institute
Ministry of Economics
Ministry of Education and Science
Max-Planck Society
Ministry of Research and Technology
University of Bonn

United Kingdom

Professor Derek Bosworth (University of Manchester)
Centre for Exploitation of Science and Technology
Confederation of British Industry
The Cookson Group
Professor Rod Coombes (University of Manchester)
Department of Trade and Industry
IBM
ICL
Kobe Steel Ltd
London School of Economics
National Audit Office
Office of Science and Technology
The Royal Society

Canada

Department of Consumer & Corporate Affairs
Department of Industry, Science & Technology
Medical Research Council
National Advisory Board on Science & Technology
National Research Council
National Sciences & Engineering Research Council of Canada

Washington

American Association for the Advancement of Science
Congressional Research Service
Department of Commerce
Industrial Research Institute

National Academy of Sciences
National Science Foundation
The World Bank

Korea

Australian Embassy, Seoul
Electronics & Telecommunications Research Institute
Hyundai Research Institute
Industry, Science & Technology
Korea Academy of Industrial Technology
Korea Advanced Institute of Science & Technology
Korea Institute of Science & Technology
Korea Science & Engineering Foundation
Korea University
Ministry of Science & Technology
Ministry of Trade, Industry & Energy
Presidential Council on Science and Technology
Samsung Advanced Institute of Technology
Science & Technology Policy Research Institute

Japan

ATR International
Dainippon Pharmaceutical Co Ltd
Department of International Affairs
Embassy of Australia
Professor A Goto, Hitotsubashi University
Industrial Science & Technology
Industrial Science & Technology (an agency of MITI)
Japan Industrial Technology Association
Japan Key Technology Centre
Kansai Research Institute (Kansai Science City)
National Institute of Science & Technology Policy
Research Development Corporation of Japan
Toyota Motor Corporation
Professor J T Yamaguchi, Keio University

Taiwan

ACER Inc
Australian Commerce & Industry Office
Chung-Hua Institution for Economic Research

Council for Economic Planning & Development
Hsinchu Science Based Industrial Park
Industrial Technology Research Institute
Ministry of Economic Affairs
National Science Council (Division of International Programs)
Teco Electric & Machinery Co Ltd

APPENDIX B: CSIRO'S PRIORITY-SETTING SYSTEM

B.1 Background

CSIRO's main task is the conduct of strategic and applied research in support of national economic, social and environmental objectives.

In October 1987 the CSIRO Board decided that in order for CSIRO to determine its future strategic directions, it needed a prior view of Australia's research priorities. As such the Board decided to take a role in determining the national research priorities.

In March 1988, the CSIRO Board established a Sub-Committee on National Research Priorities. In March 1990 the Executive Committee of the Board further reaffirmed the link between CSIRO's corporate planning and national research priorities.

In 1990, the CSIRO introduced a research priority-setting system developed by the Board, the Executive Committee of the Board and a group of CSIRO planning officers. CSIRO developed an assessment framework derived from the conceptual framework of that of the US Industrial Research Institute (see Foster 1985, pp. 12–7).

In order to set broad research directions the CSIRO Executive Committee first applied the priority-setting process in a series of workshops in 1990. The research priorities generated at the workshops were the basis of the 1991–96 CSIRO Strategic Plan, and were used as a mechanism for allocating a small Priority Research Fund administered by the Executive Committee.

The priority setting by the Executive Committee is now carried out on a triennial basis, linked to the Commonwealth funding cycle. The second priorities setting exercise was completed in late 1993, and is being used to develop the revised 1994–99 Strategic Plan, expected to be released in 1995.

B.2 The priorities-setting framework

CSIRO decides on the priority areas for research by identifying those areas of research which it perceives have the potential to return the highest economic, environmental and other social benefits to the nation.

When assessing the return to Australia from effort in a particular research purpose, CSIRO (CSIRO 1991a, p. 8) assesses the net benefit of each research purpose against two major factors:

- ***attractiveness****, combining the potential economic, social and environmental benefits for Australia and Australia's ability to capture the benefits by converting technological progress into commercial or other gains; and*
- ***feasibility****, combining what technological progress research could potentially accomplish and the nation's and CSIRO's ability to achieve the progress in a timely way.*

This system attempts to classify activities from the national perspective according to whether they deserve strong emphasis, selective emphasis or limited support. CSIRO states that Australia should place **strong emphasis** on research to support those sectors where:

- the research is highly attractive, that is, the likely benefits of successful research are high; and
- the research is highly feasible, that is, there is a high likelihood of achieving a high level of technical progress in Australia.

CSIRO says Australia should give **selective emphasis** to researching those areas of either high attractiveness-low feasibility, low attractiveness-high feasibility or medium attractiveness-medium feasibility. Those areas for which both attractiveness and feasibility are relatively low should receive only **limited support** (CSIRO 1991b, p. 11).

B.3 The assessment of relative priorities in practice

Criteria for assessment

The four criteria adopted by CSIRO for priority assessment are:

- potential benefits of successful research;
- Australia's ability to capture the benefits;
- R&D potential; and
- R&D capacity.

Many separate factors are relevant for the assessment of each of the criteria. In the first triennium priority-setting exercise the Executive Committee took into account certain factors under each of the criteria (refer box B1 and box B2).

Box B1: **ATTRACTIVENESS — likely benefits of research**

Attractiveness to Australia measures the likely benefit of successful research and is the product of *potential benefits* and *Australia's ability to capture the benefits*. It is determined by factors over which the research organisations have little direct control.

CSIRO defined **potential benefits** as the maximum economic, environmental and other social returns possible for Australia from technological improvement in the sub-division under consideration. The benefits include both first-order benefits (ie benefits to the sub-division in question) and benefits potentially flowing on to other sectors and the nation as a whole.

CSIRO identified some key economic, environmental and other factors implicit in the assessment of potential benefits as the:

- importance of technological improvements to sub-division performance vis-a-vis other factors;
- size of market;
- contribution to increased productivity;
- projected market growth;
- exports, import replacement;
- benefits to Australia associated with use of research-based goods and services by other sectors of the economy;
- amount of avoided damage;
- enhanced social amenity; and
- health and safety improvements.

CSIRO uses **Australia's ability to capture the benefits** as a measure of the efficiency of technology transfer and adoption relative to an ideal, namely complete capture, of potential benefits by Australia. The measure is taken to reflect the ability of Australian companies and organisations to convert technical progress into commercial and other returns.

Relevant questions are:

- can Australian users compete internationally?
- is the technology socially and politically acceptable?
- can local industry/other users exploit the full potential of the technology in a timely way?
  - is the application uniquely Australian?
  - linkage with leading companies/enterprises;
  - adequacy of skills/investment base
  - access to international and marketing networks
  - risks of competitive leakages

if not:

- can substantial benefit be retained?
  - probability/risk of creating new enterprises;
- is acceptance/implementation of relevant 'non-commercial' research by public sector bodies likely?

Source: CSIRO 1991b, p. 5.

In practice CSIRO has to try to ensure that all participants have the same understanding of the criteria and that they are independently assessed.

Supporting data and information

The CSIRO Executive Committee based its decision-making on data and qualitative information assembled for this purpose. The data included information on each sub-division to facilitate comparisons between them (see CSIRO 1991b, p. 7 for details). For the 1993 triennial review of research priorities the CSIRO corporate planning office prepared and made available a data compendium (see CSIRO 1993a). The data included briefs on the state of the Australian economy and forecasts of the world and Australian economies.

Box B2: **FEASIBILITY — ability to achieve technical progress**

Feasibility is a measure of the ability to achieve technical progress in Australia (per unit of R&D investment). It is the product of the *R&D potential* and the *R&D capacity*.
CSIRO uses **R&D potential** as a measure of the technical potential of relevant areas of research.

Relevant questions are:

- how fertile are the relevant research fields?
- where is the current technology on the “S” curve (technology performance versus effort curve)?
- how close is current technology to the realisable potential?

R&D capacity is a measure of national research efficiency in realising the R&D potential and achieving technology goals in a timely way.

Relevant questions are:

- is Australia internationally competitive?
- should the research be done in Australia?
- is there a critical mass of effort?
- what is Australia’s capacity to deliver the R&D?
    - skills
    - facilities
    - resource investment
    - time frame for effective application.

Source: CSIRO 1991b, p. 6.

In addition to its grounding in industrial and economic statistics, the CSIRO priorities assessment framework draws on CSIRO’s knowledge of research opportunities and its leadership in promoting technological change.

Procedures used

The CSIRO Executive Committee first applied the priority-setting process in a series of workshops in 1990.

The Director responsible for each research purpose prepared an evaluation sheet which presented short arguments under each of the four evaluation criteria.

A number of scoring variants were employed in the different priority-setting exercises. These included an assignment of a fixed number of points in relation to a particular criterion, those points then being distributed amongst the research purposes. The CSIRO stated that the precise method used in ranking the research was not critical as long as it was conceptually logical and capable of achieving useful discrimination between areas of research.

Box B3: **Procedure for group scoring exercises**

Prior to the group convening

1. Participants in a priority-setting exercise are provided with a "scoresheet" and supporting data and information prior to a group session. They score each research purpose against each criterion on an individual basis. CSIRO states that this allows them to:
   - form and record their initial judgments free from the influence of other participants; and subsequently
   - review their initial scores for all purposes against each criterion and check that they have the desired relativity.
2. The group facilitator collates scores from individuals in a tabular form which points clearly to differences between individual participants.

During the group session

3. Taking each research purpose in turn, the "champion" gives a brief presentation, after which participants review their initial scores if they wish.
4. Each cell of the scoring matrix is reviewed in turn. (This may be done either by consideration of all criteria for each purpose in turn or by consideration of all purposes for each criterion). Participants whose scores are "outliers" are invited to give the group the reasons for their differing opinions. (The Executive Committee used the score of the Director championing the research purpose as a benchmark). Rescoring takes place each time.
5. When all four criteria have been worked through purpose by purpose, participants check their scores as a set to ensure that their relativity properly reflects their final comparative assessment.
6. Group scores for each judgement (the collective rating of each research purpose in relation to each of the criteria) are obtained by simple averaging of the final individual scores.
7. Group scores for attractiveness and feasibility are calculated and all group scores are plotted on three (attractiveness, feasibility and R&D return) screens. With simple spreadsheet programming, these plots can be regenerated and displayed as the scoring iterations proceed.
8. The group reviews the screens as a final check that the relative positions properly depict the outcome of the group discussion.

Sources: CSIRO 1991b, p. 10; CSIRO 1993b.

Group consensus

CSIRO used group consensus as the priority-setting mechanism (see box B3).

Scores are used as a means of identifying and exploring differing judgments. The process in essence involves:

- making adequate preparations so that participants explore the views underlying the scores;

- ‘champions’ for each research purpose leading the discussion and addressing issues as they arise; and
- developing the full commitment of all participants.

Developing an overall judgment

CSIRO states that its framework enables it to make a rating of the likely return on R&D for a particular purpose. It argues that since:

> ... both capture [of the potential benefits] and R&D capacity refer to the relative effectiveness of achieving the full potential benefits and R&D potential respectively, they can simply be multiplied by their companion criteria to provide estimates of the actual benefits likely to be realised (the attractiveness) and the technological progress likely to be made (the R&D feasibility) (CSIRO 1991b, p. 11).

That is:

Attractiveness (Δ in benefits ÷ Δ in technical progress) = potential benefits x capture; and

R&D feasibility (Δ in technical progress ÷ Δ R&D investment) = R&D potential x R&D capacity.

Equally, the R&D return is the product of attractiveness and R&D feasibility. That is:

$$\frac{\Delta \text{ benefits}}{\Delta \text{R\&D investment}} = \frac{\Delta \text{ benefits}}{\Delta \text{ technical progress}} \times \frac{\Delta \text{ technical progress}}{\Delta \text{ R\&D investment}}$$

The composite scores are then plotted on an R&D return (attractiveness-feasibility) screen (reproduced in chapter B2).

Each Institute also carries out a similar assessment of research purposes relevant to their Institute to establish their ranking of research priorities.

Developing priorities for the second triennium

The workshop procedure of priority setting for the second triennium began in July 1992 when the CSIRO Board held a workshop assisted by McKinsey & Co to identify global and national challenges to which CSIRO could contribute.

This was followed by a three-day ‘retreat’ in February 1993 attended by the Executive Committee, members of the Board and three external speakers. A ‘brainstorming’ session was held on the first day to develop the strategic context for setting research priorities, followed by two days devoted to the analysis of research directions for each of the 17 SEO sub-divisions.

Members of the CSIRO Executive Committee scored the criteria for each SEO sub-division. Each CSIRO Director was allocated two or three SEO subdivisions, and acted as 'lead' Director for those categories.

During this process, CSIRO made many improvements to the initial 1990 triennial review process. Major features of these improvements included:

- greater external stakeholder participation in the priorities process at sectoral levels, with the aim of building greater commitment to the process at these levels, and improving the quality of input to corporate priority setting;
- the CSIRO Socio-Economic Objective (SEO) research classification structure was upgraded and a CSIRO Research Priorities Data Compendium developed. This included improved data on CSIRO's external environment, particularly in relation to the provision of time series data and trend analysis, medium to long term sectoral/industry projections and coverage of key global, national, sectoral and industry/enterprise issues.

B.4 From national priority setting to resource allocation

CSIRO states that the national research priority-setting exercise indicates in a qualitative sense where national funding levels may be adjusted. It says nothing about:

- where the research should best be undertaken;
- the nature of the balance between strategic and applied research; and
- who should pay for the research (CSIRO 1991b, p. 16).

CSIRO has decided that the national priority-setting process will not be used by CSIRO as an automatic decision tool for determining how much would be invested by it in research for each purpose, either in absolute or relative terms. Instead it took the conclusions of national research priorities and examined:

- the relative R&D capacity of CSIRO and other research performers in the sub-division; and
- the extent to which research for a particular purpose, however desirable it might be nationally, should be publicly supported by having regard to the extent to which the potential benefits are appropriable by individual beneficiaries.

On the completion of the priority-setting exercise the CSIRO then revised and finalised the role statements for each sub-division for the next five years. The final role statements address, among other things:

- whether the subdivision's share of CSIRO appropriation funds should be earmarked for increase or decrease over the next 5 years;
- specific areas within the sub-division which should receive selective support;
- the extent to which appropriation funds would focus on strategic research; and
- the extent to which maintenance of an agreed desirable level of CSIRO effort in the subdivision would be contingent upon additional external support from the client group (CSIRO 1991b, p. 17).

Planned resource allocation by CSIRO

In 1990 the CSIRO developed a funding process to improve its capacity to transfer resources from lower to higher priority areas at all levels. This was done by revising the role statements for each subdivision following the setting of national research priorities and formed the key record of the process and guidance to strategic effort over the next five years (1991–92 to 1995–96).

A target research profile for CSIRO was developed by the Executive Committee, followed by target research profiles for each Institute in accordance with this profile. After comparing the target research profile with the existing distribution of effort, the Executive Committee assessed a level of change necessary to meet the target. This level has been set at 3 per cent of CSIRO's appropriation funds.

Each Institute is obliged to commit funds at the agreed level of change (that is, 1.5 per cent of appropriation in the first instance) to support the successful proposals made under the reallocation mechanism. In addition to this general obligation, Institutes will also be requested to identify matching funds (that is, equivalent to the level of support they receive through the mechanism) to be redirected from lower priority areas to the new initiatives.

Given the Board's decision to continue the requirement to match a dollar of priority funding with a reduction in funding elsewhere, the total research funding at the SEO sub-division level for the priority areas of research could reach $11 million in 1994–95 (see table B1). Matching must be at least 50 per cent with 100 per cent being the preferred norm. At least 50 per cent of matching is to come from outside the SEO sub-division. Up to 50 per cent may be matched from within the sub-division.

Table B1: **Increased funding to targeted SEOs,** 1994–95

Socio-economic objective	*Increased funding ($ million)*
Mineral resources	1.5
Manufacturing	1.5
Information & communication	1.5
Environmental knowledge	0.5
Environmental aspects of economic development.	0.5
"Priority Fund"	**$5.5**

Source: CSIRO 1993b, p. 8.

Following the 1993 Priorities Workshop, the CSIRO Board and Executive Committee agreed to produce a five year strategic plan at the beginning of the second budget triennium (called the CSIRO Strategic Plan 1994–95 to 1998–99) to supersede the 1991–92 to 1995–96 Strategic Plan.

The CSIRO Board has agreed on the priority decisions for the second triennium:

> Research priorities for the 1994-97 triennium were decided. Internal funding for research in minerals, manufacturing, and information and communication industries will increase; environmental research funding will remain constant. Rural research will continue to rate highly (CSIRO 1993c, p. 3. Also see table B1 and box B4).

The annual planned allocations to SEOs for the second triennium from the priority funds, commencing in 1994–95, is given in table B1.

Actual resource reallocation by CSIRO

The reallocation of resources set in motion by the 1989–90 priority-setting exercise for the first triennium (1991–92 to 1993–94) led directly to some redistribution of research effort by socio-economic objective as shown in table B2 below.

In 1991–92, for example, $4.9 million was allocated to the following priority areas: mineral industries ($1.4 million); environmental aspects of economic development ($1.3 million); and other areas of research such as manufacturing ($0.4 million), and information and communications industries ($0.3 million). These funds were to be matched by the recipient Institutes through the redirection of resources from lower priority areas.

Box B4: **Priorities Decisions 1994–95 to 1996–97**

Mineral Resources
Increased appropriation for defined areas of the strategic research base.

Manufacturing
Increased appropriation for defined areas of the strategic research base with the expectation that this will produce substantial increases in external earnings in these areas.

Information and Communication Industries
Increase appropriation subject to maintaining CSIRO target for external earnings.

Environmental Knowledge
Total appropriation effort to be maintained through specific proposals in priority Environmental Knowledge areas. Any growth in CSIRO's effort to be largely from external funds.

Environmental Aspects of Economic Development.
Appropriation to be maintained at present proportion of effort with requirement that increases will come from external funding.

Plant Production and Primary Products
Proposals to be selective. Recognise importance of soil conservation in maintaining the productive resource. External funding for forest to increase to the CSIRO target level.

Animal Production and Primary Products
Proposals should be selective, focusing particularly on product quality and marketability as well as sustainable production systems. Selective support for aquaculture research in anticipation of industry development. External funding should remain at or above the CSIRO target level.

Rural-based Manufacturing
Selective emphasis for processed food area. External funding for forest products to increase to the CSIRO target level.

Energy Resources
Australia's R&D capacity should be increased. CSIRO should position itself as a research resource available to industry with any growth coming from industry input.

Energy Supply
Currently CSIRO's work for this SEO sub-division is undertaken by 11 Divisions. This work will be reviewed by responsible Directors before June 1994 with a view to improving co-ordination and external delivery. External earnings should increase to CSIRO target level by June 1996.

Construction
Nationally, construction is becoming increasingly well organised to benefit from and fund research. Expansion of CSIRO effort will be supported by external funding.

Transport
Generic research will be carried out largely under the other Sub-divisions. Direct applications should be externally funded.

Commercial Services
Nationally, Commercial Services provide increasing opportunities for research in a number of areas including Information Technology. CSIRO's major contribution is in areas of Water Services and Utilities. Activity in other areas will depend on identified opportunities and external funds.

Community Services
Expect very little, if any, appropriation funding; targeted applications of research conducted for other purposes; opportunistic approach substantially externally funded.

Health
Strong role for CSIRO activity in the area of human nutrition (Public Health). Involvement in areas of research outside of human nutrition to be on an opportunistic basis only - substantially externally funded.

Defence
Appropriation funding only if flow-on benefits to other areas are expected; otherwise an opportunistic approach substantially externally funded.

Source: CSIRO 1993b, p. 12.

In 1992–93, in addition to the reallocation from the priority fund, the Board allocated $5.4 million non-recurrent funds in accordance with the priority framework. Similarly, in 1993–94 the Board allocated $4.5 million non-recurrent 'Board initiative May Statement' funds in accordance with the priority framework.

Table B2: **Distribution of Priority Funds and related Board initiatives,** 1991–92 to 1993–94 (in $ million)

Research purpose	*Priority Funds 1991-92*	*Priority Funds 1992-93*	*Board Funds 1992-93*	*Priority Funds 1993-94*	*Board Funds 1993-94*
Mineral resources	1.4	1.3	1.6	1.2	1.3
Environmental aspects of economic development	1.3	1.3	1.8	1.3	1.1
Rural-based manufacturing	0.4	0.1	0.2	0.2	0.3
Environmental knowledge	0.4	0.3	0.1	0.4	0.2
Manufacturing	0.4	0.5	0.3	0.6	0.9
Information and communications	0.3	0.4	0.3	0.1	0.1
Plant production and primary products	0.3	0.3	0.5	0.4	0.1
Animal production and primary products	0.2	0.2	0.2	0.2	0.2
Energy resources and supply	0.3	0.0	0.1	0.0	0.1
Health	0.0	0.1	0.2	0.0	0.0
Commercial services	0.1	0.0	0.0	0.3	0.2
Construction	0.0	0.0	0.0	0.1	0.1
Total	**4.9**	**4.6**	**5.4**	**4.7**	**4.5**

a Priority funds are to be matched by recipient Institutes through the redirection of resources from lower priority areas.
b In 1992-93 the CSIRO Board allocated another $5.385 million of non-recurrent funds in accordance with the priority framework. In 1993-94 it allocated 'non-recurrent Board Initiative May Statement funds' in accordance with the priority framework.
Note: The amounts distributed to the research purposes have been rounded to one decimal place and do not add exactly to the totals below.
Source: CSIRO 1991c, 1992a, 1993c.

Table B3 shows how the distribution of research effort actually changed over the years 1990–91 to 1993–94. The growth in the amounts of appropriation funding was lowest for research in the SEOs of information and communications industries, followed by plant production and primary products, manufacturing, energy resources and supply, and rural-based manufacturing.

A direct indicator of the impact of the priority-setting exercise is the extent to which actual appropriations changed (see table B3) in line with the revealed priority setting (as shown in table B2). Table B4 shows the extent to which there was a change in the growth of annual appropriation expenditure in each SEO relative to the average growth of all the SEOs taken together. It shows that the growth of appropriation funding in 1993–94 over 1990–91 for all SEO groups was about 7 per cent. This compares with the growth of about 34 per cent in appropriation funding in the SEOs of minerals resources and 19 per cent in environmental aspects of economic development research over the same period (both of these SEOs were targeted priority areas in the first triennium).

There was also above average growth in allocations to the SEOs of animal production and primary products (about 13 per cent) and environmental knowledge research (about 9 per cent). This was broadly, but not entirely, consistent with the revealed priority setting as indicated in table B2.

Another indicator of the impact of the priority-setting exercise on the research done is the extent to which the amount of sponsored research responds to the priority-setting exercise. CSIRO stated that the priority-setting exercise decisions provided some guidance to the Institutes and Divisions in their decision making in the pursuit of external income.

Increased external earnings in response to the efforts of research managers in attracting sponsored funding partly reflect the priorities exercise conducted during 1989–90 when CSIRO nominated the SEOs of environmental aspects of economic development and strategic research for the minerals industry as high priority areas. Both these nominated high priorities SEOs achieved above average increases in sponsored income in 1993–94 and 1990–91 (see table B3).

What table B5 also shows is that the growth of sponsored earnings in 1993–94 over 1990–91 exceeded the average growth for all SEO groups (33 per cent) in other SEOs, namely, the information and communication industries (205 per cent), manufacturing (55 per cent), environmental knowledge (55 per cent), and energy resources and supply (54 per cent). These SEOs were then not ranked as highly as the then key priority SEOs of mineral resources and environmental aspects of economic development.

The incentive to focus on earmarked priority areas seems to have had a less clear impact on the growth of actual external earnings achieved. The growth in external earning was highest in the SEOs of information and communications, third highest in manufacturing, and fifth highest in energy resources and supply, though these areas were not selected as the key priority areas in the first triennium. Growth in external earnings in the other listed SEO groups was generally consistent with the priorities setting exercise.

Table B3: **Distribution of research effort, 1990–91 to 1993–94**
(1993–94 dollars, $ million)

	1990-91	*1991-92*	*1992-93*	*1993-94*	*% change 1993-94/ 1990-91*
Plant production and primary products	93	89	98	97	5
Appropriation	71	68	74	71	-1
Sponsored	21	21	23	26	24
Animal production and primary products	76	79	83	83	8
Appropriation	53	56	59	60	13
Sponsored	24	23	24	23	-3
Rural-based manufacturing	57	55	60	61	7
Appropriation	35	33	34	37	5
Sponsored	22	22	26	24	12
Mineral resources	46	55	67	62	36
Appropriation	34	39	48	46	34
Sponsored	12	15	19	16	42
Energy resources and supply	33	38	39	39	16
Appropriation	25	27	27	25	3
Sponsored	9	12	11	13	54
Manufacturing industries	85	88	105	96	13
Appropriation	67	66	79	68	2
Sponsored	18	22	26	28	55
Information and communications industries	30	33	34	35	16
Appropriation	26	26	27	22	-15
Sponsored	4	8	6	13	205
Environmental aspects of economic development	59	74	79	77	31
Appropriation	44	55	58	53	19
Sponsored	14	19	21	24	66
Environmental knowledge	58	51	73	69	19
Appropriation	46	39	56	50	9
Sponsored	12	12	17	19	55
Minor sectors	84	82	80	86	2
Appropriation	66	66	65	67	2
Sponsored	18	17	16	19	2
Total	**621**	**645**	**717**	**705**	**13**
Appropriation	**467**	**476**	**528**	**498**	**7**
Sponsored	**155**	**169**	**189**	**206**	**33**

Source: Information provided by CSIRO.

This mixed impact is likely to be the result of the other imperative facing research managers, that is, to achieve the 30 per cent external earnings target. These increases also took place when the average increase in sponsored income in 1993-94 over 1990-91 for all SEOs was about 33 per cent (table B5) compared with the average growth of appropriation income of about 7 per cent (table B4). It is difficult to judge which of the inducements (the priority setting or 30 per cent target) had a stronger effect.

Table B4: **Growth of appropriation funding by SEOs, 1990–91 to 1993–94** (1993-94 dollars)

Socio-Economic Objectives	*% change 1991-92/ 1990-91*	*% change 1992-92/ 1991-92*	*% change 1993-94/ 1992-93*	*% change 1993-94/ 1990-91*
Mineral resources	15.2	21.6	-4.5	33.8
Environmental aspects of economic development	24.2	5.7	-9.0	19.4
Rural-based manufacturing	-5.3	3.4	6.8	4.6
Environmental knowledge	-13.6	43.0	-11.6	9.1
Manufacturing industries	-0.4	18.6	-14.0	1.6
Information and communications industries	-0.8	5.8	-18.8	-14.7
Plant production and primary products	-4.2	8.6	-4.8	-0.9
Animal production and primary products	6.5	5.2	1.2	13.4
Energy resources and supply	7.7	3.2	-7.4	2.9
Minor sectors	-0.1	-2.0	4.3	2.1
All SEOs	**2.1**	**10.9**	**-5.7**	**6.8**

Source: Information provided by CSIRO.

CSIRO agrees that taken together the Board's priority and matching funding decisions provide a conservative reallocation of funds between SEO sub-divisions (CSIRO 1993b, p. 13). Nevertheless CSIRO stated that:

> CSIRO's strategic planning processes and the Director's performance agreements will provide the main means of working in the direction of required change within Institutes. The results of this will be that change at the SEO group and class level will inevitably be much greater than at sub-divisional level (CSIRO 1993b, p. 13).

The impact on resource allocation to priority areas at the sub-division and class level is indeed higher as discussed in chapter B3.

Blyth and Upstill of CSIRO said the priority-setting exercise has also been useful in introducing:

- Change from a resource allocation process based on 'equal misery for all' to one based on favouring areas of highest return (ie high attractiveness and feasibility); and
- Flexibility of resource allocation enhanced through the expansion of multi-disciplinary programs in recent years from less than 10 to over 35 across CSIRO (Blyth and Upstill 1994, p. 12).

Table B5: **Growth of sponsored income by SEOs, 1990–91 to 1993–94,** (1993-94 dollars)

Socio-Economic Objectives	*% change 1991-92/ 1990-91*	*% change 1992-92/ 1991-92*	*% change 1993-94/ 1992-93*	*% change 1993-94/ 1990-91*
Mineral resources	32.1	22.9	-12.7	41.8
Environmental aspects of economic development	30.0	10.6	15.4	65.8
Rural-based manufacturing	2.0	15.7	-5.2	11.8
Environmental knowledge	-5.5	43.8	14.0	54.9
Manufacturing industries	18.0	22.4	7.1	54.7
Information and communications industries	79.4	-14.3	98.1	204.5
Plant production and primary products	-4.0	13.5	13.5	23.7
Animal production and primary products	-3.0	3.3	-3.4	-3.2
Energy resources and supply	33.3	-0.8	16.5	54.1
Minor sectors	-10.0	-6.4	20.6	1.6
All SEO groups	**9.0**	**12.0**	**9.2**	**33.3**

Source: Information provided by CSIRO.

B.5 Ownership of priority-setting process

CSIRO has developed the priority-setting process essentially in-house with some input from stakeholders and others.

Blyth and Upstill (1994) stated that CSIRO's priority-setting process had been been carried out reasonably well against a range of critical success factors. Under 'ownership' they found:

- The priority method was developed iteratively with the active involvement of the CSIRO top management team.
- The process/method has been diffused within the Organisation, down to project level in some cases ... .
- Involvement of CSIRO Institutes and Divisions in priority-setting exercises at lower levels prior to the CSIRO exercise; outcomes were fed into the corporate exercise.
- Championed by the Chief Executive from the very start.

- Broad recognition by Government stakeholders of the Organisation's use of the process and acceptance of the outcomes.
- Balanced consideration of factors relevant to the internal environment with factors from the external environment (p. 11).

Earlier, Blyth and Upstill (1994, p. 10) had stated that external participation is highly rewarding and that ideally there should be one internal (expert) to one external representative to each research purpose because:

> It adds credibility to the outcomes of the exercise, it builds good relations with customers and stakeholders who value their role in assisting the organisation set its priorities and directions, and it allows mixing of minds, broadening the scope of the exercise beyond a purely scientist's perspective.

Blyth and Upstill (1994, p. 10) stated that the CSIRO priority-setting process included holding workshops ranging from those involving representatives from internal management, external stakeholders, current customers, users and staff, as well as workshops involving internal managers only. Despite this, comments made by participants to the Commission and the Senate inquiry suggest that a sense of ownership of CSIRO's research agenda is still lacking.

The CSIRO Evaluation Committee (CSIRO 1995a) confirmed that CSIRO needed to listen more to its commercial customers as well as its Government stakeholders. With respect to customer relations, it stated:

> ... overall performance is still below customer's expectations in areas such as listening to customer needs, contractual responsiveness and timeliness and marketing our capabilities. CSIRO needs to respond better to the customer's requirements for service, particularly through more receptive listening (CSIRO 1995a, p. ii).

The CSIRO Evaluation Committee also noted that there was a need for a 'whole-of-Government' view on research priorities and recommended that :

> ... an annual workshop be held between senior representatives of interested Departments and CSIRO, linked to CSIRO's strategic and operational planning cycle. The outcomes would assist CSIRO to set out objectives against expenditure in broad packages as part of the presentation of its Strategic Plan to the Minister for approval (CSIRO 1995, p. ii).

APPENDIX C: OTHER GOVERNMENT RESEARCH AGENCIES

This appendix outlines the main functions, structure, funding, priority setting, and technology transfers of the main government research agencies other than CSIRO and DSTO which are discussed in part B.

C.1 ANSTO

The Australian Nuclear Science and Technology Organisation (ANSTO) was established in 1987[1], replacing the Australian Atomic Energy Commission. The Organisation has a dominant objective to provide government with authoritative advice on nuclear issues stemming from its operation of nuclear plant and facilities. However, ANSTO stated that the nature of some of its research activities are similar to those of CSIRO.

ANSTO's mission is to:

- ensure that its research, technology transfer, commercial and training activities in nuclear science and associated technologies will advance Australia's innovation, international competitiveness and environmental and health management; and
- maintain and further develop its scientific and technological resources by continuing to operate as a national centre for science and technology to advance Australia's national and international nuclear policies and interests.

Strategies

ANSTO has drawn up a Strategic Plan for 1991–92 to 1995–96 to achieve its stated objectives and priorities. The plan sets out the corporate goals and strategies that ANSTO undertakes.

ANSTO has set out the following R&D strategies to carry out its mission:

- devoting 70 per cent of ANSTO's research resources to applied research;
- earning external revenue at 30 per cent of appropriation;

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1 ANSTO is an independent statutory authority established under the *Australian Nuclear Science and Technology Organisation Act 1987* as amended by the *ANSTO Amendment Act 1992.*

- reinforcing the development of strategic alliances for research both domestically and internationally;
- ensuring that applied research is market driven;
- evaluating all activities against business plans;
- investing in major items of capital equipment appropriate to the needs of the industrial, environmental and health communities;
- developing its Business and Technology Park to assist in technology transfer;
- developing specific stand–alone enterprises to operate in the commercial arena;
- selling of its technology, products and services on a commercial basis with an emphasis on services in the short term; and
- targeting national and global commercial opportunities with a focus on the Asia Pacific region (ANSTO 1991).

Functions

ANSTO performs the following main functions:

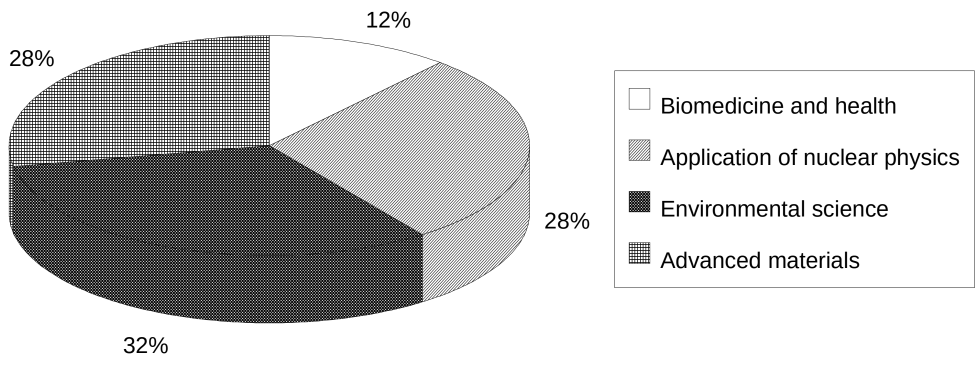
- undertake research and development in relation to nuclear science and technology; the production of and use of radioisotopes, and the use of isotopic techniques and nuclear radiation, for medicine, science, industry, commerce and agriculture;
- encourage and facilitate the application and utilisation of the results of such research and development;
- condition, manage and store radioactive materials and waste from its own activities or from companies in which it has a controlling interest, or from the use by other persons of radioactive materials produced by the organisation or such companies or the activities of other persons who are specified in the regulations;
- provide and sell goods and services in connection with the production and use of radioisotopes, and the use of isotopic techniques and nuclear radiation, for medicine, science, industry, commerce and agriculture;
- make available to other persons, on a commercial basis, the knowledge, expertise, equipment and facilities of the organisation by providing training and management expertise; or selling or leasing equipment; or selling land and facilities; or taking any other action which the organisation thinks appropriate;

- provide advice on aspects of nuclear science and nuclear technology and other related matters;
- publish scientific and technical reports, periodicals and papers related to its activities;
- collect and sell or distribute, as appropriate, information and advice on matters related to its activities;
- arrange for training of scientific and research workers, and the establishment and award of scientific research studentships and fellowship;
- make arrangements with universities and other educational research institutions, professional bodies and other persons for the conduct of research (ANSTO Act and second reading speeches, 1987 and 1992).

Structure and its research programs

ANSTO is governed by a board comprising up to seven members, one of whom is the organisation's Executive Director. ANSTO has 851 staff. In December 1993 the ANSTO Board of Directors was restructured to include individuals who also held Board membership with CSIRO. This decision was seen as a way of increasing the level of cooperation between the two agencies (Schacht 1993).

Figure C1: **Distribution of ANSTO's research effort, 1993–94**



Source: ANSTO 1993b, Program of Research.

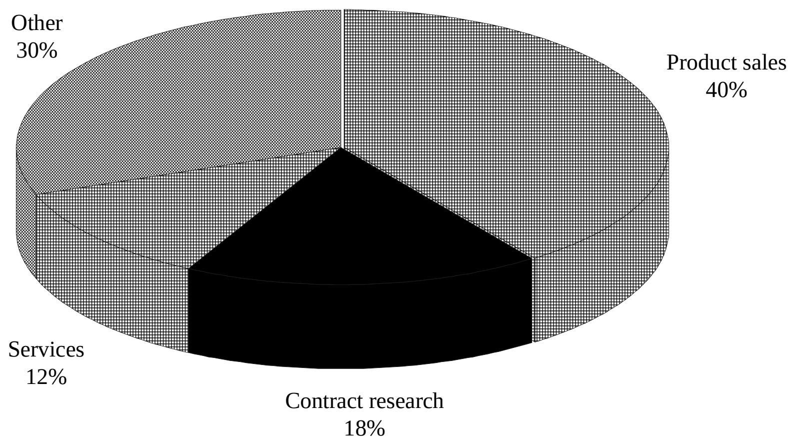
ANSTO has identified four research project areas relevant to its work to achieve national socio-economic objectives. Figure C1 shows the distribution of research expenditures on the main areas of ANSTO's research in 1993–94.

Funding

ANSTO's income for 1993–94, comprising Commonwealth appropriation and external revenue amounted to $90.4 million. Of this, $64.2 million (71 per cent) came direct from Commonwealth Parliamentary appropriations, and $26.2 million (29 per cent) from the private sector through sales and from research funded by industry and other users (see ANSTO Annual Report 1993–94, p. 48). For 1994–95, the estimated budget outlay for ANSTO is just over $66 million.

ANSTO's non-appropriation income for 1993–94 represented 40.1 per cent of the appropriation. The breakdown of this is shown below (figure C2).

Figure C2 **ANSTO non-appropriation income by source, 1993–94**



Source: ANSTO 1994, *Annual Report* 1993–94.

About 76 per cent of the 'other' income category is derived from leasing of properties and equipment.

ANSTO operates under a triennium funding plan with the Commonwealth. This enables ANSTO to plan with more certainty. 1991–92 was the first year of the second triennium funding period.

Prioritising research

ANSTO is obliged under its enabling Act to provide advice to Government on nuclear science and technology and to cooperate with international organisations and other national organisations overseas.

ASTEC states that ANSTO's strategic plan uses a priority setting process similar to that developed by CSIRO (ASTEC 1994e, p. 41). This has resulted in resources being shifted to environmental science and biomedicine and health.

ANSTO said:

> [it] operates within a set of Key Research Areas in the nuclear field, but many decisions regarding specific priorities are similar to CSIRO, made within an a mechanism controlled internally. The key research areas recommended by the recent Mission Review of ANSTO were arrived at after considerable domestic and international consultation by the external reviewers (Sub. 413, pp. 1-2).

ANSTO uses its Program Advisory Committees (PAC) as a mechanism to determine priorities. ANSTO has representatives of other appropriate bodies on its Advisory Councils (CCST 1994, p. 7). In the draft report submission, ANSTO said that the attractiveness of a research proposal and the setting of priorities is one of the major functions of the PAC. Other functions of PAC include: advising on potential opportunities for research which can lead to innovative technology as well as identification of technology spin-off from research projects; and advising on companies which could have a commercial interest in proposed projects and their outcomes (Sub. 413).

It went on to say that it:

> ... agrees with the [draft] report in its implied support of the need for considerable brainstorming and roundtable discussion with persons both within and outside the organisation, before a decision is made to commit resources to a medium or long term project. Mechanisms such as the PAC ... should continue to be reviewed (Sub. 413, p. 2).

ANSTO stated that it will place emphasis on several key applied research areas such as environmental science, advanced materials, biomedicine and health, applied physics, training and information technology. In this context, ANSTO considered that a dynamic and responsive evaluation and planning process is critical. The principal features of this process include: use of Business Plans (updated yearly) to plan and evaluate ANSTO programs; responsibility at the primary unit level for performance including the achievement of revenue targets, research milestones and cost effectiveness; regular internal evaluation of performance; evaluation twice yearly of the performance of research and commercial primary units by program advisory committees, having majority membership from outside organisations (ANSTO 1991, p. 9).

The Auditor-General's Office recently completed an evaluation of ANSTO's strategies, practices and impacts. It found that ANSTO's evaluation processes have not been assembled into a document which could be called ANSTO's formal evaluation strategy. However, it found that sound evaluation practices had been followed (ANAO 1993c, p. 74).

Technology transfer

The development of Business and Technology Park (The A J Woods Centre) is an integral part of ANSTO's strategy for technology transfer. This long–term project is part of ANSTO's commitment to assist in closing the gap between the R&D activities of government instrumentalities and tertiary institutions and their adoption by industry. Currently three private companies are operating from the park.

The two key objectives of the Business and Technology Park are:

- provide a basis for the transfer of technology to industry in a way that diversifies the opportunities, stimulates the economy and develops value added exports; and
- provide a means for technology based industries to access the resources of ANSTO (ANSTO 1991).

ANSTO is also commercially active through four commercial outlets. Australian Radioisotopes, Australian super-computing technology, Enviromet, and Tracerco. Associated organisations include the Australian Institute of Nuclear Science and Engineering, the Australian Centre of Advanced Risk and Reliability Engineering, and the Reactors Safety Committee.

ASTEC reports (ASTEC 1994e, p. 62) that ANSTO's links with industry are wide ranging, but still immature. Interaction with companies is oriented towards small companies and SMEs. ANSTO had interaction with 212 private sector companies in 1992–93, of which 43 per cent were 'small' companies, 24 per cent SMEs and 33 per cent large companies.

External funding and links with industry

In May 1989, the Commonwealth Government announced a target for external funds for certain government trading enterprises. In November 1990, the Government set ANSTO an external target to achieve 30 per cent of the appropriation funds (initially non–capital appropriation funding) by 30 June 1994. ANSTO was allowed to retain all external revenue without any offsetting reduction in appropriation. The target was designed to provide an incentive for ANSTO's research to become more relevant to user needs.

In 1987–88, prior to the introduction of the target, ANSTO's external earnings were 23.4 per cent of total appropriation. By 1992–93, external earnings increased to 39 per cent (26.5 per cent for ANSTO and 12.5 per cent for Australian Radioisotopes — ARI) of its appropriation funds (ASTEC 1994e). ARI operates as an entity separate from the rest of ANSTO. However, the external earnings include the sale of ANSTO and ARI products and services. Examples of ARI products include nuclear medicine and radioisotope products for medical and industrial applications. For the remainder of ANSTO, the primary source of growth in external revenue has been 'commercial sales' (about one third of total external earnings) such as neutron doping of silicon, services (health and safety consultancies and analytical services), and training (ASTEC 1994e, p. 17). The breakdown of external earnings for 1993–94 is provided earlier under the 'funding' section.

In the applied research areas, revenue can be considered one measure of performance. These projects need a customer willing to initially fund the project based on some agreed guidelines. In determining the appropriate mix of revenue earning activities and taking the 30 per cent rule into account ANSTO states:

- the use of senior scientists as consultants to generate income may not be cost effective; however
- the use of a scarce resource, experienced scientists, to undertake routine scientific services, could detract from ANSTO's ability to undertake longer term research (ANSTO 1991).

The external target had some impact on what ANSTO publishes, and the type of research it undertakes. For example, ANSTO considered that a decrease in the publications output of the organisation commencing in 1987 can be directly attributed to revenue targets set in pursuit of the external earnings requirement. While refereed journal articles decreased, there was a rapid rise in commercial reports in the period. ANSTO scientists said that there was some fall in strategic basic research and public good research because of the general increase in commercial research (ASTEC 1994e, p. 35).

Pricing external clients

The pricing of projects that benefit industry is as much an issue for ANSTO as for CSIRO. At present, it is not clear what is being subsidised by ANSTO and whether that subsidy is justified. While ANSTO agrees that good management demands work for external clients to be rigorously costed, it considered that it is also important to have some flexibility in pricing a project. There are a number of factors which can influence the pricing. ANSTO stated that these include: the opportunity to gain market reputation; to purchase a piece of equipment which can be used in other projects; sharing of intellectual property; enhancement of skills and competition from other providers.

Performance indicators

ANSTO states that the Biomedicine and health division has developed criteria on which to measure performance. Other divisions should formally establish performance indicators. Performance goals should be established for all projects prior to the commencement of the project, and there should be public disclosure of the success or otherwise of the government funded projects.

In Biomedicine and Health, some indicators of performance are the development and exploitation of intellectual property in cooperation with multi-national companies, universities and government laboratories; the development of radiopharmaceuticals for clinical trials and sale by Australian Radioisotopes, publications in peer-reviewed scientific and medical journals; career development of base level research scientists; safety and the financial management of the program (ANSTO 1993b).

C.2 AIMS

The Australian Institute of Marine Science (AIMS) was established as a Commonwealth Statutory Authority in 1972 with a specialist charter for marine research and development. The agency reports to the Minister for Science and Technology.

AIMS is located at Cape Ferguson near Townsville in Queensland. According to its 1993–94 Annual Report, the Institute employed a total of 122 staff under appropriation funding, and an additional 21 scientific and technical staff were funded from external earnings.

Role and functions of AIMS

The role of AIMS is to undertake research and development to generate new knowledge in marine science and technology, promote its application in industry, government and ecosystems management; and undertake complementary activities to disseminate knowledge, collaborate effectively, assist in the development of national marine science policy and enhance the Institute's standing as a centre of excellence (Cook 1994a).

The *Australian Institute of Marine Science Act 1972* (amended in 1992) sets out the functions of the Institute as follows:

- carry out research and development in relation to marine science and marine technology;.
- encourage and facilitate the application and use of the results of research and development of that kind;
- arrange for carrying out research and development of that kind;
- cooperate with other institutions and persons in carrying out research and development of that kind;
- provide other institutions and persons with facilities for carrying out research and development of that kind;
- collect and disseminate information relating to marine science and marine technology and, in particular, to publish reports and other papers;
- provide and sell goods (whether produced by the Institute or purchased or otherwise acquired by the Institute) and services in connection with matters related to its research and development activities in marine science and technology;

- make available to other persons, on a commercial basis, the knowledge, expertise, equipment and facilities of the Institute;
- do anything incidental or conducive to the performance of any of the above functions (AIMS 1994).

AIMS, as a government provider of research, plays a vital role in carrying out more strategic and longer term research. It said:

> ... we believe that agencies such as our own [AIMS] occupy, particularly with respect to the more strategic work and the longer-term, more program-oriented research which agencies such as university departments and individual firms don't have the ability or the resources or perhaps the longer-term charter to tackle. ... we are commencing projects on north-west shelf. Those projects are going to be undertaking strategic marine systems work that is relevant to the offshore oil and gas industries, the fishing industries and the marine tourism industries, etcetera. (transcript, pp. 1103–4).

Industry also agreed that AIMS should be performing this larger-scale, longer-term work. Industry particularly felt that:

> ... it would do site-specific studies associated with its own developments, but it felt that it was the government's role to undertake the larger-scale, longer-term work (transcript, p. 1104).

Funding

In 1993–94, the total income of AIMS was just below $20 million. Of this, $16.9 million was sourced from appropriations while $3.1 million came from other sources[2]. The appropriations represented about 85 per cent of the total income for AIMS.

The budget outlay for AIMS is estimated to be $16.5 million in 1994–95, a slight decrease over 1993–94 (Cook 1995a). Table C1 sets out expenditure by AIMS on various programs.

A significant portion of AIMS' resources are used for corporate support services (22 per cent), and technical support services (19 per cent).

2 Other sources include consultancies and grants, interest, profit on sale of assets, and sundry revenue.

Table C1: **AIMS, direct appropriation expenditure by programs, 1993–94**

	Program	*1993-94 ($'000)*	*Per cent of total expenditure*
1	Coastal processes & resources	1 494	9
2	Coral reef ecosystems	2 276	13
3	Environmental studies and biotechnology	1 690	10
4	Tropical oceanography	2 176	13
5	Technical support services	3 307	19
6	Corporate support services	3 767	22
	Subtotal	14 710	86
	External projects	2 506	14
	Total expenditure	17 216	100

Source: AIMS 1994, p. 119.

Priority setting

The research and development program of AIMS is defined by the AIMS Act (1972 and the 1992 amendment), by the strategic priorities as determined by its Council and by the decisions of the Government from time to time.

AIMS said:

> Its activities are primarily focussed on tropical coastal and continental shelf research, and the development and application of technology to problems in this zone (Sub. 98, p. 13).

The McKinnon Review noted that AIMS allocates its resources to high priority areas and seeks to make the maximum national contribution. Nevertheless, it considered that the priority setting process still appeared to be science driven:

> ... the priority setting processes both within CSIRO and in AIMS ... still appear to be science-driven processes with few published objective indicators of their long term usefulness (McKinnon Review 1993, p. 13).

The Review recommended that:

- At the Commonwealth level, there be a Committee of Ministers (for Marine policy) to oversee the development and implementation of an Oceans Management Policy encompassing national priorities for marine science and technology to achieve environmentally sustainable development of marine resources and marine industries; and for regular appraisal of needs in the marine sector.

- An Australian Marine Industries Sciences Council (AMISC) be established, reporting to the Committee of Ministers. The AMISC should comprise an independent chairperson plus eight other members, appointed on a personal basis but including the main research users and providers.

According to the Review, AMISC would advise the Committee of Ministers for Marine policy on oceans management policy, including marine environment matters, marine science and technology priorities and marine industry opportunities.

Overall, it appears that AIMS' priorities are influenced by its own assessment of what is important in marine science research and by government directions including the external earnings target. However, the McKinnon Review recommendations could bring substantial change in the marine priorities and policy making. The Committee of Ministers would be concerned with national priorities, while AMISC would provide advice on science and technology priorities.

Under the McKinnon proposal, the priority-setting process through AMISC would include both *research users* and *providers*.

AIMS expressed a slightly different view in its response to the government. At the Brisbane public hearing it said:

> We saw the Marine Sciences and Industries Council as a high-level policy setting body and we thought that a board of a marine institute would be the major source of advice on directions of marine research effort for the Institute (transcript, p. 1112).

According to this, AIMS would still be allocating funds to its different activities as well as performing the research.

However, in its submission to the McKinnon review, AIMS said that AMISC would not be effective unless it can influence the funding, and the decisions of other marine organisations:

> ... it is the view of the AIMS that a such a group [AMISC] could not be fully effective unless it was given the power to influence, in a tangible way (*through redirection of finances and resources*), the decisions of the other marine organisations (AIMS 1993, p. 7).

The White Paper 'Working Nation' (Keating 1994) noted that the Government will establish an *Australian Marine Industries and Sciences Council* within the Department of Industry, Science and Technology (DIST). It will advise the Government and help position Australia's marine industries to capture growing world markets, facilitate import replacement and promote the transfer to industry of marine science and technology. Funding for this initiative will be met from within DIST's running costs (pp. 64, 219). The Council will:

- develop a marine industries strategy, and
- establish a taskforce to investigate and report on the potential for the design and construction in Australia of high speed and other advanced marine transport cargo systems (White Paper, pp. 64–5).

Technology transfer

Recognising the need for a client-focused, commercial research and consulting industry, the policy of the AIMS Council is that:

> AIMS, as a priority, shall cooperate with Australian marine industries to transfer appropriate technology on a commercial basis (Sub. 98, p. 5).

The Institute further said that:

> ... [AIMS] provides strategic and contextual information that commercial researchers can incorporate into local studies or applied technological and other skills not present in the consulting industry. To this end, strategic links with regional companies, industry peak bodies and regional government bodies are viewed as important (Sub. 98, p. 5).

Technology transfer also occurs through collaboration with other organisations, universities, and commercial arms. For example, AIMS collaborated with other organisations in two enterprises with commercial arms. The first enterprise involves James Cook University, Great Barrier Reef Marine Park Authority and AIMS in pooling their expertise in research, teaching, training, and management to offer assistance to developing countries on a fee-for-service basis. In the second undertaking, AIMS, the Queensland government, and some of its agencies, and two universities are examining the possibility of setting up a pharmaceutical and fine chemicals industry (JCPA 1992).

External funding and links with industry

AIMS was set up originally with a broad charter in marine science which provided little incentive to work closely with research users, including Australian marine industries. In 1989, the government, adopting the recommendation of the McKinnon review into marine science and technology, determined that AIMS should achieve greater involvement in applied research, representing up to 25 per cent of activity over 5 years.

In November 1990, following advice from the Minister for Science and Technology, the AIMS Council set a target for external earnings of 30 per cent of appropriation to be reached within 5 years (commencing 1 July 1991). A specific goal behind this was to promote links with industry and other research users. The Government decided to encourage AIMS to develop closer links with industry by allowing it to retain all income from external resources without reduction in its appropriation (ASTEC 1994e).

In 1993–94, AIMS' external earnings[3] were just above 17 per cent of the appropriations (AIMS 1994). However, ASTEC noted that AIMS anticipates that external revenues will exceed the target level by 1995.

Since 1991, most of its external funds (61 per cent) have been received as grants from the Commonwealth and State government bodies, and from Commonwealth institutions, including the Great Barrier Reef Marine Park Authority and the CRC program, while 32 per cent of the external funds came from commercial and overseas sources. Other sources include Institute generated revenue (ASTEC 1994e, p. 20).

AIMS said that the external target had some positive impact on its management:

> ...it has had enormous impact on our internal management. ... there has been much greater tightening of the management within all the organisations - a much greater handle on where the money is going, how to make money efficiently used in the organisations (transcript, p. 1108).

AIMS further added that another advantage of the external funding is that it tends to channel the strategic research into ways that can help eventually produce applied research or produce results that will lead to applied research.

Nevertheless, the target did raise some concerns about the type of research AIMS performs and the extent of intellectual capital that it could retain for the applied work, an issue which it is examining now. AIMS said:

> There is a question mark over the impact on the more strategic research in the organisation, given that most of external funding is biased towards the applied end and that certainly has been the case in AIMS. ... so there has been an impact both in our pure and strategic work and we are looking now at how we can ensure that that's balanced as much as possible because we see that we are not going to have the intellectual capital ... in the future for the applied work if we don't keep the strategic base strong (transcript, p. 1108).

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3 AIMS defines external income as non-appropriation income, generated from all sources, excluding income from sale of assets (see for example, AIMS 1994, p. 118).

C.3 AGSO

The Australian Geological Survey Organisation (AGSO) is the national leader in geoscience mapping and information services. The Organisation is part of the Commonwealth Department of Primary Industries and Energy (DPIE). Its' primary clients are the Commonwealth Government and its agencies, State and Territory Governments and their agencies, the minerals and petroleum industries, the geoscientific research community (including CSIRO, Bureau of Resource Sciences and tertiary institutions) and the general public.

AGSO's primary mission is to build a vigorous, client-driven national geoscience mapping effort to encourage economically and environmentally sustainable management of Australia's minerals, energy, soil and water resources (Cook 1994a).

The current major program activities of AGSO are: the National Geoscience Mapping Accord; National Environmental Geoscience Mapping Accord; the Continental Margins Program, the Geophysical Observatories Program; and the National Geoscience Information System.

AGSO's role

- Develop a publicly available, comprehensive and integrated geoscientific knowledge base for the Australian continent, the Australian offshore area and the Australian Antarctic Territory, especially through the provision and coordination of appropriate databases, as a basis for encouraging and improving the effectiveness of exploration for, and assessment of, Australia's endowment of petroleum, mineral, and groundwater resources and for contributing to land-use planning and to the resolution of environmental issues, including the mitigation of natural hazards.
- Provide independent and timely scientific and technical advice and information to Government, industry, and the public to facilitate the formulation and implementation of policies necessary for the effective management of the land and its petroleum, mineral and groundwater resources.
- Provide specific national geoscientific capabilities, such as the geophysical observatory functions of seismic monitoring for both earthquake risk and underground nuclear explosions.
- Participate in appropriate multilateral and bilateral geoscientific programs to contribute to Australia's international policy objectives (AGSO 1994).

Funding

In 1994–95, the estimated Commonwealth budget outlay for AGSO is $63 million (Cook 1995a), an increase of about 8 million or 15 per cent over 1993–94 ($55 million).

Linkages with industry and other users

One mechanism, which improves linkages with industry and other institutions, is the Cooperative Research Centres (CRC). AGSO's increasing involvement in a number of CRCs provides an important avenue for increasing collaboration between AGSO, CSIRO, industry and the universities in pursuing national research objectives (AGSO 1994). The most important involvements are with:

- the CRC for Australian Mineral Exploration Technologies;
- the CRC for the Antarctic and Southern Ocean Environment; and
- the CRC for Australian Geodynamics.

The Richards review (Commonwealth of Australia 1993a) believed that AGSO should be a major source of information required across Australian society to generate wealth wisely from the nation's natural resources and to protect the environment, and the potential value of AGSO can be realised if AGSO is well linked and coordinated with other research and data gathering bodies and if it is responsive to the needs of those who use the information it generates.

The review put forward a vision for AGSO that it should:

> ... collaborate with State Geological Surveys, CSIRO, other State and Commonwealth agencies, universities and industry in pursuit of its primary mission, recognising that linkages with these groups are the key to its successful operation (Richards 1993, p. 73).

External earnings

AGSO's external earnings target for 1993–94 is 25 per cent of the appropriations. This target will increase to 30 per cent in 1994–95.

Priority setting process

AGSO seeks informal feedback from its clients on a regular basis through the triennial meetings of the AGSO Advisory Council and the Advisory Council Evaluation Program. Under the program, each of the scientific program is evaluated closely every four to five years. Evaluations are conducted by a panel chaired by the a member of AGSO's Executive with representatives of the AGSO Advisory Council and other key groups (DPIE 1993).

In its submission to the Commission (Sub 435), the DPIE further noted that AGSO's core research programs are strongly mandated by the Government and have clear objectives. Work programs are set in consultation with clients and are subject to an annual priority setting process, and outcomes are subject to the normal program evaluation process.

In carrying out its role, the AGSO develops and implement priorities for strategic national geoscientific research. AGSO stated that its priority setting process involves wide consultation with petroleum and mineral exploration industries and taking advice from the AGSO's Advisory Council (AGSO 1994, p. ix). The Advisory Council includes representatives from Geological Surveys of NSW, and NT, Australian Academy of Science, CSIRO, nominees from industry Associations and Councils, Australian Geoscience Council, Australian Society of Exploration Geophysicists and AGSO representatives.

Nevertheless, the Richards Review (Commonwealth of Australia 1993a) recommended that:

> ... AGSO adopts a formalised approach similar to that used by CSIRO to **establish priorities** between and within program elements in order to achieve better focus in its efforts and to make better use of the available resources (p. 63).

The CCST report said that:

> The requirement of priority setting in AGSO is to clearly establish that all program elements and their size reflect the program priorities and needs in a quantitative fashion; to demonstrate that appropriate use is being made of resources; and that all resources available to AGSO are being brought to bear on the priority programs in the most cost-effective and efficient manner. The priority setting process is therefore a component of strategic planning and is ongoing. The priority setting process...provides a systematic way of assessing the priority of all program elements and projects, and their supporting activity elements in terms of a matrix derived from the concepts of "Attractiveness" and " Feasibility" developed in the CSIRO priority setting process (p. A1.1).

The Government's response to 1993 Richards review accepted the need for an improved priority setting process within AGSO and directed AGSO management to develop an appropriate process which gives opportunity for client groups to influence decision making, and which gives improved visibility of the process to the Minister responsible. DPIE stated that these recommendations have largely been implemented (see sub. 435).

APPENDIX D: HIGHER EDUCATION RESEARCH AND DEVELOPMENT FUNDING MECHANISMS

D.1 Unified National System

As part of the unified national system process, institutions were required to have a minimum sustainable student load of at least 2000 equivalent full-time student units (EFTSUs) and to negotiate with the Commonwealth an educational profile and associated funding arrangements.

The governing council of an institution is to develop an educational profile which sets a broad policy framework within which the overall teaching and research programs are to be determined. The Government then negotiates the details of this profile with the executive officer of the institution (Dawkins 1988, p. 30).

These negotiations occur in three year cycles, with the opportunity to negotiate any major alterations or proposed new developments as the need arises. As noted in chapter C2, universities are required to produce a number of plans outlining their activities (teaching plan, research management plan, equity plan, Aboriginal and Torres Strait Islander education strategy and a capital management plan).

The teaching component of the profile indicates which teaching activities institutions intend to undertake, and includes student load, commencements and graduations.

The research component of the educational profile outlines the institution's research strategy for the triennium. It provides an outline of the coverage of intended research activity, including the range of fields in which the institution is undertaking research, and the scale of that activity (Dawkins 1988, p. 31).

The educational profile is also to include a statement of intent in identified areas of national priority. Through this statement, institutions indicate their goals, strategies and related performance measures in priority areas (Dawkins 1988, p. 32). The profile is intended to be the basis of an institution's operational planning.

In 1988, the Government developed a funding approach intended to focus more on what tasks institutions actually perform rather than historical precedent. This was in response to distortions which it had identified in the base allocation of Commonwealth education operating grants (Baldwin 1990, p. 1). The Government undertook an analysis to identify institutions which were significantly over- or under-funded on this basis.

From 1989, institutions were allocated a single operating grant which replaced the general recurrent, equipment, minor works and special research grants. The White Paper said:

> Components of the operating grant will not be separately identified, and institutions will be free to determine the most efficient allocation of funding among the various categories of expenditure (Dawkins 1988, p. 80).

Relative Funding Model

In February 1989, three relative teaching costs studies were commissioned by DEET and the HEC, the results of which provided the basis for the relativities matrix which became central to the teaching component of the relative funding model.

The model was developed in 1990 by a joint HEC/DEET working group, and was used as the basis for a once only adjustment package to implement the *White Paper* objective of eliminating significant funding inequities between institutions. The adjustments were made over the 1991–93 triennium.

The first step taken in developing the model was to estimate the magnitude of the research related quantum and then to deem the balance of the operating grant to be teaching related.

The teaching component of the model was based on the assumptions that costs are related to student load, discipline mix and the levels of courses offered. A relative teaching matrix was therefore constructed in which discipline groupings were aggregated into clusters according to cost similarities. The matrix comprised disciplines grouped into five clusters at the undergraduate level, three at the postgraduate level and two at the higher degree research level.

Box D1: **Research Management Plans**

A research management plan sets out the university's mission and goals with respect to research. It also sets out a structure for its research program, together with management and administrative processes for carrying it out. The university's position on intellectual property is usually included.

It will often identify areas of research strength, or priority areas for research as determined by the university. For example, Victoria University of Technology has identified eight major research areas, including Asia Pacific studies, bioprocessing technology, environmental safety and risk engineering.

Generally, the plan will briefly describe the university's funding arrangements, mechanisms or strategies adopted to support and develop R&D. Mechanisms may include seeding grants, supplementary grants, teaching relief grants, fellowships and research training. James Cook University said that its internal research funds were distributed by the Research Funding Panel using the performance indicators defined by the Research Committee. It said that in 1993, it allocated 5.1 per cent of its recurrent grant to internal research funding and administration (Sub. 99, p. 2).

Staff requirements and development issues may also be addressed. For example, the Macquarie University research management plan states that:

> It is an expectation that all academic staff will be actively involved in research and there is a commitment by the University to provide them with the necessary time and infrastructure resources.

Macquarie University explicitly includes 'teaching relief' as one of its mechanisms to support research. Similarly, the Victoria University of Technology research management plan allows for:

> Greater flexibility in the allocation of teaching loads between staff and recognition that supervision of higher degree students as part of the teaching function of staff will allow some researchers to increase the proportion of their time spent on research.

The university's position on research equipment and infrastructure funding may also be briefly described and in some cases, such as the Victoria University of Technology, strategies to address research infrastructure requirements may be noted.

Universities may also indicate processes for evaluating research performance through performance indicators. Macquarie University assesses productivity in terms of quality of intellectual output, research training (number of postgraduate research students, postdoctoral fellows etc) and success in attracting research funds. Victoria University of Technology uses publications, citations, growth in research income, number of research projects (funded and commissioned), professional awards, postgraduate student numbers and graduation rates.

The research component of the model was identified as the quantum of the operating grant which can be related conceptually to research activities and associated research infrastructure other than those inextricably linked to higher degree research training, the costs of which are recognised in the allocation of the teaching component of the model. The draft proposal of the relative funding model noted that:

> There has been no definitive calculation of that amount [the quantum], nor could there be, given the impossibility of distinguishing between research training and other research activities within institutions. Nevertheless it is clear that there are research activities conducted within the institutions and funded from operating grants which are not directly associated with the training of postgraduate students (DEET/NBEET 1990, p. 13).

The research related component of the model was considered to notionally cover the costs incurred by the universities in undertaking research:

- initiated internally;
- initiated by the ARC and other Commonwealth competitive granting bodies; and
- initiated by industry and other non-Commonwealth sources (in recognition that there will be elements of infrastructure not provided even on a full cost-recovery basis).

In estimating the size of this component, it was considered that a matrix based on teaching costs was an inappropriate mechanism. Instead the Working Group considered a number of different approaches in order to estimate the quantum. The research related quantum was estimated to be approximately 6 per cent of the operating grant in 1988.

The relative funding model draft proposal stressed that:

> ... the allocation of research related funds, like the allocation of teaching funds, is simply one component of the model allocation; it is only the total model allocation that is being considered in any assessment of relative funding. The research component would not be considered or funded separately, and institutional operating grants would continue to be a single block grant with institutions left to decide how to apply the funds (DEET/ NBEET 1990, p. 9).

Operating grants

The main areas of higher education research and research training funded by DEET are shown in the table D1 below.

One estimate of the amount of funds devoted to research in higher education is obtained by adding together allocations for research training, the research quantum, the ARC, the IAS and a number of other small specific research programs. By this process almost $1.2 billion was provided in 1995–96.

Table D1: **Some DEET funding for research and research training, 1995-96**

Mechanism	*DEET* *$m*
Research funded from operating grants	
Research Training	420
Research Quantum	263[a]
Total	**683**
Australian Research Council	350[b]
Institute of Advanced Studies	130
TOTAL	**1163**

a Of this only $213 million is to be reallocated in 1995. The additional $50 million is a non-reallocated component of funding increases since 1990.
b Of this only $190.5 million is awarded on the advice of the ARC.
Source: Compiled from Cook 1995a, pp. 5.8–5.9.

An alternative approach involves estimating the amount of time spent on research by those in higher education institutions. Research expenditure has been estimated at $1.53 billion in 1995–96 by this procedure, of which $965 million represents the estimated research component of general university funding for both teaching and research (Cook 1995a, p. 3.18).

Neither of these figures includes funds coming to universities from sources such as the NHMRC, CRC, or firms and other external funders.

D.2 Australian Research Grants Committee

As noted in chapter C2, the ARGC was established in 1965, in response to the 1964 Martin Report on higher education. Its emphasis was on pure basic research, with funding of grants determined solely on the excellence of the proposals. Similarly for funding allocated to the individual discipline areas. Successful applications were determined through a peer review process, which relied on expert assessors, including a significant proportion from overseas (Brennan 1993, p. 91).

Attempts were made to fund projects in all fields down to an equal level of quality, with funding reallocated amongst the panels only when particular panels argued that they were not getting a ‘fair share’ of the funds. However, these reallocations were not based on any ‘relevance’ criteria, but rather on a formula based on the relativities in terms of quality (Brennan 1993, p. 91).

D.3 Australian Research Council

The ARC was established in 1988, as the successor to the ARGC, under the *Employment, Education and Training Act 1988*. It is one of the five Councils of NBEET.

Its establishment followed a recommendation in an ASTEC report, *Improving the research performance of Australia's universities and other higher education institutions*. The report found that:

> Although the existing plurality of funding sources has benefits for researchers, opportunity costs are high since grant schemes are generally too small to allow funding over a range of grant sizes, disciplines and activities, or to provide a systematic policy overview of higher education research. This limits the flexibility of research funding in response to priority changes as well as under-utilising academic talent (ASTEC 1987, pp. 5–6).

It added:

> There is a need in Australia for a major scheme responsible for awarding grants for the conduct of research, the provision of specialised equipment and the support of career employment opportunities for researchers as well as for the formulation of policy advice germane to higher education research. We consider that an ARC should be established to meet these needs and to promote higher education research in the national interest (p. 6).

Funding for the ARC was provided by a 'clawback' of $65 million per annum (phased in over the 1989–91 triennium) from the operating grants of the pre-1987 universities and through subsuming a number of schemes (such as the Queen Elizabeth II Fellowships and the ARGC).

The structure of the ARC consists of four main committees, with a number of panels beneath them. The Committees and their respective responsibilities are briefly illustrated in figure D1, while figure D2 gives an example (the Research Grants Committee) of a Committee and panel structure. The Research Grants Committee has a number of discipline panels, which serve as a source of expertise in those disciplines, and several priority area panels. The priorities (and the corresponding panels) vary from year to year.

The Research Grants Committee focuses primarily at the individual project level and advises the ARC on the award of grants to individual researchers and to research teams. Grant applications are assessed by way of peer review, involving external assessors (both in Australia and overseas). There are about 10 members on each panel.

Figure D1: **ARC supporting councils and their responsibilities**

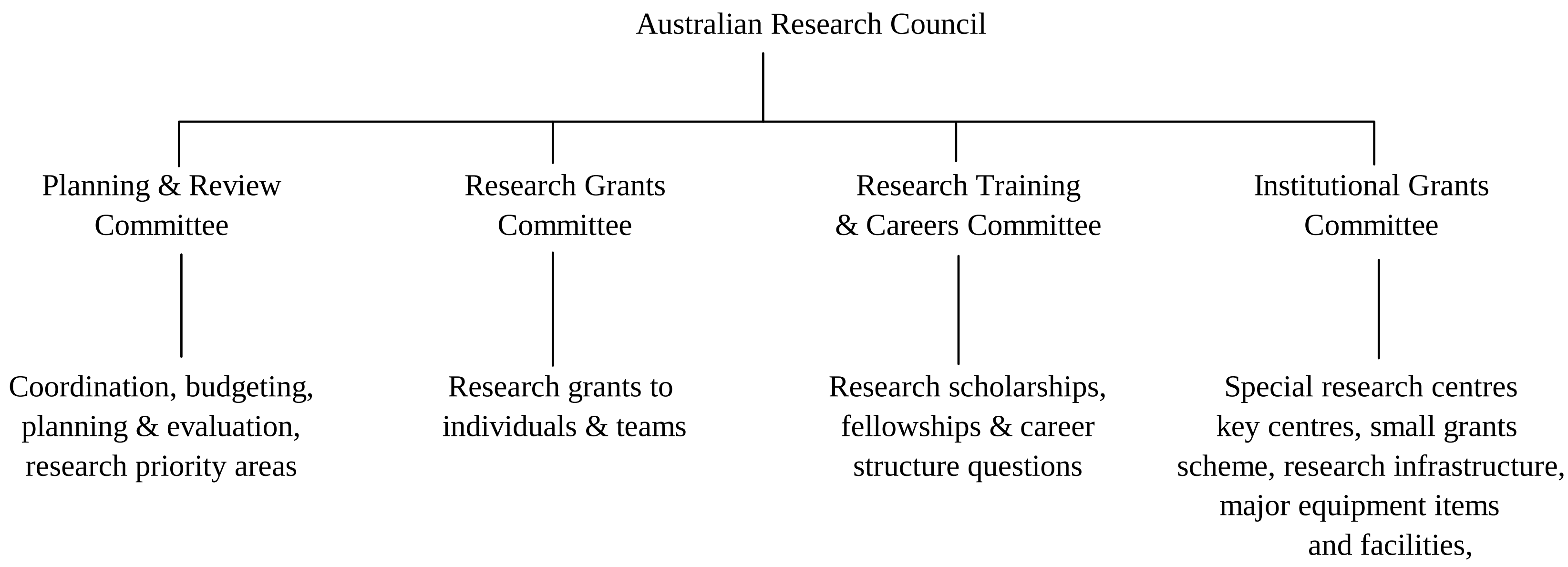
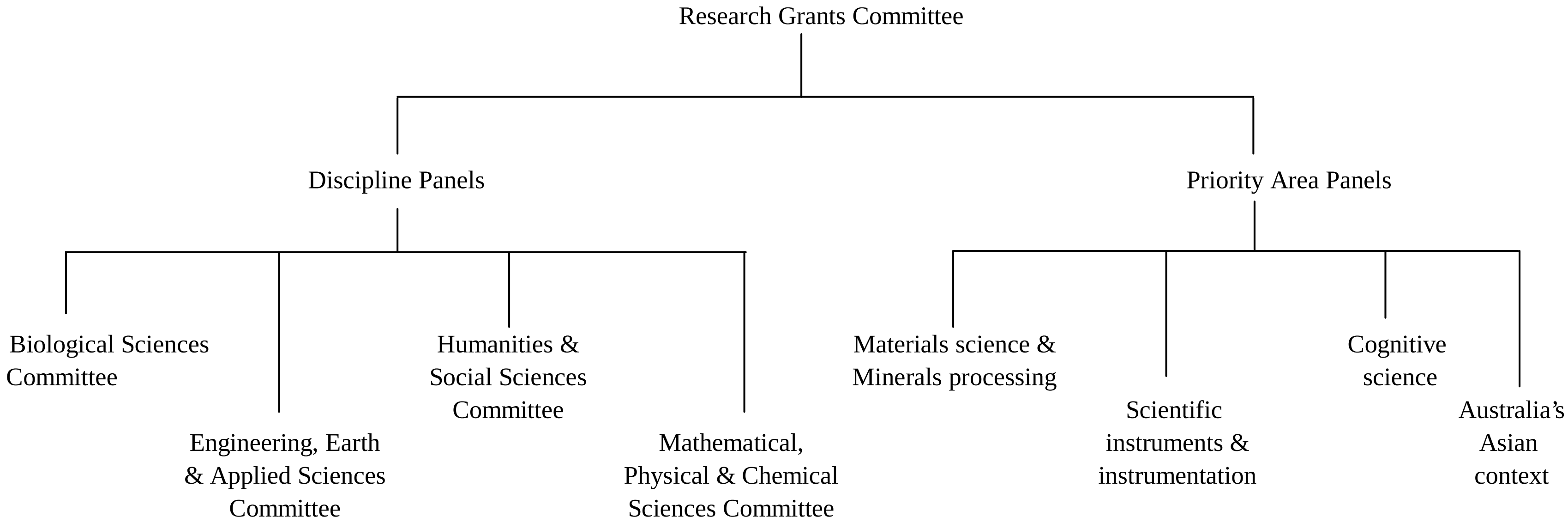


Figure D2: **Research Grants Committee panels**



Research Grants Program

The ARC's Research Grants Program includes the Large Grants Scheme, the Small Grants Scheme and the Collaborative Grants Scheme. These schemes provide funds to selected individuals or research teams throughout Australia and are allocated for specific research projects on a competitive basis on the advice of the ARC.

Large Grants

Large grants are allocated to specific projects on a competitive basis, and are determined by the Research Grants Committee with the assistance of the Discipline and Priority Area panels (see figure D3). Applications are invited from individual researchers and research teams for grants in support of pure and applied research in the broad areas of biological sciences; engineering, earth and applied sciences; physical, mathematics and chemical sciences; humanities and social sciences; and the designated priority areas.

The objectives of the Large Grants Program are to award grants to support research which is likely to lead to a significant advance in the understanding of a subject or to contribute to the solution of an important practical problem (DEET 1994g, p. 5).

In 1995–96, $85.6 million will be provided through the large grants program (Cook 1995a, p. 5.11). The success rate for large grants in 1994 and again in 1995 was 22 per cent. The minimum value for large grants is $20 000 for social sciences, humanities and mathematical sciences and $30 000 for other disciplines (DEET 1994g).

Research grants are administered by higher education institutions through their Research Offices which report to DEET on progress in relation to the grant, including details of expenditure and requested variations in the grant (DEET 1994g, p. 10).

Small Grants

The small grants scheme commenced operation in 1989. Small grants are the responsibility of the Institutional Grants Committee of the ARC and are provided as block grants to institutions which allocate specific grants in accordance with their research profiles and priorities. A central objective is to provide institutions with discretionary resources which give them a substantial degree of autonomy in the support of high quality research in ways that will link directly with the execution of their individual research management plans.

Under the small grants scheme, each institution receives a base allocation ($50 000) plus an extra amount determined according to a formula which takes into account an institution's success in attracting ARC large grants and the distribution of small grants in the previous year (Cook 1995a, p. 5.11). An institution is guaranteed a minimum allocation of at least 70 per cent of its allocation in the previous year to ensure that institutions will always have some stability.

The chair of the ARC approves lists of recommended grantees, projects and grants from each institution.

In 1995–96, $23.8 million will be provided for small grants (Cook 1995a, p. 5.11). Funds are allocated to projects that cost below $20 000 in the humanities and social sciences, mathematics and theoretical physics and below $30 000 for other disciplines.

Small grants cannot be used to support or in any way duplicate a project funded by large grants.

Collaborative Research Grants

The Government announced the establishment of the Collaborative Research Grants Program in the policy statement *Higher Education: Quality and Diversity in the 1990s*, to encourage greater collaboration between industry and higher education institutions in the field of applied research (Baldwin 1991, p. 8).

Collaborative grants support cooperative undertakings of smaller scale and timeframe from those under the CRCs program and which do not require a permanent centre to be established (DEET 1995, p. 5). The types of research supported by the program are broad, projects in basic, strategic, applied and developmental research are considered. They are provided on a dollar for dollar matching basis with industry, and are awarded for up to three years.

For 1995–96, funding of around $13.0 million will be provided (Cook 1995a, p. 5.12). The average grant is between $50 000 and $100 000 per annum. Only a few grants over $200 000 will be offered in 1995 (DEET 1995, p. 6).

Australian Postgraduate Awards Scheme

Australian Postgraduate Awards (APAs) provide competitive awards for students undertaking higher degree studies by research in higher education institutions. Under this scheme, students are exempted from HECs. Total funding in 1995–96 is $65.6 million (Cook 1995a, p. 5.13).

APAs will be allocated to institutions based on a formula which reflects the quality of each institution's research training environment as well as its success in national competitive grants, its research postgraduate load and its research postgraduate completions (SSCEET 1994, p. 17).

The industry partner is required to contribute $5000 in cash and an additional $5000 in cash or kind for each year of the higher degree training course. In 1995–96, $7.3 million is available for this scheme (Cook 1995a, p. 5.13).

Australian Postgraduate Awards (Industry) Scheme was introduced in 1990 and 'provides higher degree research training for high calibre postgraduate students on research projects developed to meet the needs of industry' (Cook 1995a, p. 5.13).

Research Fellowship Scheme

The ARC Research Fellowship Scheme is intended to provide a career path for outstanding researchers. It is also designed to attract expatriate Australians back to Australia, as well as to allow leading researchers to pursue their research interests in Australia as an alternative to going overseas. Fellowships are open to overseas nationals although preference is given to Australians in the Postdoctoral Research Fellowship and Australian Research Fellowship categories.

The fellowships are normally geared to postdoctoral researchers through to senior researchers at professional level. In 1995–96, funding of $24.8 million will be available for the Research Fellowship program (Cook 1995a, p. 5.12). The Fellowships provide salary support in the range from around $37 000 to $80 000. Period of tenure ranges from 12 months to a maximum of five years.

There are four types of Fellowships:

- Australian Postdoctoral Research Fellowships (for researchers normally with less than three years postdoctoral experience);
- Australian Research Fellowship (for researchers normally with at least three years postdoctoral experience);
- Queen Elizabeth II Fellowship (for outstanding researchers who would normally have no more than six years postdoctoral experience);
- Australian Senior Research Fellowships (for researchers with established reputations who would normally have no more than fifteen years postdoctoral experience).

With regard to place of tenure the 1996 guidelines state:

> In 1996, Australian Postdoctoral Research Fellowships and the Queen Elizabeth II Fellowships may be taken up at any Australian higher education institution, private

> research institutions or government research organisation which has the resources to support the research. Australian Research Fellowships and Australian Senior Research Fellowships may be held at any higher education institution or research organisation, other than a research establishment which is substantially funded by the Commonwealth Government such as [ANU's IAS, CSIRO, AIMS and ANSTO] (DEET 1994h, p. 5).

The Australian Research Fellowship (Industry) Scheme has been discontinued and from 1995 support for this can be provided through the Collaborative Research Grants Program (Sub. 361, attachment A).

Research Centres

The Research Centres Program supports two types of centres: the Special Research Centres and the Key Centres of Teaching and Research. In 1995–96 funding for the Research Centres will be $18.2 million (Cook 1995a, p. 5.12).

The Special Research Centres program commenced in 1982. The Centres are established on the basis of research excellence and the potential that they have to contribute to Australia's development. The primary objective of the Centres is to concentrate research effort in areas of national importance (Cook 1995a, p. 5.13). Funding is provided at a rate of between $0.4 million and $0.9 million a year for six years in the first instance, with the possibility of a three year extension to a maximum of nine years, subject to satisfactory review. Reviews of individual Centres are held after three and six years of operation. After nine years, a Centres program funding ceases and is made available for competitive bidding (although a Centre is able to reapply for further funding in competitive process (DEET 1993a, p. 261).

The Key Centres of Teaching and Research Program commenced in 1985. The concept of the Centres was brought forward by the Universities Council in its Advice (Part 3 of the 1985–87 triennium report) and supported by the Commonwealth Tertiary Education Commission (CTEC). Responsibility for the program was transferred from CTEC to the Australian Research Council in 1988 (DEET 1993a, p. 261). The rationale behind the selection of the original centres was the creation of units based on the excellence of their research activity, and their potential to contribute to the economic, social and cultural development of Australia.

Selection of the centres was the responsibility of a small independent committee which sought advice from a range of organisations and individuals reflecting the views of government, the tertiary education sector, the research community and the community generally. The first seven established in 1985 were followed by a further 15 in May 1988 and another ten in May 1989.

These centres are linked more closely to the needs of industry than the Special Research Centres and are usually based on existing departments in higher education.

The Key Centres are designed to give equal weight to teaching and research in institutions. They aim at boosting expertise in areas relevant to national development and promoting cooperation between higher education and industry. A large proportion of the Key Centres obtain considerable additional funding from other sources such as industry (Schacht 1993a, p. 69).

In 1992 reviews were carried out of 11 Key Centres on Teaching and Research. The reviews provide an opportunity to recommend that performance has been unsatisfactory or diverging from the role of the Research Centres program objectives. All but one Key Centre received a continuation for a further three years.

In mid-1995 a cohort of some eight new centres is to be established and will receive funding of between $200 000 and $500 000 a year (Cook 1995a, p. 5.13).

Research Infrastructure Program

Changes to ARC Infrastructure Mechanisms A and B and C

In the 1993–94 budget, the Government announced funding to continue the Research Infrastructure Program beyond 1994 at an enhanced level. The Commonwealth announced that from 1995, funding would be provided through two components: Research Infrastructure (Block Grants), which would replace ARC Mechanisms A&B and Research Infrastructure (Equipment and Facilities), which would replace Mechanism C (DEET 1993b, p. 3). As a transitional arrangement, each institution’s allocation in 1995 and 1996 will be not less than 75 and 50 per cent respectively of the total Mechanisms A and B grants received in 1994 (DEET 1993b, p. 64).

Total funding for the Research Infrastructure Program in 1995–96 is $58.7 million. An additional $35.6 million is to be provided beginning in 1996. The bulk of this additional funding is expected to be allocated through the Research Infrastructure Block Grants Program (Cook 1995a, p. 3.14).

The Research Infrastructure (Block Grants) are allocated to institutions on the basis of the National Competitive Grants Index. For 1995–96, $42.3 million will be allocated under this program (Cook 1995a, p. 5.14).

Applications for grants under the Research Infrastructure (Equipment and Facilities) Program are assessed by an ARC selection panel. Total funding for this program in 1995–96 is $16.4 million.

The ARC noted that from 1995 only the Research Infrastructure (Equipment and Facilities) Program will be an ARC program. The Research Infrastructure (Block Grants) Program will be allocated by DEET (Sub. 361, attachment A).

Research Infrastructure Block Grants (Mechanism A)

Prior to 1993, only pre-1987 universities were able to apply for Mechanism A grants. Following the report by the DEET/ARC/NBEET working party on Research Infrastructure, for 1993 and 1994 all members of the Unified National System were eligible to apply for Mechanism A grants. Additional funds were transferred into Mechanism A to cover the inclusion of the additional institutions. Allocation of Mechanism A grants is on the basis of the Competitive Grants Index. For 1994, Mechanism A Grants totalled $23.7 million.

The total amount of Mechanism A funding for 1994 is divided on a proportional basis among the institutions depending on the two-year average amount of competitive research funds each institutions had received (DEET 1994a, p. 4).

For the purposes of this program, research infrastructure consisted of the institutional resources essential for the mounting of high quality research projects of programs in a particular field, including the direct costs associated with particular projects or programs, but excluding direct costs which were considered to be covered by research grants. For example, the following may be regarded as elements of research infrastructure and funded under the program:

- non-capital aspects of facilities such as libraries, computing centres, animal houses, herbaria, experimental farms;
- equipment purchase, installation and maintenance; and
- salaries of research support staff (including research assistants and technicians) employed to provide general support for activity in a given area, eg. a research assistant providing assistance for a number of research projects but not one dedicated to a particular project.

Elements such as capital works, salaries of teaching and research staff, and travel costs were not considered research infrastructure for the purpose of the program (DEET 1994a, p. 5).

Research Infrastructure Development Grants (Mechanism B)

Funding through Mechanism B commenced in 1990 and operated for five years to 1994. Mechanism B was established specifically to assist the new universities created from former CAE's and Institutes of Technology to bridge the gap in their research capabilities relative to those of the traditional research-performing institutions. This support was intended to assist them to develop to the point where they could compete successfully for competitive grants. In 1994, a total of $18.8 million was allocated to eligible institutions (DEET 1993b, p. 64). The definition of research infrastructure for the purposes of this program was as noted above for Mechanism A.

All eligible institutions could apply for funding regardless of whether they were successful in winning funding in previous years under the scheme. However, a significant proportion of the $18.8 million for 1994 was committed to the five former Institutes of Technology. In 1994, the five former Institutes of Technology received as a minimum forward commitment, no less than 75 per cent of the previous year's allocation (DEET 1993d, p. 9). This was to enable these institutions to maintain a reasonable level of continuity, or research infrastructure support. It was provided to these institutions as a single block grant, allocated to support those components recommended for funding.

A total of $5 million was reserved each year from Mechanisms B and C which was to be available only where matching funds are available from industry, State and other sources.

All other funds were allocated competitively on the basis of applications received from institutions.

Cooperative Research Infrastructure Development Grants (Mechanism C)

This program was introduced to forge cooperative links between institutions and to lead to more efficient utilisation of shared resources. For example, Mechanism C funds have been used for specific large items of equipment which can be used by large numbers of researchers from different institutions, for example, Monash University, University of Melbourne, La Trobe University and the ANU establishing the Victorian Institute of Earth and Planetary Sciences (VIEPS). Mechanism C began operating in 1991. The definition of research infrastructure for this program was as noted for Mechanisms A and B above.

The objective of this infrastructure program was to encourage institutions to develop cooperative arrangements amongst themselves, and with organisations outside the higher education sector, wherever possible (DEET 1994e, pp. 7–8).

For 1994, $17.7 million was available under this program (DEET 1993b, p. 64). The minimum grant would not normally be expected to be less than $50 000. The funds were to be allocated to:

- equipment, particularly items not currently covered by existing mechanisms; and
- large scale facilities, such as library holdings, vessels, computer facilities, herbaria, animal houses and data banks.

Evaluation Program

DEET monitors the effective utilisation of resources allocated to its research programs through an evaluation program. Evaluation activities include reviews of the outcomes of ARC funding, discipline forward strategies, discipline panel reports, the development of quantitative indicators, and reviews of the Centres Program and Small Grants Scheme. Funds in 1994 for evaluation, amounted to $0.6 million (DEET 1994b, p. 30).

Reviews of ARC grant outcomes form the largest component of the evaluation program. They cover funding over a recent five year period and are undertaken by a panel of eminent researchers drawn from the international community. The basic task is to assess research output and its impact in relation to funding input (Sub. 182, p. 9).

D.4 Other Commonwealth funding

National Health and Medical Research Council

In 1926, following a report of a Royal Commission on Health, a Federal Health Council was established to promote cooperation between the Commonwealth and the States on matters of health. The NHMRC was established in September 1936 by executive order upon which it continued to operate until June 1993 when it became a statutory authority.

The functions of the NHMRC are undertaken by a number of committees. By 1993, the five principal committees (discussed in more detail below) oversaw 28 standing committees and many more working parties and expert advisory panels. In 1993, the Public Health Committee alone comprised more than 40 subcommittees, working parties or panels (Bienenstock 1993, p. 17).

The Council is currently funding 1 604 research projects as well providing block funding for five major research centres and institutes (Cook 1995a, p. 5.57).

Under the heading of ‘directed funds’ are Special Initiative Grants, Special Units and Special investigations.

The Health Care Committee (HCC)

The HCC advises on health services issues, which includes, assessment of new technology in health care, dental health, quality of health care, and health issues relating to children, women, mental health and elderly. (Bienenstock 1993, p. 21).

The Public Health Committee

The Holman review[1] found that most PHC efforts were directed towards assessment of toxicology of hazardous substances, the control of communicable diseases, general environmental health issues and radiation protection. Its work had a measurable impact on the implementation of public health policy and service delivery by government health authorities, and it had established a strong reputation among government authorities as an independent body with acknowledged technical expertise (Bienenstock 1993, p. 23).

Australian Health Ethics Committee

The AHEC continued the work of monitoring and supporting around 150 institutional ethics committees through activities such as workshops, introducing a newsletter and providing advice and speakers on request. The Committee also developed the broader ethics role, conducting some preliminary work into the ethics of health resource allocation, guidelines to promote ethical conduct in the health field, and issued various discussion papers on health ethics issues (Bienenstock 1993, pp. 25–6).

Public Health Research and Development Committee

The PHRDC recommends on expenditures relating to health and medical research. It was formed in 1987 to provide additional support for non-biomedical health research (Bienenstock 1993, p. 17).

Medical Research Committee

The MRC, like the PHRDC, recommends on expenditures relating to health and medical research. It administers funds provided through the NHMRC and provides support for biomedical sciences. The MRC when appropriate, identifies and funds national priorities in medical research; endeavours to

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1 Holman, C.D.J. Report on an inquiry into public health committee of the NHMRC, October 1993.

reduce duplication; distributes funds between the various fields of medical research and ensures that the work supported is subject to periodic review and assessment (Coghlan 1991, p. 5).

Commonwealth support of health research activities includes funding for medical and public health research through the Medical Research Endowment Fund (MREF) and the PHRDC. It is the MRC which advises and makes recommendations to the Council on the application of MREF. Some key purposes of the MREF are to provide assistance:

- to the Departments of the Commonwealth or of a State or Territory that are engaged in medical research;
- to universities for the purpose of medical research;
- to institutions and persons engaged in medical research; and
- in the training of persons engaged in medical research.

MREF derives its funds from, among other things, parliamentary appropriation and acquittances.

MRC's five funding streams

- Project grants

Project grants are for the support of individual projects for periods of up to three years. They provide funds for scientific and technical staff (but not the principal researcher's salary), the purchase of consumables and some equipment. These grants support individual researchers in a university or teaching hospital, or a small research institute (NHMRC 1989, p. 23).

Requests for research funding comprise a statement of tasks, timing and expectations of research in a specific area, with researchers developing suitable proposals that are assessed by peer review. Both the PHRDC and the MRC use the same process of peer review to assess project grant applications. Applications are assigned to (usually) three external assessors (who provide a rating from 1–10 on scientific merit and track record), and then most applications are interviewed by a Regional Grant Interviewing Committee (RGIC) which draws on the initial applications and assessors reports. (Bienenstock 1993).

- Program grants

Program grants are for the support of the effort of large research groups working in a common area. Grants are made for a period of five years with a review of the program undertaken in the fourth year. Funding may be obtained up to 10 years (NHMRC 1989, p. 23).

- Special units

These have been established in areas of perceived need and as for program grants, provide funding for five years with a review in the forth year and funding available for 10 years (NHMRC 1989, p. 24).

- Block grants

Block grants are awarded to support large research institutions, containing groups active in a number of disciplines within a major field of medicine relevant to substantial health problems. The large research institutes provide opportunities for collaborative research and have considerable technical resources. A breakdown of funding sources for the block funded medical research institutes is contained in box D2.

- Training

Training mechanisms include Postgraduate Research Scholarships Scheme and the Training Fellowships Scheme.

Box D2: Some data on the NHMRC Medical Research Institutes and the JCSMR

The following is some broad indicative data on the operating revenues which fund the research activities of the medical research institutes. The data is taken from annual reports and, because of differing classifications and accounting practices, it is not clear how directly comparable the data is.

John Curtin School of Medical Research

The School receives the bulk of its funding (some $17.2 million) from the Department of Human Services and Health, channelled through the ANU operating grant. It also receives funding of some $2.4 million from external sources (Annual Report 1993, p. 104).

The Walter and Eliza Hall Institute of Medical Research

The Institute's NHMRC block grant in 1993 was about $7.2 million and represents about 42 per cent of their overall budget. Income for 1993 was around $17 million and can be broken down as follows:

Sources of funds (1993)	*$'000*	*%*
NHMRC grants	7 225	42
CRC	954	6
Commonwealth departments	152	1
Victorian Government	1 638	10
Australian Government fellowships	982	6
Industrial grants & contracts	1 979	12
General income	334	2
Donations	218	1
Australian grants & fellowships	1 355	8
Overseas grants & fellowships	2 222	13
Total	**17 060**	**100**

Source: Annual Report 1993–94, p. 184.

Murdoch Institute for Research into Birth Defects

The Institute's NHMRC block grant for 1993 was about $1.3 million. This represents about 22 per cent of its income. Income for 1993 amounted to almost $6 million and can be broken down as follows:

Sources of funds (1993)	*$ '000*	*%*
NHMRC grants	1 299	22
Grant - H&CS	1 879	32
Other grants	141	2
Donations	922	15
Interest, dividends & sales	980	16
Other income	714	12
Total	5 936	100

Source: Annual Report 1993, Financial statements p. 16.

Garvan Institute of Medical Research

The Institute's block grant is about $2.5 million and represents about 36 per cent of its income for 1993. Income for 1993 amounted to $7.1 million and can be broken down as follows

Sources of funds (1993)	*$ '000*	*%*
NHMRC grants	2 533	36
State grant	920	13
Other grants and contract revenue	2 200	31
Other income	1 460	20
Total	**7 113**	**100**

Source: Annual Report 1993, p. 74.

Howard Florey Institute of Experimental Physiology and Medicine

The Institute's NHMRC block grant is about $5 million and represents about 66 per cent of its operating income. Income for 1993 amounted to $7.9 million and can be broken down as follows:

Sources of funds (1993)	*$ '000*	*%*
NHMRC block grant	5 205	66
NHMRC, fellowships, scholarships & special research projects	166	2
Victorian State Government	658	8
University of Melbourne	502	6
Private donations and foundations	561	7
Institutes and medical foundations	357	5
Other income and interest	427	5
Total	**7 875**	**100**

Source: Annual Report 1993, p. 58.

Baker Medical Research Institute

The Institute's NHMRC block grant is about $3.8 million and represents about 49 per cent of its income. Income for 1993 amounted to $7.9 million and can be broken down as follows:

Sources of funds (1993)	*$ '000*	*%*
NHMRC	3 841	49
Victoria State Government	673	8
Fundraising, corporate & private support	1 165	15
Baker benefaction	843	11
Other income	1 387	17
Total	**7 909**	**100**

Source: Annual Report 1993, pp. 36, 39.

APPENDIX E: BUSINESS R&D GRANT SCHEMES

Introduction

The Discretionary Grants Scheme (DGS) and the Generic Technology Grants Scheme (GTGS) were established in June 1986, and at the time referred to together as the Grants for Industry Research and Development (GIRD) Scheme.

The DGS was introduced to provide support for companies which, because of their taxable income status, were unable to obtain adequate benefit from the broad-based 150 per cent R&D tax concession introduced on 1 July 1985.

The GTGS was introduced to provide support for collaborative R&D projects in generic (‘enabling’) technology areas that were considered critical to Australia’s economic growth. With biotechnology declared as one of the generic technology areas eligible for support, the National Biotechnology Program (which had operated since June 1983) was subsumed within the GTGS.

The DGS and GTGS were scheduled to cease on 30 June 1994, but the Government extended their operation by eighteen months to 31 December 1995, pending the outcome of this inquiry. However, the *Working Nation* White Paper of 4 May 1994 contained the announcement that the DGS, GTGS and three other grant programs under the Industry Innovation Program would be replaced by a single scheme — the Competitive Grants For Research and Development Scheme.

In this appendix, an assessment is provided of the extent to which the DGS (section E.1) and GTGS (section E.2) met their objectives in an effective and efficient fashion. Such an evaluation is a necessary background to assessing the likely effectiveness of the single grants scheme in assisting the types of projects that received support under the former schemes.

In section E.3, details are provided of the likely effects of introducing one of the main proposals recommended by the Commission — an automatic grant to companies in tax loss.

A summary of the main findings is presented in box E1.

Box E1: **Summary of main findings**

Discretionary Grants Scheme (DGS)

- Grants amounted to $120 million between 1986–87 and 1993–94, involving 1302 applications of which 40 per cent were successful.
- Less than 10 per cent of potential recipients typically receive grant support.
- Most applicants have been small young companies; however proportionately more grants have gone to the larger of these companies.
- About 6 per cent of the successful companies accounted collectively for half of the funds awarded, either benefiting from much larger grants than average or from multiple grants.
- The rate of (after-tax) subsidy provided depends on the delay before achieving taxable profits and ranges upwards from 32 cents in the dollar:
  — this is double that from the tax concession;
  — it is inflated by the ability ultimately to deduct expenditure on R&D projects already assisted by grants.
- Reliable estimation of the net social returns from the scheme is precluded by lack of knowledge about key parameters.
- Depending on the assumptions/judgements about such parameters as the R&D inducement rate of the scheme, the spillover returns necessary for the DGS to ‘break even’ in net social benefit terms range from 40 to 60 per cent.

Generic Technology Grants Scheme (GTGS)

- About $115 million was allocated under the GTGS between 1986–87 and 1993–94; 435 applications were processed with an average success rate of 25 per cent.
- The share of project costs covered by the grants varied from 20 to 95 per cent.
  — the rate of subsidy to firms could be relatively very high, given their access to the tax concession and depending on their degree of control over the project and its results.
- There was a predominance of arrangements involving one research institution and one commercial collaborator
  — funding was relatively highly concentrated on large companies, benefiting from multiple grants.
- The top 11 per cent of commercial participants were involved in projects accounting for nearly half of the total funds awarded.
- While R&D assisted involved more research and experimental development than the DGS, applied research was more often involved than strategic research.
- Depending on judgements about inducement effects of the scheme, the required spillover returns range from 45 to 65 per cent.
  — while higher than for the DGS they are plausible, given the larger portion of strategic research funded by the GTGS.

Automatic R&D support for tax loss companies

- The Commission's proposed automatic grant scheme would provide ongoing assistance to the large number of companies in tax loss that currently do not benefit from competitive grants.
- This scheme could be expected to induce an increase in R&D of around $50 million, more than double that from selective grants.
- The additional cost to revenue of replacing the ‘DGS component’ of the Competitive Grant Scheme would be about $50 million.
- The spillover returns needed for the scheme to ‘break even’ in net social benefit terms range from 34 to 65 per cent, depending mainly on the inducement rate for companies in tax loss
  — these are comparable to those needed to achieve a break even outcome from the selective grant scheme.

E.1 Discretionary Grants Scheme

Operation of the scheme

Objectives

In the original Ministerial Directions for the scheme (see IR&D Board 1987, pp. 58-9), applications for discretionary grants were to be considered where the Board was satisfied that:

- the applicant company, or the company which controls the applicant company, had and would continue to have for the duration of the project, insufficient taxation liability to enable it to obtain adequate benefit under section 73B of the *Income Tax Assessment Act 1936* to undertake the project;
- the project was directed to the development of internationally competitive and internationally traded goods, systems or services; and
- the project would not proceed satisfactorily without a discretionary grant.

Recent descriptions of the objectives of the DGS (such as IR&D Board 1993b) have therefore stressed its role as a complement to the 150 per cent R&D tax concession in that it aimed:

- to assist companies unable to take adequate advantage of the 150 per cent R&D tax concession because of insufficient taxation liability.

Further, reflecting the view that the provision of support for R&D is only a means to an end, the ultimate objective of the scheme was the same as that for the Industry Innovation Program as a whole, namely:

- to encourage wealth creation through the growth of internationally competitive companies, by successful innovation based on research and development (IR&D Board 1992).

Selection (eligibility and merit) criteria

In a recent statement of eligibility criteria (IR&D Board 1993b), the following conditions needed to be *jointly* satisfied for a project to be eligible for DGS support:

- eligibility was restricted to *companies* (incorporated or unincorporated business enterprises and associations); and
- eligible activities were confined to the traded sector, and the project had to result in the development of an internationally competitive good, service or system; and

- applicants were unable to take adequate advantage the R&D tax concession (because of insufficient taxation liability) for the duration of the project; and
- the project would not proceed satisfactorily without support; and
- the project could be completed within three years.

Projects were assessed on the basis of merit against other applications, with preference given to proposals which:

- demonstrated an ability to commercialise the results of the R&D (as indicated by factors such as management capability, market need, market competitiveness and dynamism, company market knowledge, and company technical and production strengths);
- generated national benefits for the Australian economy; and
- met the objectives of the scheme and were consistent with the Government's industry strategies — at the time of the Ministerial Directions, the Government's industry development policy objectives included a specific wish to assist small start-up companies wanting to enter the international market place and companies involved in industry restructuring.

Value of grants approved per year

The DGS was a competitive grants scheme with a limited budget allocation. The value of grant payments in current prices peaked in 1988–89 at $18.4 million, reached a low of $13.4 million in 1992–93, and increased to $16.4 million in 1993–94 (table E1).

Table E1: **Value of DGS agreements signed and payments made**

	86-87	*87-88*	*88-89*	*89-90*	*90-91*	*91-92*	*92-93*	*93-94*
Agreements signed ($m)	19.9	19.2	23.2	15.3	15.1	14.3	12.2	18.8
Payments ($m) (current prices)	6.4	17.4	18.4	15.7	14.0	14.0	13.4	16.4
Payments ($m) (1989-90 prices)	7.7	19.8	19.9	15.7	13.4	13.1	12.3	n.a.

Source: IR&D Board, *Annual Report* (various issues); ABS, Cat. No. 8114.0.

Applicants and recipients

Over the eight-year period 1986–87 to 1993–94, 1320 applications for DGS grants were made (table E2) — including 19 applications outstanding from the previous Australian Industrial Research and Development Incentives Scheme. There has been a downward trend in the number of DGS applications per year since the peak of 249 in 1987–88. Applications had dropped to 81 in 1993–94.

Table E2: **Number of DGS applications and grant recipients**

	86-87	*87-88*	*88-89*	*89-90*	*90-91*	*91-92*	*92-93*	*93-94*	*Totals*
Outstanding (start of year) [a]	19	64	69	56	38	30	39	5	
Received	239	249	174	181	144	139	113	81	1320
Processed [b]	194	244	187	199	152	130	147	78	1331
Approved [c]	92	69	63	79	67	43	58	61	532
Outstanding (end of year)	64	69	56	38	30	39	5	8	
Success rate [d] %	47.4	28.3	33.7	39.7	44.1	33.1	39.5	78.2	40.0

a The 19 projects outstanding for the first year are applications transferred from project grant applications under AIRDIS.
b Applications processed includes those either approved by the Board, rejected by the Board or withdrawn by the applicant.
c Applications approved includes agreements signed or offered during the reported year.
d Ratio of approvals to processed.
Source: IR&D Board, *Annual Report* (various issues).

However, the fall for the most recent year reflects in part the changes associated with the application procedures introduced with the reorganisation of grant schemes under the Industry Innovation Program in early 1993. The IR&D Board sought to reduce the compliance burden on applicants by introducing a two-stage application procedure — applicants were required firstly to register an Expression of Interest (EOI), involving minimal information, and only those with some likelihood of receiving a grant were then invited to develop a full application. In 1993–94, 195 EOIs were processed and 89 (or 46 per cent) invited to develop a formal application (IR&D Board 1994d).

Because of the merit-based nature of the DGS and the limited funds available, not all eligible applications received grants. Of the 1320 applications processed up to 1993–94, 40 per cent were approved for grant support. The success rate fluctuated somewhat from year to year, most especially in the first two years of the scheme. The very high success rate for 1993–94 reflects the effect of the introduction of the two-stage application procedure, which culled more than half the applications at the first stage. The eventual success rate for first-stage applicants was around 30 per cent.

Role as a complement to the R&D tax concession

Aspects to be considered in assessing how effectively the scheme performed as a complement to the 150 per cent R&D tax concession include:

- to what extent did the scheme assist the companies at which it was targeted — namely, those unable to benefit adequately from the R&D tax concession?; and
- how did the rate of R&D support under the DGS compare with that available under the tax concession?

Coverage of target companies

Number of potential DGS applicants

The DGS targeted companies that were unable to obtain adequate benefit from the 150 per cent tax concession. Companies normally met this criterion because they had insufficient taxation liability. A much less common reason was their corporate structure — for example, trusts, charitable organisations and non-taxable organisations were ineligible for the concession.

As a first step in considering how effectively the scheme supported companies with insufficient taxable profits, it is necessary to examine the extent to which such companies *applied* for DGS assistance.

Evidence on the proportion of R&D performing companies that might typically be in tax loss in any year is available from BIE (1993c). The BIE found that a significant proportion (perhaps around one-third) of companies which register for the R&D tax concession are in tax loss. In addition, some eligible businesses do not register for the tax concession because they are in tax loss. Taking both factors into account, it is estimated that the number of potential DGS applicants might typically be around 600 or more per year.

Comparing this figure with the annual applications in table 2 suggests that only a small proportion of companies that might not have benefited adequately from the tax concession apparently sought DGS support. Why might this have been so?

First, some companies might have been unwilling to apply because of the compliance costs — applicants were required to define the project, prepare a business plan, demonstrate that commercialisation finance was available, and document likely benefits arising from the project. The two-stage application process introduced with the IIP attempted to ease the initial compliance burden on applicants.

Second, some companies might have thought that they could not meet all of the eligibility criteria, in particular being able to demonstrate that the R&D would not proceed satisfactorily in the absence of the grant, and other requirements such as an ability to commercialise the R&D.

Third, the fact that not all applicants in a competitive selection process could be successful might have acted as a disincentive to apply even if a firm satisfied the eligibility criteria.

Fourth, some companies might not have applied simply because they were unaware of the support available to them.

Finally, companies seeking to undertake large-scale projects involving R&D expenditure of more than $1 million could have sought support under the joint registration (syndication) provisions of the tax concession. As noted in section D3.6, syndication is a mechanism allowing companies to trade their tax losses for R&D funding.

Success rates by type of applicant

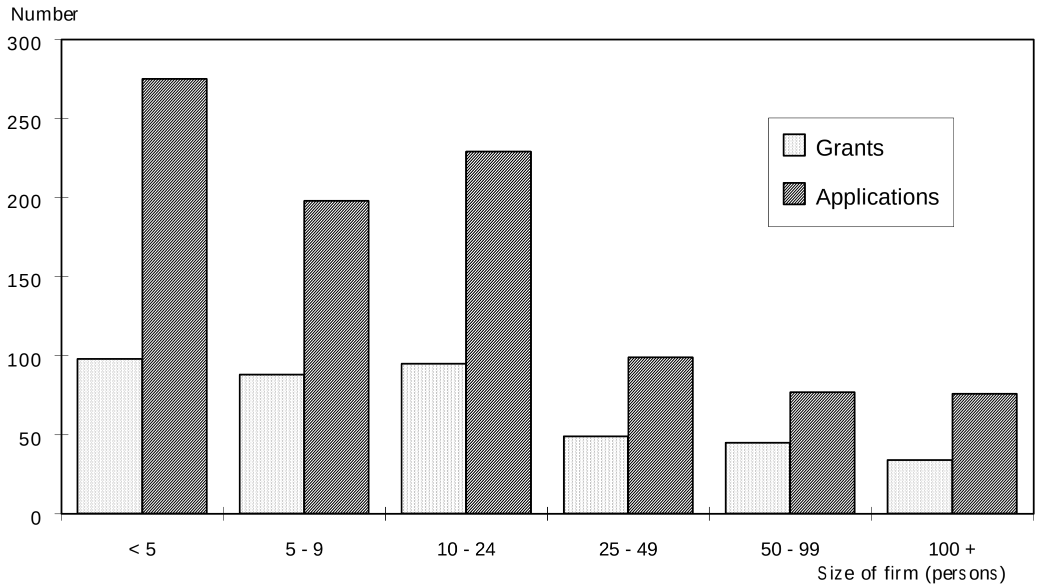
To obtain insights into the extent to which targeted companies sought and received support, the IR&D Board database of DGS applicants and recipients was analysed. Over the period June 1986 through to November 1993, 1287 applications for DGS grants were lodged with the IR&D Board by 1077 companies, and 470 grant agreements were signed.[1] Of particular interest are classifications of applicants by size of firm, age and taxable income status.[2]

It is clear from figure E1 that DGS applications were mainly lodged by relatively small companies. Of the 954 applications for which firm size data are available, around half were from companies with fewer than 10 employees, nearly three-quarters from firms with less than 25 employees, and around 90 per cent from firms with less than 100 employees (a conventional benchmark for defining small firms in Australian manufacturing).

1 In this period, 503 projects were approved, in the sense that an agreement number was allocated, but 24 of these were subsequently withdrawn either by the company or the IR&D Board, while for a further 9 the agreement had not been signed as of November 1993. Hence, the figures quoted in this section in respect of success rates differ slightly from those of table E2.

2 Unfortunately, the taxable income information available from the DGS database was found to have too many shortcomings to allow a meaningful investigation of the 'insufficient tax liability' condition of eligibility.

Figure E1: **Number of DGS applications and grants, by company size**

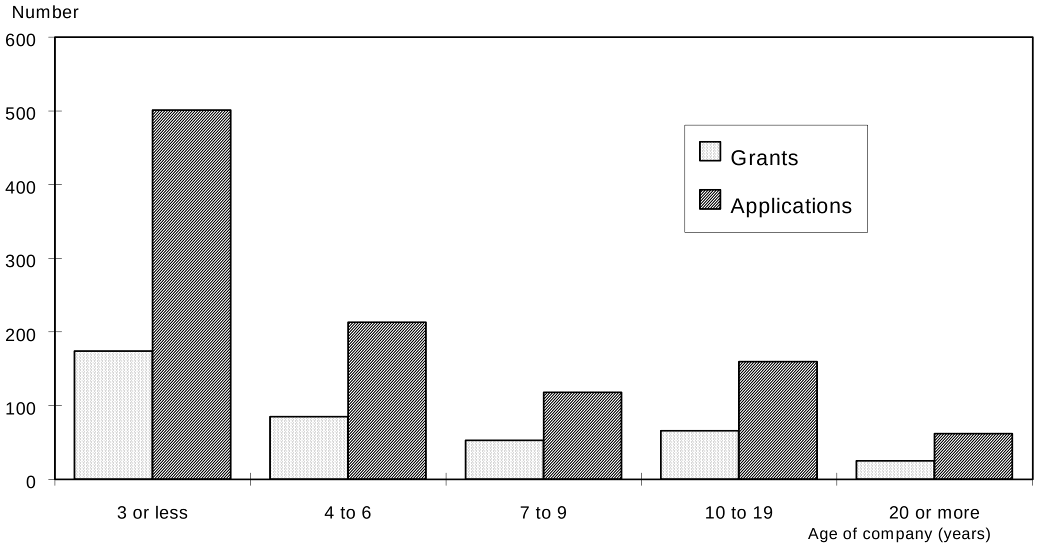


Source: IR&D Board database.

While the grants awarded were also mainly concentrated in small companies, the distribution is not quite so highly skewed because the success rate tended to vary directly with the size of firm. Very small companies tended to be less successful than larger companies in *receiving* grants (figure E1) — for example, around 36 per cent of applications submitted by companies with fewer than 5 employees were approved, whereas the success rate among companies with between 50 and 99 employees was 58 per cent. However, the success rate for the largest category of 100 or more employees (45 per cent) was quite similar to that for applicants in the 5 to 9 and 10 to 24 persons categories (44 and 42 per cent respectively).

The IR&D Board has noted that the lower success rate among very small companies reflects the fact that such companies are usually not able to develop adequate plans for the commercialisation of their R&D. In considering applications, companies are required to have the funds and a viable strategy for commercialising the results of the R&D. Because small companies are frequently lacking in these areas, grants tended to be awarded to smaller or start-up companies only where commercialisation costs were relatively low, or where they had developed a strategic alliance with another company to commercialise the R&D project (IR&D Board 1990).

Figure E2: **Number of DGS applications and grants, by company age**



Source: IR&D Board database.

The distribution of DGS applications and grants by age of company is presented in figure E2. Applications were clearly skewed towards new companies — nearly 50 per cent of applications were from companies that were three years or less at the time of their application, and nearly two-thirds were six years or less.[3] Success rates did not vary appreciably across firms of different ages — for example, 35 per cent of companies aged three years or less were successful in receiving grants compared to 40 per cent of companies aged 20 years or older.

Frequency of multiple DGS grant recipients

Information on the number of applications and grants are provided in table E3. Of the 1077 companies that applied for a DGS grant up to November 1993, 924 made only one application. Around 70 per cent of the remaining 153 companies made two applications, and only ten companies made as many as four or more applications.

Of the 1077 applicant companies, 407 received at least one grant. These successful companies between them received 470 grants — there were 353 single grant recipients and 54 multiple grant recipients, with the latter group receiving 117 grants or an average of 2.2 grants each. Hence, only around 13 per cent of DGS recipients received more than one grant. However, 28 per cent

3 Age of company is calculated as the number of years between date of incorporation and the year of application. For companies lodging multiple applications over a period of years, age is calculated at the time of their first application.

of funds approved over the period up to November 1993 went to multiple grant recipients.

Table E3: **Number of companies applying for and receiving DGS grants**

Number of applications	*Number of grants*					
	0	***1***	***2***	***3***	***4***	***Total***
1	628	296				**924**
2	34	48	28			**110**
3	6	7	15	5		**33**
4	2	1	2	1	1	**7**
5	0	0	1	1	0	**2**
6	0	1	0	0	0	**1**
Total	**670**	**353**	**46**	**7**	**1**	**1077**

Source: IR&D Board database.

The pattern of success and failure provided in table E3 suggests a number of broad types of DGS applicants/recipients. By far the most common was what might be termed the ‘one-failure’ type — as represented by the 628 companies which lodged one unsuccessful application, and never reapplied.

The second most common was the ‘one-success’ type, of which there were 296 — these companies lodged one application and successfully obtained a grant, but never reapplied.

Among the companies which made multiple applications, the most common was the ‘moderately successful’ type, of which there were 68 — these companies were successful with at least 40 per cent (but not all) of their applications. Next, there was the ‘very successful’ group, of which there were 34 — these companies applied for grants between two and four times and were successful on *every* occasion.

Finally, there was the ‘very unsuccessful’ group, of which there were 47 — these companies either failed to obtain a grant on every occasion (38 companies) or put in three or more applications and were successful only once (9 companies).

Distribution of DGS grants

The 470 DGS projects which received grants up to November 1993 ranged in size from $27 000 to nearly $2 million, with an average of $272 000. While nearly two thirds of the grants approved (or 62 per cent) were less than $250 000, such grants only accounted for around 30 per cent of the value of funds approved (table E4). On the other hand, there were 57 grants of $500 000 or more, including 13 grants of more than $1 million. These large grants comprised 12 per cent of the number of grants but nearly 40 per cent of the value of funds approved.

Table E4: **Distribution of DGS grants, by size of grant**

Size of grant $'000	*Grants* No.	*Grants* %	*Funds* $m	*Funds* %
less than 50	30	6	1.2	1
50 to 99	82	17	6.1	5
100 to 249	181	39	30.7	24
250 to 499	120	26	42.0	33
500 to 999	44	9	30.5	24
1000 or more	13	3	17.5	14
All grants	470	100	128.0	100

Source: IR&D Board database.

Because of the multiple DGS grants received by some companies, the distribution of funds on a *company* basis is more highly concentrated (table E5). This most clearly demonstrates the selective nature of DGS support.

Summary of DGS grants and funds awarded

It appears that in the seven-year period to 1993:

- 73 companies (or only 6 per cent of the 1077 companies which applied for support) between them received around half the funds awarded.

At the other extreme:

- 334 companies shared the other half of funds awarded, while
- 670 applicants received nothing.

Judged from this viewpoint, the scheme appears to have operated in only a very limited way as a complement to the tax concession. But because of its discretionary nature and limited funding, the scheme could never operate as a full complement to the tax concession.

Table E5: **Distribution of DGS grants, aggregated by company**

Size of grant $'000	*Companies*		*Funds*	
	No.	*%*	*$m*	*%*
less than 50	23	6	0.9	1
50 to 99	67	16	5.0	4
100 to 249	152	37	25.6	20
250 to 499	92	23	32.1	25
500 to 999	52	13	36.4	28
1000 or more	21	5	28.0	22
All grants	407	100	128.0	100

Source: IR&D Board database.

Characteristics of 'repeaters'

The IR&D Board has expressed concern at the propensity of some companies to make repeated use of grant-based incentives (1988, p. 22). The Board suggests that this reflects an inability on the part of these companies to commercialise the results of their R&D, otherwise they would have progressed to the stage of profitability where they could take advantage of the tax concession.

To test this possibility, some key characteristics of companies that received more than one DGS grant were examined (table E6). It appears that repeat users tended to be smaller and younger than single grant recipients, and their average grant was also somewhat larger.

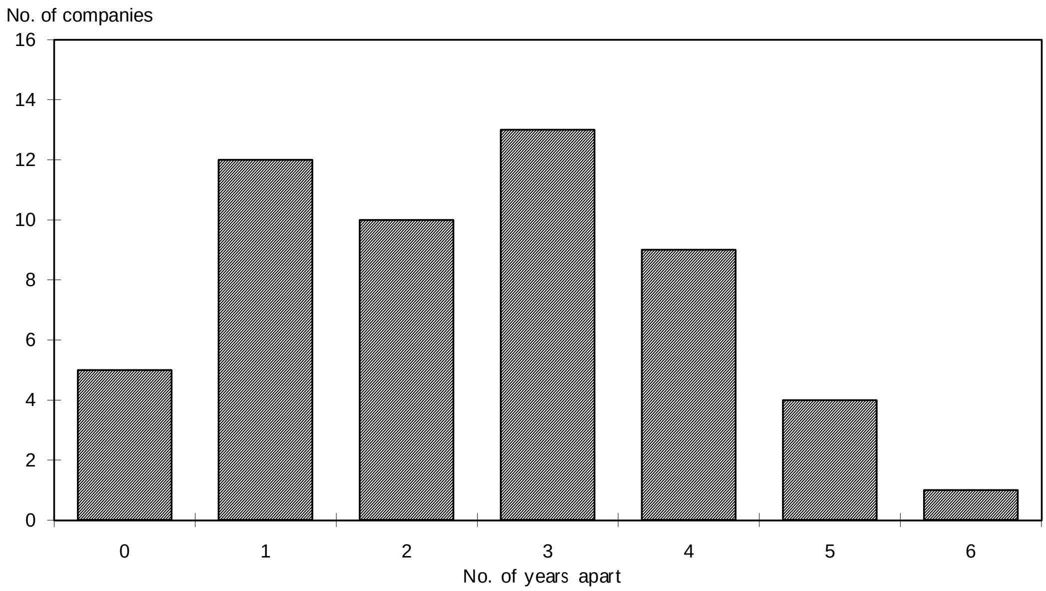
Table E6: **Characteristics of single and multiple DGS recipients**

Characteristic	*Single (n=353)*	*Multiple (n=54)*
Average no. of employees	66	28
Average age (years) [a]	7.3	4.3
Average company grant	$260 000	$315 000

a In the case of multiple grant recipients, age is calculated at the time of their first grant.
Source: IR&D Board database.

Insofar as the repeaters were typically relatively new companies that could take several years to progress to the stage of profitability, repeat use of the DGS is perhaps not surprising. However, to shed further light on whether this constitutes a source of concern, it is necessary to look at the time profile of the use of the DGS by these multiple grant recipients (figure E3).

Figure E3: **Time profile of use of DGS by multiple grant recipients**



Source: IR&D Board database.

The time profile depicts the number of years between the first and most recent grants received by the 54 multiple grant recipients. One-half of these companies received their grants up to two years apart, and around three-quarters up to three years apart. Because projects which received support could last up to three years, some of these companies might therefore have been in a situation of insufficient taxation liability for a period of up to six years — perhaps not an undue length of time for new, innovative companies.

Around one-quarter (14 companies) received their grants between four and six years apart, implying a period of insufficient taxation liability of possibly seven to nine years. While even this length of time might not be too unusual for new innovative companies, it nevertheless suggests that a failure to successfully commercialise the supported projects might have contributed to these companies remaining in tax loss and requiring on-going DGS support, rather than progressing to a stage of profitability where they could access the tax concession. Any definitive conclusion would require that these companies and projects be scrutinised closely — a task beyond the resources of this inquiry.

Nature of eligible R&D projects

The DGS was confined to projects ‘directed at the development of internationally traded goods, systems or services’. Originally, service activities were not deemed eligible — they were only declared to be an eligible activity in December 1990.

Nominal rate of R&D subsidy under the DGS

The maximum assistance provided under the DGS was 50 per cent of total R&D project expenditure, and all grants awarded were at this maximum rate. All grants provided by the IR&D Board are treated as assessable income, and hence taxable.

But the calculation of the subsidy to R&D resulting from the grant is complex, because the receipt of a taxable grant for R&D expenditure affects a company’s claim under the 150 per cent tax concession as defined by the so-called ‘contamination provisions’. These provisions do not eliminate a future claim to tax deductions whenever an eligible project receives a grant — they only reduce the rate of concessional deduction, usually from 150 per cent to 100 per cent (IR&D Board 1994a, p. 70).

For example, a company carrying out a $100 000 project funded by a 50 per cent taxable grant can deduct the $100 000 expenditure at 100 per cent once it is paying tax. It is also liable for tax on the grant at that time. The real value of the tax concession entitlement is reduced the longer the time taken to achieve taxable profits, but similarly, the real value of the tax payable on the grant is also reduced.

Hence, the subsidy (S) for R&D under a taxable grant can be expressed as:

$$S = g\,[1 - (t\,/\,(1 + i)^{r})] + [\,B\,/\,(1 + i)^{r}\,]$$

where g = grant share of project expenditure, t = company tax rate, i = nominal discount rate, r = number of years before profitability, and B = value of entitlement to deductions under the tax concession (after application of the ‘contamination provisions’).

This expression shows the value of the subsidy relative to a base at which there is no support at all provided for R&D. However, if the grant replaces other measures, its *net* value to firms will be less than that shown above. For example, in the absence of the grant, a firm may previously have been entitled to deductions (perhaps delayed) of 150 per cent or 100 per cent of expenditure.

In considering the subsidy provided by the tax concession elsewhere in this report, the measure used is the extent to which the ‘concessional’ 50 per cent component of the tax deduction reduces the after-tax cost — on the assumption that if there were no tax concession, the expenditure would be deductible at 100 per cent. On this basis, the R&D tax concession provides a subsidy of 18 cents in the dollar.

Calculations of the net subsidy provided by the 50 per cent taxable grant for a grant recipient, relative to the incentive provided by a deduction of 100 per cent, and 150 per cent are presented in table E7. In practice, the more relevant base for the selective grant is the deduction that would apply in its absence, that is 150 per cent. The net subsidy in this sense is also shown.

Table E7: **Subsidy per dollar of R&D for a 50 per cent taxable grant**

		Delay before taxable profits [a,b,c]		
Subsidy relative to:	*Tax paid in same year* [c] *(¢/$)*	*2 years (¢/$)*	*4 years (¢/$)*	*6 years (¢/$)*
100 per cent deductibility	32.0	35.1	37.7	39.8
150 per cent deductibility	14.0	20.3	25.4	29.7

a These calculations apply the contamination provisions of the tax concession. Those provisions define the extent to which companies claiming the tax concession who received a grant in respect of R&D expenditure, have the benefit of the grant clawed back or offset. For a taxable grant, the amount of expenditure to which clawback applies (that is, which is eligible for deduction at 100 per cent rather than 150 per cent) is equal to twice the amount of the grant. Hence, for a grant rate of 50 per cent of project costs, this means that the whole of the project expenditure is deductible at 100 per cent and *none* is deductible at 150 per cent.
b This refers to the delay after the grant period. Where grant recipients experience a delay in claiming the concession for the R&D expenditure incurred with the grant project, the value of claims by grant recipients under the tax concession and payment of tax on the grant are discounted at a 10 per cent nominal interest rate per year.
c The company tax rate is assumed to be 36 per cent.
Source: IC estimates.

It can be seen that the subsidy provided to grant recipients with a 50 per cent taxable grant is around 35 cents in the dollar if it moves into tax profit two years after the grant period, and around 40 cents if the delay is six years.

As well as the rate of subsidy therefore being higher under the DGS, there were also differences in the nature of support between the tax concession and the DGS.

Whereas only individual projects were supported under the DGS — projects that in principle would not proceed satisfactorily in the absence of a grant — the whole of a company’s R&D might be eligible for the tax concession. Hence, the importance to a company of the higher rate of support under the DGS depends on how large the supported projects are relative to the company's overall R&D expenditure.

An analysis of the DGS database revealed that for around two-thirds of grants awarded, the projects supported represented all the R&D undertaken by the recipient companies. Indeed, in only 15 per cent of cases did the projects represent less than 50 per cent of companies' overall R&D effort. Not surprisingly, the relative importance of these projects decreased with size of firm — in 80 per cent of very small companies (with fewer than five employees) the projects represented the whole of their R&D effort compared to 41 per cent of companies with 50 or more employees.

The requirements that firms needed to satisfy to receive DGS support were more stringent than those needed to claim the 150 per cent tax concession. Under the tax concession, companies are able to obtain the tax saving provided that the R&D is eligible and the company has sufficient taxation liability. By contrast, because the DGS was a competitive (merit-based) scheme, applicants needed to demonstrate not only that they were unable to take adequate advantage of the tax concession, but also that they were able to commercialise the R&D, and that the project would generate benefits for Australia.

There were also differences between the DGS and the tax concession in respect of certain eligibility criteria. For example, the DGS was confined to projects 'directed at the development of internationally traded goods, systems or services'. Unlike the tax concession, companies in the non-traded sector were therefore not eligible for support under the DGS. On the other hand, the DGS covered a wider range of legal entities — unincorporated (as well as incorporated) companies were eligible, along with trusts, charitable organisations (non-profit) and non-taxable organisations. Finally, there were differences in respect of types of eligible R&D expenditures — purchase of core technology was eligible for the tax concession but not covered under the DGS, whereas expenditure on market research was eligible for the DGS (but not for the tax concession), provided that it was undertaken directly in support of an R&D project.

Role in assisting the development of internationally competitive Australian companies

The ultimate objective of the DGS, as with all schemes in the Industry Innovation Program, was to improve the international competitiveness of Australian companies through encouraging innovation based on R&D. In considering the effectiveness of grant support in achieving this objective, it needs to be remembered that R&D is but one of several key inputs into technological innovation; and technological innovation is but one contributor to overall company competitiveness.

For most companies undertaking R&D, creating a competitive advantage depends on actually introducing new or improved products, processes or services to the marketplace. It is useful, therefore, to look first at the commercialisation record of DGS supported projects.

Commercialisation outcomes of DGS supported projects

As noted above, the main recipients of DGS grants were small companies. However, the risk of failure in such companies is often high — small companies frequently have neither the financial resources nor the expertise to fully commercialise the results of their R&D.

Because of this, the ability to commercialise the R&D became a key basis on which applications were assessed — companies were required to have sufficient funds available for successful commercialisation, and/or to have suitable marketing/distribution arrangements in place, before a grant was approved.

In recent years, the IR&D Board has reported information on the outcomes of completed DGS projects. For example, in 1991–92, a survey was undertaken of 213 companies which had received DGS support (this number representing around 60 per cent of companies that had been supported up to that time). The outcomes are reported in table E8.

Table E8: **Outcomes of 213 DGS supported projects, 1991–92**

Outcome	*No.*	*%*
Commercial success (sales achieved)	75	36
Company in liquidation	25	12
Company taken over	16	7
Technical failure	11	5
Project terminated	2	1
Too early to assess	84	39
Total	**213**	**100**

Source: IR&D Board 1992, p. 14.

The survey results indicated that only 36 per cent of the projects had been successfully commercialised by that time, with this figure likely eventually to be somewhat higher as some proportion of the 40 per cent of projects for which it was too early to assess their outcome might ultimately be commercialised. The Board also noted that the fact that around 12 per cent of recipient companies had failed did not necessarily mean that the grant support was wasted. Often such a project is taken up by another company and carried through to completion and commercialisation — such technology transfer can enable good technology to survive company failure.

Recipients' perceptions of impact on competitiveness

In 1993, Price Waterhouse (PW) conducted a small-scale study of the economic and infrastructural benefits arising from a sample of DGS projects (PW 1993). The sample was selected randomly (by the IR&D Board) from those whose funding had been completed by late 1990.

PW investigated the ways in which recipients had benefited from projects undertaken with DGS support. The factors that were rated most highly in terms of the extent of the benefit were (in order): improved competitiveness; increased sales of associated products; understanding of core technologies; and increased market share. Grant recipients, therefore, saw the creation of a competitive advantage as being among the most important outcomes of the DGS supported projects.

The IR&D Board has reported evidence that companies receiving DGS support have performed much better than manufacturing companies as a whole, in terms of turnover and employment growth (IR&D Board 1992, p. 14). However, one should caution against any inference of a simple link between the DGS support provided and this observed performance because of the following factors: (1) the importance of the supported projects to firms' overall performance is unknown; (2) given that many projects were still not commercialised, they were not actually contributing to the observed sales performance; and (3) grant recipients have particular characteristics (such as small size, etc) which alone could account for much of the observed differences.

Estimates of private returns to DGS supported projects

The IR&D Board has recently commissioned two studies to assess the likely financial returns and benefit-cost ratios of R&D projects that have received Board funding (Sultech 1993; and Deloitte Touche Tohmatsu 1993). However, those studies have largely been confined to assessing projects awarded under the Generic Technology Grants Scheme.

Two other IR&D Board commissioned studies provided some evidence of private returns to DGS projects. Of the 31 completed projects reviewed by Price Waterhouse (1993), 21 were assessed by companies as being at least moderately successful. Total sales to date of $46 million had been generated by these projects, with annual sales projected to be $79 million in two years time, $191 million in five years time and $216 million in seven years time. The corresponding figures for total profits were $8.8 million, $15 million, $26 million and $14 million. Given that the value of grants awarded to all 31 (successful and unsuccessful) projects was $8.6 million, the sales generated to date were some 5.3 times the value of the grants.

A confidential consultancy commissioned by the IR&D Board (Invetech) reported relatively simple statistics on revenues generated in 1992–93 by DGS projects. Some relevant information for projects that would not have been undertaken without grant support, but not all of which had been commercialised at that time, is reported in table E9.

Table E9: **Outcomes of DGS supported projects, 1992–93**

No. of companies	121
Total value of grants up to 1991-92 ($'000)	31 886
Average grant ($)	263 523
Total revenue from grant projects in 1992-93 ($'000)	35 539
Average revenue ($)	293 717

Note: The figures reported relate to projects that would not have proceeded without a grant from the IR&D Board.
Source: IR&D Board, Sub. 219, p. 88.

The DGS projects generated revenue in the single year 1992–93 which exceeded the total value of the grants up to that point in time. If revenue were to be projected over the life of these projects, and expressed in net present value terms, the ratio of returns to grant outlays would be found to be much greater than unity.

But these benefits are simply the *private* returns of companies receiving grant support. Since the grants are ultimately paid for by taxing other economic activities, an assessment of the *net* (economy-wide) benefit also needs to take into account the competitive advantage or disadvantage imposed on non-assisted firms in attracting resources (capital, labour, technology) and winning markets (IC 1992). Because of this, it is generally agreed that demonstrating that private returns accrue to companies that receive grant support is not an appropriate indicator of the effectiveness of a program. Rather, economy-wide (social) benefits need to be demonstrated *beyond the private returns to the recipient firms* to justify the government support provided to the R&D projects. This is taken up in the following section in the context of a social benefit-cost framework.

Cost effectiveness and efficiency

A detailed assessment of effectiveness against stated objectives can still leave unclear whether the DGS was worth having (which also has implications for the current Competitive Grants scheme). An alternative approach is to consider whether the scheme was likely to generate a net social benefit for Australia. On the benefits side, the key elements are:

- the extent to which the program induced *additional* R&D — that is, R&D which would not have been carried out in the absence of the program; and
- the benefits to the wider community (spillovers) generated by the *induced* R&D.

On the costs side, the key elements are:

- costs of administering the scheme;
- the resource cost associated with the efficiency losses arising from having to raise a higher level of taxes to finance the program — the marginal excess burden of taxation (MEB) times the program and administration costs; and
- compliance and other costs incurred by applicants.

Such a social benefit-cost framework is fraught with difficulty. Of these elements, the one which is both critical to the outcome and involves great uncertainty is the spillover return to the additional R&D induced. The substantial literature on the returns to R&D was reviewed for this inquiry — refer appendix QA. But what that and other studies (eg BIE 1994b) reveal is how variable those returns can be.

In the framework used by the BIE to evaluate the benefits from the tax concession, the average *spillover* return to the induced R&D was based on estimates of the average *private* return to the induced R&D and assumptions about an average *spillover to private return* ratio (1993c, p. 235).

The subsidy provided by the DGS is higher than that provided by the tax concession (though varying with the delay before the grant recipient moves into tax profit (table E7)). It might therefore be argued that because projects supported by selective grants require a higher subsidy to proceed than under the tax concession, the additional projects which the grants induce may well have lower private returns and — on the assumption of a roughly proportionate relation between private and spillover returns, as in the BIE methodology — lower spillover returns, on average, than under the tax concession.

Because of the problems associated with estimating the likely average private return to the induced R&D, and the lack of a strong basis for assuming a direct relationship between private and spillover returns, a slightly different approach is used here. Rather than assume particular values for the spillover return, the spillover return that would be needed for the social benefits to be at least as great as the social costs is calculated, that is, the *required break-even spillover return*.

Another measure sometimes reported is the 'bang-for-a-buck', which indicates the ratio of the induced R&D to program costs. While superficially attractive, this measure is flawed by the fact that program costs do not indicate a net social cost to society. Traditionally, such costs have been treated in economics as transfers, with no social cost at all. More correctly, they are viewed as being a social cost in the sense that the higher the revenue required, the higher the costs imposed by altering the behaviour of those who are taxed. This cost, the cost of public funds, is included in the calculation of the required break-even spillover return, and this is the measure the Commission prefers and reports.

But there is uncertainty also in respect of other parameters needed for the social benefit-cost assessment. The elements needed for this calculation are described as follows.

Data required for the social benefit-cost assessment

Additional R&D induced

The main source of evidence on the likely inducement from R&D assistance is surveys of recipients and non-recipients. Surveys of recipients face a major source of bias, however, because recipients have obtained the grant on the condition that the research would not proceed satisfactorily without it.

Survey evidence is available from the Price Waterhouse (1993) and Invetech studies on what proportion of the DGS projects that received support were induced by the availability of the grant, and what proportion would probably have been carried out anyway.

Of the 30 DGS grant recipients interviewed, PW was told that around two-thirds of the projects would *not* have proceeded in the absence of the grant. Allowing for some strategic response on the part of grant recipients, this estimate is likely to be biased upwards. A useful control on the results obtained from successful grant recipients is to survey unsuccessful companies, for whom there is less likelihood of a strategic response favouring the schemes. Of 50 unsuccessful companies whose views were sought by PW, 29 proved not to be contactable (by telephone), 16 advised that the project had proceeded and 5 that the project had not proceeded. Hence, of those unsuccessful DGS applicants contacted, around three-quarters proceeded without grant assistance. Insofar as some of the companies that could not be contacted were defunct, however, this would overstate the proportion of projects that *would* have been carried out anyway.

The small size of the PW sample limits the generality of the results. A more comprehensive survey was undertaken subsequently by Invetech. In that study, all companies that had received a DGS grant up to 1993 were surveyed. Out of 208 respondents, 123 (59 per cent) indicated that the R&D project would not have proceeded without the grant support.

In the draft report, to allow for the likelihood of a strategic response favouring the scheme, the Commission made a (modest) adjustment downwards of the inducement rate to 50 per cent in one of its simulations.

The Board was highly critical of this approach, and suggested that:

> ... estimation of inducement levels [used by the Commission] are open to ridicule (Sub. 363, p. 36).

On the correction for response bias, the Board accused the Commission of implying that:

> ... the Invetech analysis is suspect because companies could be expected to lie to keep government support flowing (Sub. 363, p. 37).

Response bias (strategic response) is a commonly accepted problem associated with any survey results. The Commission reaffirms its view that it is more likely to be prevalent for a selective scheme (like the DGS) than an automatic scheme (such as the tax concession).

As noted, apart from the normal sources of response bias, there is the fact that recipients of grants obtained such grants *on condition* that their project would not otherwise have ‘proceeded satisfactorily’. Just as claimants have an obvious incentive when applying to demonstrate that their claim complies with the requirements (Fölster 1991), they clearly have an incentive subsequently to confirm that this was in fact the case. To answer otherwise would essentially amount to admitting having received assistance under false pretences. It would take a very sophisticated questionnaire to overcome this strong influence on the results. In practice, the questionnaire used was relatively straightforward, merely asking respondents to indicate whether in the absence of the grant they would have proceeded with the project (or whether the time required to complete the project would have increased or they would have missed a market opportunity). For this reason, the Commission in one of its simulations has used an inducement rate which is significantly lower than the survey results, although it also reports results with minimal adjustment.

Some respondents to the Invetech survey indicated that in the absence of the grant the project would have taken longer to complete or would have missed a (market) opportunity. The Board suggests that these projects should be included in the measure of inducement.

However, there is a problem with assessing the degree to which projects would be speeded up by grants. Completing a project more quickly involves both costs and benefits. Once begun, it is in companies' interests to complete the project in the time frame which maximises benefits over costs. Thus the impact of the grant in changing the speed of development is difficult to judge because, once begun, companies have a profit incentive to perform the R&D at an appropriate rate over time.

Moreover, where a project would have taken place without the grant but the grant enabled the project to be completed sooner, spillover benefits would still have been generated even without the grant — though at a time further into the future. A similar argument applies for projects that might have lost a market opportunity if not for the grant. In those cases, the spillovers would still have been generated without the grant — but more so from those other companies competing with the grant recipient who got to market sooner.

In short, the Commission considers it most meaningful to focus on projects that would not otherwise have proceeded as the appropriate indicator of inducement. In the absence of information on what proportion of R&D *expenditure* was induced by the scheme, the same proportion as for *projects* is assumed to apply.

In considering the use of the inducement level in the cost-benefit analysis, it is important that the value of incentives as perceived by firms is matched by an appropriate cost to revenue. For example, it became obvious to the Commission through the course of the Inquiry that the 'contamination' provisions associated with grants were not well understood. Moreover, many companies in tax loss appear to understand only imperfectly that the 150 per cent tax deduction is available to them when they move into tax profit. Many, for example, do not register for the tax concession, despite being entitled to do so.

The net effect is that many companies perceive that the benefit of the grant is simply the 50 per cent of project costs which initially accrue. It is this perception which generates the inducement that occurs. It is arguable then that the cost to revenue associated with an inducement of this level ought to be based on the cost of grants of 50 per cent of project costs. This was the set of assumptions that was reported in the draft report.

Over time, however, this perception will change as companies come to appreciate their entitlements to tax deductions and become liable to taxation on the value of the grant as they move into profit. At this lower level of perceived benefit, inducement is likely to fall. Importantly though, the cost to revenue of the scheme will also be lower. Thus for the purpose of conducting a cost-benefit analysis, the Commission makes two sets of assumptions about inducement.

The first is that inducement broadly accords with the surveys, that is 55 per cent of projects would not have proceeded without the grant. There is an argument that this should be associated with a net subsidy of 50 per cent of project costs, with an associated cost to revenue. To put the scheme in the best possible light, however, in the simulation that follows the lower net subsidy rate of 30 per cent is assumed.

The second is that inducement is 35 per cent. This is to adjust for response bias in the survey. In determining the extent of adjustment to make, the following 'reality checks' are relevant:

- if inducement of 55 per cent were correct and firms believed they were getting a net subsidy of 50 per cent, the fact that they actually receive an expected net subsidy of 30 per cent will cause them to alter their behaviour. If inducement were reduced by the same proportion as the reduced incentive, it would be slightly under 35 per cent.
- an incentive of 35 per cent is approximately double the incentive offered by the tax concession when the BIE measured the upper bound on inducement at 17 per cent.

Administrative costs

The IR&D Board provided limited information on the administrative costs associated with running the IIP grant programs as a whole (Sub. 219, pp. 91–2). Expenditure on Central Office support staff was estimated to be $2 million in 1992–93, and State Office support was also estimated at $2 million. Over the life of the scheme, the DGS averaged around 40 per cent of the funds awarded under the grant programs. Hence the portion of these administrative costs attributable to the DGS could typically have been around $1.6 million per year. This is likely to be an underestimate, however, because data on other administrative costs were not available — including the costs of the Board itself in relation to the grant programs and the costs associated with the grant Committees. The Board also notes that 93 staff are employed, in a budget of $4 million. This would appear to make little allowance for staff on-costs (superannuation, rent, corporate management overheads, and so on), which are often costed at two to three times salary costs.

On the basis of adding in only the costs associated with the Board itself, administrative cost might be put at around $2 million.

Compliance costs

The submission provided by the New South Wales Government reported on one company's experience in applying for a DGS grant, which illustrates the problem that compliance costs can pose:

> ... a company applied for a [Discretionary] grant of $125 000 and, although favourably considered initially, the application was ultimately unsuccessful. [In the following year] the company made another application for a grant of $600 000, [but] again the application was unsuccessful. The company used an external consultant for preparing these submissions at a cost of $25 000 plus their own time in information gathering, evaluation and presentation (Sub. 260, p. 15).

In February 1993, the IR&D Board sought to reduce the burden on applicants by introducing a two-stage application procedure, with applicants firstly required to register an Expression of Interest (involving minimal information) and only those with some likelihood of receiving a grant were invited to develop a full application.

In recent years, the number of DGS applications has averaged somewhat more than 100 per year. On the basis of the foregoing example, an average compliance cost of $10 000 per applicant was assumed in the draft report. The IR&D Board thought that was a substantial overestimate because ‘most firms do not use consultants’, and suggested a ‘more reasonable’ figure of $3 000 (Sub. 363, p. 38).

However, when firms do not use consultants they are obliged to meet the costs from within their own resources. The opportunity cost of management and staff time involved in an application can be substantial.

Rent seeking

A related, but distinct, form of cost associated with subsidy schemes that has been increasingly recognised as important in the literature is known as ‘rent seeking’ (see Buchanan et al. 1980). This refers to the efforts of managers to enhance their companies’ claims for support by, for example, devising proposals that are more likely to meet the assistance criteria, and lobbying those in a position to alter the criteria or adopt an interpretation favourable to their claims.

These costs can be substantial, because they entail the time of senior management, which is necessarily diverted from the business of the firm. The greater the degree of discretion and the looser the criteria for providing support, the more significant and costly that rent-seeking activities are likely to be. The wide discretion available under the Competitive Grants scheme would suggest that it is a relevant consideration. (For a recent discussion in relation to technology support programs in the United States, see *The Technology Pork Barrel*, by Cohen and Noll 1991).

Unfortunately, it is in the nature of this phenomenon that its costs are not easy to measure in practice, and the Commission has not attempted to make explicit allowance in its calculations of the costs of the schemes.

Estimated cost to revenue

In 1993–94, the value of DGS payments amounted to $16.4 million. With a grant rate of 50 per cent of project costs, the overall R&D undertaken by grant recipients was therefore around $32.8 million in that year.

The program cost (cost to revenue) is estimated as the product of the R&D covered by the recipients' grants and the average subsidy rate (table E7). Because the subsidy rate can vary with the length of the delay before a company moves into tax profit, an estimate is needed of how long that delay, on average, might be.

The BIE survey of tax concession registrants (1993c) revealed that tax loss companies typically expected to realise the benefit of the concession around four or five years after carrying out the R&D. Because there is a greater representation of small, start-up firms among grant recipients than tax concession registrants, an average delay of around six years is assumed.

The cost to revenue under the subsidy measure which makes allowance for taxation impacts as companies move into tax profit is calculated by multiplying the subsidy under the 50 per cent taxable grant estimated on that basis (around 30 cents in the dollar) by the R&D performed.

Overall social costs

The cost of the grants themselves (or the cost to revenue), while ultimately paid for by taxing other entities, essentially represents a transfer of funds from one group in the economy to another (the grant recipients).

However, the administration costs are not a transfer and hence represent a resource cost that would not arise in the absence of the program.

But there is also a social cost associated with the whole program cost in the form of the efficiency losses that arise from having to raise tax revenue to fund it. This resource cost, known as the marginal excess burden of taxation, has been estimated to lie between $0.15 and $0.50 per dollar of tax revenue raised (BIE 1991b) — here, a value of $0.33 is assumed.

Hence, the social costs are calculated as the sum of the resource costs associated with financing the scheme, administration costs, and compliance and other costs incurred on the part of applicants.

Results of alternative scenarios

On the basis of these assumptions, the social costs and induced R&D under the DGS are estimated in table E10. The key assumptions in the two scenarios presented are:

- scenario 1 — the net subsidy is 30 per cent of project costs with appropriate adjustments to revenue, inducement is 35 per cent and the cost of public funds is 33 per cent;
- scenario 2 — as for scenario 1, but with an inducement rate of 55 per cent.

The first scenario is, in the Commission's view, the more likely one.

The second scenario shows a required spillover return of about 40 per cent, somewhat below the rate applying in the 'on balance favourable' evaluation of the tax concession (53 to 87 per cent — BIE 1993c). The first scenario shows a required spillover return of 60 per cent, of the same order of magnitude as in the tax concession evaluation. The similarity between these results reflects the fact that while the inducement ratio for the DGS was higher than for the tax concession, the rate of subsidy provided under the DGS was also higher, and administrative and compliance costs were also a relatively larger proportion of overall program costs.

The results are, however, highly sensitive to assumptions. For example:

- if the cost of public funds were 50 cents in the dollar, the required spillover return to the induced R&D needed for the social benefits to be at least as great as the social costs would range from 78 per cent in the first scenario to 49 per cent in the second scenario. If, on the other hand, they were 15 cents in the dollar, the range would need to be only 42 per cent to 26 per cent.
- If the DGS were considered to have an inducement rate of 90 per cent, as implied by the IR&D Board, the required spillover return for break even could be as low as around 16 per cent. On the other hand, if inducement were just 20 per cent (similar to that encouraged by the tax concession) the required spillover return would be 73 per cent.

As was noted earlier, there are reasons to think that administration costs are understated in these scenarios. If these costs were to be doubled, perhaps to make appropriate allowance for on-costs, the required spillover return would range from 53 per cent to 83 per cent.

Table E10: **Spillover return required by the DGS to break even**

		Scenario 1	*Scenario 2*
[1]	Grant payments ($m) 1993-94	16.40	16.40
[2]	Grant rate (%)	0.50	0.50
[3]	Project R&D ($m) ([1]/[2])	32.80	32.80
[4]	Inducement ratio	0.35	0.55
[5]	Induced R&D ($m) ([3]*[4])	11.48	18.04

[6]	Subsidy rate	0.30	0.30
[7]	Cost to revenue ($m) ([3]*[6])	9.84	9.84
[8]	Administration costs ($m)	2.00	2.00
[9]	Program costs ($m) ([7]+[8])	11.84	11.84
[10]	Marginal cost of funds (33 cents/$)	0.33	0.33
[11]	Social cost of funds ($m) ([9]*[10])	3.91	3.91
[12]	Compliance costs ($m)	1.00	1.00
[13]	Social costs ($m) ([8]+[11]+12])	6.91	6.91
	Required spillover return (%) ([13]/[5])	60	38
	Ratio of induced R&D to social cost ([5]/[13])	1.66	2.61

Source: IC estimates.

Similar sensitivity was found in the analysis of the 150 per cent tax deduction. What it does suggest, however, is that any single numerical result must be treated with great caution. This is especially so, when it is clear that difficult to measure intangibles, such as the costs of resources employed by firms in attempting to achieve favourable outcomes from the selection process, may weigh fairly heavily in any overall evaluation.

E.2 Generic Technology Grants Scheme

Operation of the scheme

Objectives

The objectives of the Generic Technology Grants Scheme (GTGS) enunciated in the Ministerial Directions were (IR&D Board 1987):

- to encourage the development of enabling technologies, which hold promise of significant improvements in areas of industrial innovation critical to Australia's economic growth; and
- to encourage closer collaboration between research institutions, including those in academia and industry.

Selection (eligibility and merit) criteria

An R&D project was eligible for GTGS support if it *jointly* satisfied the following criteria (IR&D Board 1993b):

- encouraged closer collaboration between research institutions and industry; and
- involved the development of strategic (generic) technologies; and
- required grant support for the project to proceed satisfactorily; and
- had strong commercial potential; and
- there was a demonstrated commitment from a commercial enterprise to exploit the results of the R&D for the benefit of Australia; and
- could be completed within three years.

Projects that met these eligibility criteria were then assessed on the basis of merit, with preference given to proposals that *inter alia*:

- entailed quality research with a high degree of novelty and strong links to commercial opportunities;
- involved commercial collaborators with demonstrated capability in commercialising the results of the R&D; and
- generated considerable 'benefits for Australia'.

One of the matters specified in the Ministerial Directions for the GTGS that were to be considered in assessing the merit of projects was the degree of proposed dissemination of the results (see IR&D Board 1987, p. 56). However, the question of dissemination appears *not* to have been accorded a priority as the GTGS has actually operated. As the Chairman of the IR&D Board explained:

> ... when the original generic program was put together, the idea was that we would create diffusion of technology. [However, in reality] we didn't create diffusion because ... [when a] person took out a patent, then that became an exclusive right to operate, and almost a little monopoly. ... But a patent does allow for diffusion of the technology, although it grants exclusion for a period (transcript, p. 846).

Generic technologies and priority areas

Over the life of the GTGS, five areas were declared as generic technologies:[4] Biotechnology; Information technology; Communications technology; Manufacturing and materials technology; and Environmental technology. Prior to the reorganisation of the various grant schemes under the Industry Innovation Program (IIP) in early 1993, grants were awarded by separate committees that corresponded to these generic technology fields.

However, the operation of the GTGS involved more detailed targeting than just a focus on five broad generic technology areas. Prior to the reorganisation, the various Committees identified *priority areas* within each of the generic technologies because it was considered imperative that R&D activities should focus on areas considered to have the greatest chance of generating significant economic benefits for Australia (IR&D Board 1987, p. 39). Such priority-setting exercises required wide consultation and gathering of information about Australia's research capabilities, industrial and natural resource strengths, market opportunities, overseas trends and likely future developments.

For example, in 1986–87, the target areas for biotechnology were plant agriculture, animal production, human pharmaceutical/medical, biotechnology support, food processing, agricultural surpluses, and water treatment (IR&D Board 1987, p. 80); while in 1987–88 the priority areas were genetic engineering, enzyme application and fermentation technology, cell manipulation and culture, and protein engineering (IR&D Board 1988, p. 99).

As another example of the priority setting that took place, nine target areas were accorded priority for new materials technology grants (IR&D Board 1988, pp. 103-4). The priority areas identified for Information technology, and Communications technology are reported in IR&D Board 1989, pp. 152–3.

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4 Biotechnology, New materials technology, and Information technology were declared generic technologies in December 1986. Communications technology was declared a generic technology in November 1987, while Environmental technology and Manufacturing and materials technology were declared in September 1990. New materials was included under Manufacturing and materials technology from the beginning of 1991–92.

Value of grant approvals and payments per year

Over the eight-year period to 1993–94, around $114 million in grants were paid under the GTGS (table E11). The value of grant payments increased fairly systematically since the inception of the scheme and peaked in 1992–93 at $20.9 million.

Table E11: **Value of GTGS agreements signed and payments**

	86-87	*87-88*	*88-89*	*89-90*	*90-91*	*91-92*	*92-93*	*93-94*
Agreements signed or approved($m)	11.4	18.8	18.5	21.9	15.0	21.1	22.2	n.a.
Payments ($m) (current prices)	4.8	8.2	12.9	16.0	15.2	17.7	20.9	17.7
Payments ($m) (1989-90 prices)	5.8	9.3	14.0	16.0	14.6	16.5	19.3	n.a.

Source: IR&D Board, *Annual Report* (various issues); ABS, Cat. No. 8114.0.

Number of applicants and recipients

Up to 1993–94, 935 applications for GTGS grants were processed by the various committees (refer table E12). Of these applications, 230 were approved for grant support — implying a success rate of only 25 per cent. The success rate varied somewhat between the five technology areas, being highest in Environmental technology, and Communications technology, which also had the smallest number of applications processed.

However, the introduction of the two-stage application procedure from March 1993 was typically accompanied by an increase in the success rate because while all applicants were required to submit an Expression of Interest, only those most likely to receive a grant were invited to lodge a full application. In 1993–94, the success rate in Manufacturing and material technology, and Environmental technology was 75 per cent (but only four applications were processed in each area), and in Communications technology 67 per cent. However, applications in Information technology have typically had a below-average success rate — and in 1993–94, no grants were awarded from among the six applications.

Table E12: **Number of GTGS applications and grants up to 1993–94**

Generic technology	*Applications processed No.*	*Grants approved No.*	*Success rate[a] %*
Biotechnology[b]	254	52	20.5
Manufacturing & materials technology	265	77	29.1
Information technology	264	44	16.7
Communications technology	79	29	36.7
Environmental technology	73	28	38.4
Total	**935**	**230**	**24.6**

a Ratio of approvals to applications processed.

b Applications processed includes 53 applications carried over from the former National Biotechnology Program.

Source: IR&D Board, *Annual Report* (various issues).

Support provided

Generic technology grants were targeted at collaborative projects that involved at least one commercial partner and at least one research organisation. Whereas DGS grants were awarded at a uniform rate of 50 per cent of project costs, there was a wide variation in the grant share of project expenditure for GTGS projects, both within and across technology areas (table E13).

There has been an ongoing theme in the IR&D Board's various Annual Reports that there was a need to strengthen the contribution of commercial collaborators to GTGS projects in order to improve their market orientation and commercialisation prospects (see IR&D Board 1991, p. 8). In this respect, the Environmental Technology Committee sought from its inception in 1990–91 to achieve a greater commercial focus by setting a grant limit of 50 per cent of total project costs, making grant payment through the *commercial* rather than the research collaborator, and requiring the commercial collaborator to manage the overall project (IR&D Board 1991, p. 79). However, no other Committee required this degree of commercial commitment — contributions by commercial collaborators of only 10 to 20 per cent of project costs were not uncommon (table E13).

Table E13: **Grant share of project costs, by technology field and year**

Generic technology	*86-87*	*87-88*	*88-89*	*89-90*	*90-91*	*91-92*	*92-93*
Biotechnology	36 to 95	14 to 86	22 to 42	10 to 61	35 to 92	70 to 83	52 to 75
Manufacturing & materials	30 to 89	26 to 70	46 to 87	41 to 79	50 to 84	26 to 80	53 to 78
Information	73 to 89	14 to 88	25 to 86	44 to 87	40 to 87	40 to 77	28 to 54
Communications	n.a.	36 to 78	33 to 90	50 to 85	49	43 to 80	31 to 54
Environmental	n.a.	n.a.	n.a.	n.a.	20 to 50	20 to 50	25 to 50

n.a. = not applicable.
Source: IR&D Board, *Annual Report* (various issues).

Another indication of the typically high support provided under the GTGS is given in table E14, where the value of grants awarded is classified by quartile, based on the grant as a percentage of project cost. Nearly one-third of the value of grant funds supported projects where the grant accounted for more than 75 per cent of project costs, and around 70 per cent of grant funds supported projects where the grant accounted for more than 50 per cent of project costs. The (weighted average) grant share of project costs across all projects was around 60 per cent. The Environmental technology grants stand in marked contrast to the rest, reflecting the express desire of the former Environmental Technology Committee to achieve a greater commitment by commercial partners.

Rate of subsidy provided

Under the GTGS, grant funds were normally provided to the *research* partner rather than the commercial partner. Because the grant could be seen as funding the research institution's contribution to the project, commercial partners were able to claim their contribution under the 150 per cent tax concession (provided they met the eligibility criteria) since no grant was received by the commercial partner for its expenditure (Birch 1993).

Table E14: **Share of value of grants awarded, by extent of support**

	Grant as a % of project cost				
Generic technology	*<25*	*25 - 50*	*51 - 74*	*75+*	
Biotechnology	8	27	36	29	100
Manufacturing & materials technology	0	24	57	20	100
Information technology	9	15	37	39	100
Communications technology	0	23	26	51	100
Environmental technology	1	99	0	0	100
All generic technologies	**4**	**27**	**38**	**31**	**100**

Source: IR&D Board, *Annual Report* (various issues).

Commercial partners involved in generic technology grant projects therefore enjoyed the twin benefits of the government funding of the research carried out by the research partner, from which they stood to gain; and eligibility of their own contribution to the project for the 150 per cent tax concession.

The subsidy provided by a GTGS grant can be approximated as:

$$S = \$[g + (1 - g)\, c\, t\,],$$

where g = government contribution; c = concessional rate of tax deduction (50 per cent); and t = company tax rate.

For example, assuming a grant of 60 per cent of total eligible project costs and that the funds were provided to the research partner, this was equivalent to the commercial partner receiving a nominal subsidy of around 67 cents in the dollar (for a 36 per cent company tax rate), that is $[0.6 + (0.4) (0.5) (0.36)].

But as a qualification to this calculation, it should be noted that *collaborative* projects are involved, such that:

> In most cases, ownership of any intellectual property was vested in the university, not the company, and the companies did not get exclusive rights to the technology (Sub. 363, p. 35).

By contrast, when a company undertakes an R&D project itself or contracts out the project to an external organisation, the results of the project are its own property. This sharing of benefits with collaborative projects is likely to be one factor contributing to the need for a higher incentive in order for companies to participate.

Features of GTGS grants and recipients

In most cases (apart from Environmental technology grants), GTGS grants were awarded to the research partner, not the commercial partner. Data on the value of GTGS grant agreements signed on an individual project basis are available up to 1992–93 in the various *Annual Reports* of the IR&D Board. The 213 grant agreements signed up to 1992-93 ranged in size from around $70 000 to $2.844 million, with an average of $580 000. Compared to the DGS, therefore, less than half the number of projects were supported under the GTGS, but the average value of the grant was more than double that of the DGS. The distribution of grants awarded, are classified in table E15 by size of grant.

Table E15: **Distribution of GTGS grants, by size of grant**

	Grants		*Funds*	
Size of grant $'000	*No.*	*%*	*$m*	*%*
less than 100	4	1.9	0.3	0.3
100 to 249	16	7.5	2.7	2.2
250 to 499	83	38.9	32.5	26.4
500 to 999	90	42.3	59.7	48.3
1000 or more	20	9.4	28.2	22.8
All grants	213	100.0	123.4	100.0

Source: IR&D Board, *Annual Report* (various issues).

Multiple grant involvement by commercial partners

The notion of multiple grant involvement by companies in the GTGS scheme is a little more complex than for the DGS in that under the GTGS there could be multiple commercial partners involved in a single project.

An analysis of the 213 GTGS grants signed up to 1992–93 revealed an involvement by 228 *different* commercial partners. Of these, 184 companies were involved in a single project. The remaining 44 companies were each involved in more than one project, either individually or jointly, and their overall involvement amounted to 148 projects. Therefore, of the total number of 332 company involvements in GTGS projects, 45 per cent were accounted for by companies with multiple involvements (that is, 148/332). Two companies in particular figured prominently — BHP, with an involvement in 22 grants (either as the sole commercial partner or as one of a group of partners) and ICI Operations Australia, with an involvement in ten.

Because of the multiple grant involvement by some companies, the distribution of funding was more highly concentrated on a *company* basis than on a grant basis (table E16). The top 11 per cent of commercial participants — or just 26 companies — were involved in projects accounting for nearly half of the $123 million in GTGS funds awarded over the seven-year period up to 1992-93.

Table E16: **Distribution of GTGS grants, aggregated by company**[a]

	Companies		*Funds*	
Size of grant $'000	*No.*	*%*	*$m*	*%*
less than 100	13	6	9	1
100 to 249	85	37	14	11
250 to 499	63	28	23	19
500 to 999	41	18	29	23
1000 or more	26	11	57	47
All grants	**228**	**100**	**123**	**100**

a In cases where there was involvement by more than one commercial partner in a project, each was assumed to share equally in the grant payment.
Source: IR&D Board, *Annual Report* (various issues).

Characteristics of recipients

There was a tendency for participants in the GTGS to be larger, profitable companies, rather than smaller, often start-up companies as under the DGS. Some comparisons of average characteristics, drawn from a survey undertaken by Invetech are presented in table E17.

Table E17: **Comparison of recipients between GTGS and DGS**

Average:	*GTGS recipients (n=55)*	*DGS recipients (n=220)*
Employment per firm	2807	50
Annual turnover per firm	686 746	8 807
Annual R&D expenditure	14 689	771
Annual exports	225 059	2 769

Source: IR&D Board, Sub. 219, p. 79.

Role in fostering collaboration between enterprises and research organisations

Types of links

In considering what collaborative links were generated between research institutions and industry as a result of generic grants, it is useful to distinguish projects on the basis of whether they involved one of the following three types of *research* partner arrangements (see IR&D Board 1988, pp. 20–1): one or more universities only; other research institutions only, and universities *and* at least one other research institution. A classification of projects on this basis is provided in table E18.

Table E18: **Proportion of grants by nature of research partner**

	Universities only %	*Other institutions only* %	*Joint Uni/Other* %	*Total* %
Biotechnology	40	50	10	100
Manufacturing & materials technology	22	43	35	100
Information technology	53	47	0	100
Communications technology	56	16	28	100
Environmental technology	26	57	17	100
All generic technologies	**37**	**44**	**19**	**100**

Source: IR&D Board, *Annual Report* (various issues).

Typically, grants involved collaboration with only one type of research partner — 37 per cent of projects involved a university as the only research partner, while 44 per cent involved other research institutions only. By far the most important among the latter was CSIRO, though some projects involved collaboration with non-profit medical research institutes, the Defence Science and Technology Organisation (DSTO) and private sector research organisations. Around 19 per cent of projects involved collaboration with both university *and* other research institution partners.

Collaborative links with universities were relatively important for projects in communications technology, while universities and other research institutions were of roughly equal importance for projects in biotechnology and information technology. Projects involving joint collaboration with universities and other research institutions were relatively important in manufacturing and materials technology, and communications technology.

Numbers of links

Around 70 per cent of GTGS grants involved collaboration between only one commercial partner and one research organisation partner (table E19). However, for two technology areas this pattern was not so typical — Manufacturing and materials technology, and Environmental technology. In those areas, roughly one-quarter of projects involved three or more commercial partners jointly collaborating with one or more research institutions.

Table E19: **Proportion of grants with single or multiple research and commercial partners**

	Number of commercial partners			*Number of research partners*		
	1	*2*	*3+*	*1*	*2*	*3+*
	%	*%*	*%*	*%*	*%*	*%*
Biotechnology	84	12	4	88	8	4
Manufacturing & materials technology	47	28	25	56	26	18
Information technology	86	7	7	93	7	0
Communications technology	80	8	12	60	24	16
Environmental technology	70	13	17	74	17	9
All generic technologies	**70**	**16**	**14**	**73**	**17**	**10**

Source: IR&D Board, *Annual Report* (various issues).

Multiple GTGS grant recipients

By comparison with the DGS, the GTGS had a higher proportion of companies with multiple grant involvement. What does this high proportion of multiple GTGS grant recipients indicate? One possible explanation might be that these companies were favoured by grant Committees because they had a better track record in undertaking R&D and commercialising its results.

A more persuasive argument might be that it reflects a relative lack of depth in the industry structure in these technology areas, with only a relatively small number of key commercial players (or what the IR&D Board has described as ‘receptors for research’ (IR&D Board 1992, p. 11). By ‘receptor’ is meant a firm which has the capability to benefit the most from the R&D infrastructure and from R&D results. Receptors are likely to be relatively large companies with appropriate in-house R&D expertise to enable them to tap into public sector R&D skills and advanced technologies. Large firms might also be better able to commercialise research outcomes, insofar as they have the resources and established market networks. On the other hand, some small companies with high level technical skills may also be able to utilise public sector R&D expertise. But because small firms might lack financial resources to commercialise R&D outcomes or marketing and distribution capabilities, strategic alliances are likely to be of vital importance to offset these weaknesses.

The IR&D Board thought the extent of involvement by BHP and ICI in generic grant projects noted above to be unsurprising, given their scale and diversity of research interests.

Effectiveness of collaborative links

The New Materials Technology Committee drew two main conclusions on the effectiveness of collaborative links, based on its experience in the first four years of operation of the scheme (see IR&D Board 1990, pp. 48ff):

- collaborative activity was an effective means of carrying out strategic R&D provided there was *strong project management* to ensure the maximum coordination and use of available resources and facilities;
- the most effective consortia were those in which there was *strong industrial leadership*.

The Price Waterhouse (1993) study of 15 GTGS projects examined whether the scheme had generated any attitudinal change on the part of companies and research institutions. The commercial partners surveyed reported that the scheme had resulted in only minimal to moderate impacts on their attitudes and behaviour in respect of R&D and technology, because they tended already to be strongly committed to R&D and had well-established R&D management structures. However, one area where a more significant impact was apparent was that the support had improved R&D linkages or networks with *other companies* — though it is unclear whether the networking extended only to those commercial partners jointly involved in the projects, or more widely to other companies. In the case of the research institution partners, the collaboration experience had led them to better appreciate the needs of commercial partners.

Commercialisation outcomes of GTGS projects

Trend to emphasis on commercial prospects of projects

The IR&D Board described two trends which it thought were developing in the GTGS in the first few years of its operation (1989, p. 11). First, there were indications of projects being science or technology driven:

- research partners, as the party with the dominant financial interest in the project, were tending to take the lead role in the preparation of applications, and in the management of projects; and
- researchers were tending to formulate projects and then seeking out companies to collaborate with them.

Second, there was a lack of market driven focus and commercialisation prospects:

- it was only infrequently that commercial enterprises or consortia selected a project, and went looking for a researcher to undertake it; and
- it was apparent that many commercial partners would have extreme difficulty in effectively commercialising the results, given the nature of the technology and the realities of the market.

Participants to the Inquiry expressed similar views. According to Runes Business Services Pty Ltd, two features of the early operation of the scheme contributed to a lack of commercial success.

> Firstly, in the initial years, the contribution by the commercial party was very small, 10 per cent, and much of it in kind — there was no hurt money. Secondly, the tertiary institution managed the funds and even though they were not the project manager, unfortunately those that control the money control the research. As well, tertiary personnel had relatively few commercial skills. Further, there was a significant culture difference leading to misunderstandings and lack of commitment to commercialisation (Sub. 66, p. 8).

The Australian Photonics Cooperative Research Centre, which is currently associated with five GTGS grants, thought that the GTGS guidelines could be altered to enhance the effectiveness of GTGS projects conducted in CRCs.

> The [GTGS] program is now focused on prototype product development projects. However, the commitment of industry ... is not strong enough, because hands-on involvement is generally through participation in quarterly management meetings. ... The [GTGS] guidelines [should] be modified to encourage industry hands-on management, ... while recognising that Principal Investigators [from universities] may continue to provide leadership in the research elements of the [project] (Sub. 168, p. 5).

To enhance the market orientation and commercialisation prospects of grant applicants, the Board issued guidelines to the Committees which in particular placed a greater emphasis on commercial criteria for assessing the merits of applications (see IR&D Board 1989, p. 12). Such guidelines included:

- a need to focus more strongly on priority areas within strategic technologies which have market potential, strong local research capability, and are likely to have significant economic benefits for Australia;

- a need to facilitate the development of technology packages, and for companies to learn to trade in technology (Intellectual Property Agreements);
- a view that a project should not be supported unless realistic commercial opportunities are likely to arise from it; and
- a need for Committees to be more conscious of the importance of an adequate infrastructure if research outcomes are to be commercialised.

Degree of commercial success of GTGS projects

Several studies commissioned by the IR&D Board provide information on the commercialisation record of supported projects. For example, the Price Waterhouse (1993) review of 15 GTGS projects found ‘limited commercial success to date’ — commercially applicable outcomes had been achieved in only seven of the fifteen projects (PW 1993, p. 81–2). But the apparent lack of commercial outcomes reflected the fact that the majority of the projects reviewed were still in their developmental stage. This in turn reflected both the long-term nature of the commercialisation required in many cases and the relatively short time that had elapsed since R&D commenced. Given that 12 of the 15 projects were continuing beyond the grant period, there was an expectation in a number of cases of significant future commercial benefits.

Information on the time scale of commercialisation envisaged by GTGS grant recipients was obtained from a survey of grant recipients by Deloitte Touche Tohmatsu (1993). The length of time before recipients expected to achieve their first commercial sales at the time the grant commenced is presented in table E20.

Table E20: **Timescale for commercialisation of GTGS projects**

Time period	*No. of projects*	*% of projects*
Less than 3 years	14	22.2
3 to 5 years	37	58.7
6 to 9 years	11	17.5
10 years or more	1	1.6
Total	63	100.0

Source: Deloitte Touche Tohmatsu, 1993, table 9.

GTGS grants were awarded for projects expected to be completed within three years. However, only around 20 per cent of grant recipients expected a commercial outcome within that period. The time frame to commercialisation was typically up to five years and not uncommonly between six and nine years. It is not surprising, therefore, that GTGS projects have had only limited commercial success to date.

Role in supporting research of fundamental significance for industry competitiveness

In considering the extent to which the scheme met this objective, a preliminary consideration is whether, in principle, there is a need for support to be targeted at particular technology areas. As noted above, since the introduction of the GTGS in 1986, five areas have been declared as generic technologies.

The rationale for the GTGS was set out in the Second Reading Speech on the Industry Research and Development Act:

> New or emerging technologies with the potential to significantly influence industrial development in the 1990s are unlikely to be fully developed if left to the market alone. The market oriented tax concession would therefore not assist research and development in these areas. Risk is high, the development time frame is often very long and sufficient appropriation of the benefits by the researcher is often not possible. Even with the 150 per cent tax concession it is doubtful whether firms will be able to adequately diversify the risk involved for optimal investment from a community viewpoint. An element of 'technology push' is needed to provide the fundamental support.
>
> Yet these technologies have application over a range of industries and can strengthen or extend existing comparative advantages. They can be directed at the creation of new markets through the development of new products; and they can revitalise existing industry, increasing its productivity through new and improved process technology (Senate Hansard 8 May 1986, p. 2582).

A characteristic of generic technologies is that they have applications in numerous industries. As the Information Technology Committee noted in discussing how it assessed the relative merit of R&D projects, one key criterion was whether the proposed research was 'generic':

> ... in practice this comes down to determining whether the results of the research are likely to provide the building blocks for new advances across a fairly broad spectrum (IR&D Board 1991, p. 10).

This criterion is more likely to be satisfied if research projects embody 'early-stage' or 'pre-competitive' research rather than product-oriented research. Against this background, it is instructive to examine the broad types of R&D projects that were actually supported under the GTGS.

In section D1.1 of this report it was noted that business enterprise R&D as a whole is mainly 'D' rather than 'R'. By contrast, GTGS projects gave greater emphasis to 'R' rather than 'D' (table E21). Respondents to a survey of GTGS commercial partners considered that only around 10 per cent of projects were mainly experimental development, while nearly 90 per cent involved research, mainly of an applied nature. Nearly all projects were expected to result in outcomes with commercial potential either during the research program or subsequently — in around 90 per cent of cases, a new or improved manufacturing product or process, or technology to licence, was expected to result from the research.

Table E21: **Nature of R&D involved in GTGS projects**[a]

Nature of research [b]	*No. of projects*	*%*
Strategic research	12	18.2
Applied research	45	68.2
Experimental development	7	10.6
Strategic + applied	1	1.5
Applied + experimental development	1	1.5

a Information provided on 63 projects. Some respondents indicated more than one type of research.
b The nature of the research was defined for survey respondents as follows: Strategic research — general research aimed, for example, at creating opportunities for more specific, commercial R&D projects; Applied research — research for a specific commercial product or process application; Experimental development — development aimed at translating an existing research result into a marketable product or process.
Source: Deloitte Touche Tohmatsu, 1993, table 8.

Private returns expected for supported projects

To gain some idea of the commercial returns likely from the generic projects supported, the IR&D Board commissioned two studies which sought to estimate commercial returns using net present value techniques. But because only a small proportion of projects examined had reached the early marketing stage of commercialisation, the net present value estimates were necessarily based on *projected* rather than realised returns. Accordingly, the methodology used took account of two types of uncertainty surrounding these estimates of expected returns — the remaining pre-launch technical risk for projects that had not been completed as well as market uncertainty following product launch for projects that had not been commercialised.

The first study (by Sultech 1993) assessed the likely commercial returns to all 40 projects supported up to that time in the Manufacturing and materials technology (MMT) area of the GTGS, together with 23 projects from other Board grant programs. Of the latter, 14 were from the other generic technology areas, while 4 were NPDP projects and 5 were DGS projects. Benefit-cost ratios were calculated across the portfolio of projects as the ratio of the (risk-adjusted) expected net present value to total pre-launch investment costs. The total pre-launch costs comprised both the Board's and company's contribution to R&D costs, together with the company's investment in additional funds during the pre-launch period.

Commercial returns were expected for 46 of the 63 projects, in that market introduction had been achieved or was still planned. The expected net present value of these 46 projects was estimated to range from $563 million (85 per cent probability, 10 per cent discount rate) to $1221 million (50 per cent probability, 5 per cent discount rate). With a total pre-launch expenditure of $137 million (including R&D costs of $69 million), this implies a benefit-cost ratio in the range of 4.1:1 to 8.9:1. In terms of total R&D outlays (grant moneys plus company funds), the benefit-cost ratio ranged from 8:1 at the higher discount rate of 10 per cent to 17:1 at the 5 per cent discount rate.

A feature of the results is that a small number of 'big winner' projects appear to dominate the overall outcomes — just six of the 46 projects contributed 50 per cent of the total expected net present returns. But as Sultech (1993) notes:

> This extent of concentration implies a level of vulnerability of the overall portfolio returns to the fate of the largest projected return projects. However, this vulnerability is not excessive, particularly when it is noted that the projected returns for the high return projects are all based on formal business plans (p. 54).

The second study was undertaken by Deloitte Touche Tohmatsu (1993, hereafter DTT). That study attempted to have a broader scope than Sultech by surveying all recipients of GTGS grants since the inception of the program. Of the 141 companies surveyed, 82 questionnaires were returned and 63 of these provided sufficient information for net present value and benefit-cost calculations to be made. Therefore, despite the aim for greater coverage, the DTT study was identical to the Sultech study in terms of number of projects — though it had a better representation of projects across all five generic technology areas.

The DTT study followed closely the methodology used by Sultech. However, the cost measure in their benefit-cost ratios was defined as the pre-launch costs *minus* the value of the Generic Technology grant. Hence, the DTT results are not directly comparable with Sultech's, and will be biased upward because of the use of a smaller cost measure.

Across all 63 grants, DTT found a benefit-cost ratio in risk-adjusted terms ranging from 4.3:1 (10 per cent discount rate) to 6.4:1 (5 per cent discount rate). While these estimates are quite similar to those of Sultech (a range of 4.1:1 to 8.9:1), they would be somewhat lower if the same cost concept had been used.

The DTT findings revealed substantial variability in net present values and benefit-cost ratios *between* technology areas, and also across projects *within* technology areas. Some estimates (based on the 5 per cent discount rate scenario) are reported in table E22. The average net present values and benefit-cost ratios are substantially larger in two of the technology areas — Biotechnology and Manufacturing and materials technology. However, in four of the five technology areas, the average values of NPV and benefit-cost ratio are heavily influenced by a single very successful project. With that project removed from consideration, the benefit-cost ratios are virtually halved compared to those reported in table E22.

Table E22: **Estimates of expected net present values and benefit-cost ratios of GTGS projects**

		Net present value ($'000) (5% discount rate)		*Benefit-cost ratio*	
Technology area	*Projects*	*Average*	*Range*	*Average*	*Range*
Biotechnology	17	$128 823	$1 644 to $1 028 941	17.0	0.7 to 84.5
Manufacturing and materials technology	10	$66 676	$208 to $251 254	17.7	-3.0 to 88.5
Communications technology	8	$6 213	$266 to $20 146	6.4	-4.2 to 31.2
Environment technology	11	$2 237	$0 to $5 438	1.5	0 to 4.8
Information technology	17	$2 862	-$657 to $12 288	2.5	-2.2 to 19.9

Source: Deloitte Touche Tohmatsu 1993, p. 16.

A very small number of 'big winner' projects dominate the overall outcomes even more so than in the Sultech study — just 3 of the 63 projects (comprising two in Biotechnology and one in Manufacturing and materials technology) accounted for 55 per cent of the overall benefits.

Another consultancy (Invetech) commissioned by the IR&D Board reported statistics on revenues actually generated in 1992–93 by GTGS projects (table E23). This reveals that the revenue generated by these projects in the single year 1992–93 was only a fraction of the value of the grants. These low returns to GTGS projects reflects the limited commercialisation of such projects to date.

Table E23: **Actual outcomes of GTGS supported projects, 1992–93**[a]

No. of companies	37
Total value of grants up to 1991-92 ($)	18 449 185
Average grant ($)	498 627
Total revenue from grant projects in 1992-93 ($)	2 450 000
Average revenue ($)	66 216

a The figures reported relate to projects that would not have proceeded without a grant.
Source: IR&D Board, Sub. 219, p. 88.

Implications of data on expected private returns

Two features of these results are a source of some concern — the fact that not all projects that received grants were necessarily induced by the scheme, and the extreme concentration of the bulk of expected commercial returns among very few projects. If the very small number of projects with substantial private returns probably would have been carried out anyway, then there must be doubts about whether the great bulk of the estimated private benefits is actually attributable to the scheme.

Further, as noted above in relation to the DGS, demonstrating that private returns accrue to companies that receive grant support is not an appropriate indicator of the effectiveness of a program. Rather, economy-wide (social) benefits need to be demonstrated *beyond the private returns to the recipient firms* to justify the government support provided to the R&D projects. This is taken up in the following section.

Cost effectiveness and efficiency

As with the DGS, the broad question of whether or not the GTGS was worth having can be examined in terms of whether the scheme was likely to generate a net social benefit for Australia. Using the same framework as was applied to the DGS, on the benefits side the key elements for consideration are:

- the extent to which the program induced *additional* R&D — that is, R&D which would not have been carried out in the absence of the program;
- the benefits to the wider community (spillovers) generated by the *induced* R&D.

On the costs side, the key elements are:

- costs of administering the scheme;

- the resource cost associated with the efficiency losses arising from having to raise a higher level of taxes to finance the program — the marginal excess burden of taxation (MEB) times the program and administration costs; and
- compliance and other costs incurred by applicants.

However, as with the DGS, instead of estimating the net social benefit (which would require particular values for the spillover return), the spillover return that would be needed for the scheme to break even in a welfare sense — such that the social benefits would be at least as great as the social costs — is calculated. The elements needed for this calculation are described in what follows.

Data required for the social benefit-cost assessment

Additional R&D induced

Estimates of the proportion of GTGS projects that may not have proceeded without grant support are provided in a study undertaken by Invetech. That study surveyed the commercial partners in all GTGS grants awarded to that time. Of the 54 respondents, 37 (or 69 per cent) indicated that they would *not* have proceeded with the project without the grant support.

This survey response on the proportion of projects induced by the scheme is somewhat higher than that for the DGS. This is consistent with differences in the nature of projects supported in the two schemes. With the GTGS, more early-stage (pre-competitive) R&D projects were supported, for which there was more uncertainty about achieving commercial outcomes and, in principle, a greater likelihood of benefits spilling beyond the innovating firm. By contrast, DGS support was provided to projects which were closer to the market.

Allowing for some strategic response on the part of survey respondents, given that the scheme had the same requirement as the DGS for funding only where the project would not have proceeded 'satisfactorily', the inducement ratio of 69 per cent found by Invetech is likely to overstate the real responsiveness to the grant. In estimating the cost effectiveness of the scheme, an inducement ratio of 70 per cent is assumed in one scenario, while a value of 50 per cent is used in an alternative scenario.

In the absence of information on what proportion of R&D *expenditure* was induced by the scheme, these inducement ratios in terms of *projects* are assumed to apply.

Program costs

In 1992–93, the value of GTGS payments amounted to around $20.9 million. The program cost of the GTGS has an additional component because the commercial partners’ contribution to projects was eligible for the 150 per cent R&D tax concession. As noted above, the grant share of project costs for the GTGS averaged around 60 per cent — it is assumed that the average commercial partner contribution to projects was therefore around 40 per cent. In calculating that element of the cost to revenue, an average subsidy of 18 cents in the dollar is assumed for the commercial partner contribution, equivalent to the nominal subsidy provided by the tax concession with a company tax rate of 36 per cent.

Administrative costs attributable to the GTGS can be assumed to have been around the same as the DGS (around $2 million per year). Again, however, it should be noted that this is likely to be an underestimate, because data on other administrative overheads were not available — including the costs of the Board itself in relation to the grant programs and the costs associated with the grant Committees.

Compliance costs

While program costs under the GTGS over the eight-year period 1986–87 to 1993–94 were virtually identical to the DGS, the number of projects supported was only approximately half that of the DGS — that is,. the average grant under the GTGS was around double that under the DGS. However, because of the collaborative nature of GTGS projects, involving both commercial and research institution partners, the overall compliance costs of applicants for the GTGS are assumed here to be of a similar order of magnitude to the DGS. As with the DGS, no allowance is made for rent-seeking costs.

Overall social costs

As noted in section E.1, the cost to revenue associated with a grant program such as the GTGS is not in itself a social cost — while the grants are ultimately paid for by taxing other entities, they essentially represent a transfer of funds from one group in the economy to another.

However, the administration costs are not a transfer and hence represent a resource cost that would not arise in the absence of the program.

But there is also a social cost associated with having to raise tax revenue to fund the program. As with the evaluation of the DGS, a value of $0.33 is assumed.

Hence, the social costs are calculated as the sum of the resource costs associated with financing the scheme, the administration costs, and the compliance costs incurred by applicants.

Results of alternative scenarios

On the basis of these assumptions, the social costs of the GTGS are estimated for a typical year in table E24. The scenarios presented are:

- scenario 1 — assumes an inducement ratio for R&D of 50 per cent, and a marginal excess burden of taxation of 33 cents per dollar of tax revenue raised;
- scenario 2 — assumes an inducement ratio for R&D of 70 per cent, and a marginal excess burden of taxation of 33 cents per dollar.

Under the second scenario, spillover returns of around 47 per cent would be needed for the GTGS to break even, while under the first scenario, spillover returns of around 65 per cent would be required.

From a cost-effectiveness viewpoint, perhaps the main problem with the GTGS was the typically high grant share of project costs. It appears that some of the Committees regarded levels of support as high as 70 to 90 per cent of project cost as being required to enable the projects to proceed. Such high levels of support might have been warranted if the supported projects could be demonstrated to generate very much higher than average social benefits. However, it is not clear that the rate of support provided to particular GTGS projects varied mainly on that basis.

To ensure an adequate commitment to collaborative projects by the commercial partner, it is usually argued that there should be some minimum contribution (‘hurt money’) — not less than 50 per cent. Under the Competitive Grants scheme now, the maximum grant available is 50 per cent of eligible project costs. Hence, commercial partners will now, on average, make a greater contribution to collaborative projects than they would have in the past. If a grant rate of 50 per cent of project costs is assumed in the scenarios, the required spillover return to break even would fall to between 39 and 55 per cent.

Table E24: **Spillover return required by the GTGS to break even**

		Scenario 1	*Scenario 2*
[1]	Grant payments ($m) 1992-93	20.90	20.90
[2]	Grant rate (%)	0.60	0.60
[3]	Project R&D ($m) ([1]/[2])	34.83	34.83
[4]	Inducement ratio	0.50	0.70
[5]	Induced R&D ($m) ([3]*[4])	17.42	24.38
[6]	Grant payments ($m)	20.90	20.90
[7]	Administration costs ($m)	2.00	2.00
[8]	Commercial partner share of project (%)	0.40	0.40
[9]	R&D eligible for tax concession ($) ([3]*[8])	13.93	13.93
[10]	Tax revenue forgone ($m)	2.51	2.51
[11]	Program costs ($m) ([1]+[7]+[10])	25.41	25.41
[12]	Marginal cost of funds (33 cents/$)	0.33	0.33
[13]	Social cost of funds ($m) ([11]*[12])	8.38	8.38
[14]	Compliance costs ($m)	1.00	1.00
[15]	Social costs ($m) ([7]+13]+[14])	11.38	11.38
	Required spillover return (%) ([15]/[5])	65	47
	Ratio of induced R&D to social cost ([5]/[15])	1.53	2.14

Source: IC estimates.

Like the DGS, these results are highly sensitive to changes in assumptions. For example:

- if the cost of public funds were to be 50 cents in the dollar, the required spillover return to break even would range from 90 per cent in the first scenario to 64 per cent in the second scenario. If, on the other hand, they were 15 cents in the dollar, the range would need to be only 39 per cent to 28 per cent.
- if administration costs were to be doubled, and the cost of public funds were to be 33 cents in the dollar, the required spillover return would range from 81 per cent to 58 per cent.

E.3 Automatic R&D support for tax loss companies

The Commission is proposing to broaden the support for R&D for companies in tax loss. The approach proposed is to introduce an across-the-board, non-taxable grant at a rate equal to the nominal value of a tax deduction of 50 per cent of R&D expenditure (18 per cent for a 36 per cent company tax rate).

Introduction

Companies can benefit immediately from the 150 per cent R&D tax concession if they are earning sufficient taxable income against which to offset the deduction. Companies in tax loss receive a lower benefit because they experience a delay before they can realise the tax saving — until they earn sufficient taxable profits. There are currently two programs in place which aim to offset this disadvantage for tax loss companies:

- syndication — which allows companies with accumulated tax losses to trade those losses for R&D funds; and
- selective grants —which are awarded to companies on the basis of a discretionary, merit-based selection process under the Competitive Grants scheme.

The proposal will affect the following groups of tax loss companies:

- those that register for the concession, but experience a delay in actually claiming it (this group is assumed to include companies that apply for an R&D grant but are unsuccessful);
- those that receive an R&D grant (under the Competitive Grants scheme); and
- those that neither register for the concession (because they are in tax loss) nor receive a grant.

A complication is that these groupings might not be entirely mutually exclusive. For example, the BIE 1993 survey of tax concession registrants revealed that 4 per cent of respondent registrants were in receipt of a discretionary grant (1993c). Similarly, while discretionary grants are also open to organisations whose corporate structure renders them ineligible for the tax concession, it might be assumed that most unsuccessful applicants for grants who proceeded with their R&D projects registered for the tax concession — though some may fall in the third group of companies. Nevertheless, since any overlaps between groupings are likely to be small, the assumption that the groupings are mutually exclusive is made here to simplify the analysis.

To assess the impact of providing automatic R&D support for tax loss companies, attention focuses on the likely impact on the level of R&D undertaken, and the cost effectiveness of the suggested changes in comparison with the current arrangements.

Reactions to the proposal

In response to the Commission's proposal, the IR&D Board argued that:

> The reality of the proposal for automatic grants is that the majority of smaller, developing firms in Australia will drastically reduce their R&D investment (Sub. 363, p. 42).

Similarly, the Fallon Group was critical of the proposal in respect of quantum and timing impacts:

> Reduction of the cash payment from 50 cents to 16.5 cents per dollar [for a 33 per cent company tax rate] would clearly not have the equivalent encouragement effect on new R&D projects, even after allowing for the reduced compliance cost of the rebate scheme.
>
> The timing issue would have at least an equivalent damping effect. A cash refund up to 12 months or more in the future is not likely to be an effective incentive for a company struggling to find funds today (Sub. 312, p. 3).

But comments like these seem to be implying that all tax loss companies currently receive discretionary grants. The reality is that the overwhelming majority of tax loss companies receive little if any grant support under the current arrangements.

As noted in section E.1, prior to the combining of the various IR&D Board grant schemes into a single scheme in May 1994, around 60 companies in tax loss received grant support each year, based on a competitive, merit-based selection process. On average, around 40 per cent of applicants were successful in obtaining grants — hence, the majority of applicants did *not* receive grants. But in addition to these unsuccessful applicants, many times this number of tax loss companies didn't bother to seek grant support (some of the possible reasons are canvassed in section E.1). In the seven-year period up to 1993, 73 companies received half the funds awarded under the former Discretionary Grants scheme, whereas 334 companies shared the other half, and 670 applicants received nothing.

As well as allowing registrants for the tax concession in tax loss to bring forward the realisation of the tax saving in respect of 18 per cent of their R&D expenditure, the Commission's approach would also mean providing some support to other tax loss companies who currently do not get a grant — (eligible) non-applicants for the tax concession.

Hence, the IR&D Board's statement (above) that the majority of small, tax loss companies will drastically reduce their R&D investment would *not* appear to be consistent with these facts. There is the potential for the much larger number of non-recipients of discretionary grants to perform *more* R&D in response to moving from a situation of no support to a non-taxable grant of 18 per cent.

This view was endorsed by the Australian Electrical and Electronic Manufacturers' Association (AEEMA):

> Because it would be available to all companies, [a generally available scheme] is more likely to induce more R&D than the highly selective scheme which currently operates (Sub. 460, p. 5).

To test these views, the likely effect of the Commission's proposal is compared with outcomes under the current arrangements. The estimation of the likely effect of the Commission's proposal necessarily involves uncertainty, but the calculations undertaken do reflect available empirical estimates of the key parameters.

Degree of support provided to R&D by different instruments

The Commission's proposal of a non-taxable grant to *all* tax loss companies at a rate of 18 cents in the dollar would provide a lower degree of support than that currently enjoyed by those (relatively few) successful grant recipients — who receive a taxable grant at a rate of 50 per cent of project costs. To give context to what the benefit from the Commission's proposed automatic grant should provide for tax loss companies, some comparisons with the existing tax concession and selective grants are provided in table E25.

Under the current tax concession, with a 36 per cent company tax rate, the 'normal' 100 per cent deductibility element of the 150 per cent tax deduction reduces the after-tax cost by 36 cents (from $1.00 to $0.64) while the 50 per cent 'concessional' component reduces the after-tax cost by a further 18 cents (to 46 cents in the dollar). In other words, the full 150 per cent deduction reduces the after tax cost by 54 cents in the dollar.

Companies in tax loss receive no immediate benefit from the tax concession, and the value of the tax deduction declines the longer the period before the company earns sufficient taxable income — if the company moves into tax profit six years after carrying out the R&D, the value of the tax deduction is reduced from 54 cents to around 31 cents in the dollar (assuming a nominal discount rate of 10 per cent).

Table E25: **Reduction in after-tax cost per dollar of R&D (compared to no deductibility) resulting from different instruments**

Support instrument	*Immediate benefit (¢/$)*	*Additional benefit if claim concession after*			*Overall benefit if claim concession after*		
		2 years (¢/$)	*4 years (¢/$)*	*6 years (¢/$)*	*2 years (¢/$)*	*4 years (¢/$)*	*6 years (¢/$)*
Tax profit companies							
‘Normal’ 100 per cent deductibility	36.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
‘Concessional’ 50 per cent deductibility	18.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tax loss companies							
150 per cent tax concession[a]	nil	44.6	36.9	30.5	44.6	36.9	30.5
Automatic 18 per cent non-taxable grant plus 100 per cent tax deduction[b]	18.0	29.8	24.6	20.3	47.8	42.6	38.3
Selective 50 per cent taxable grant plus deductions under ‘contamination’ provisions[c]	50.0	14.9	12.3	10.2	64.9	62.3	60.2

a Where companies experience a delay in claiming the concession for the R&D expenditure incurred, the value of the tax deductions are discounted at a 10 per cent nominal interest rate per year.
b The Commission’s proposal involves revised contamination provisions for the tax concession. The contamination provisions define the extent to which companies claiming the tax concession who received a grant in respect of R&D expenditure, have the benefit of the grant clawed back or offset. Under the Commission’s proposal, companies receiving an automatic non-taxable grant of 18 per cent would be entitled to claim the tax deduction equivalent of 100 per cent of their R&D expenditure at 100 per cent deductibility when they move into tax profit. The value of these tax deductions are discounted at a 10 per cent nominal interest rate per year.
c These calculations apply the existing contamination provisions of the tax concession. For a taxable grant, the amount of expenditure to which clawback applies (ie. which is eligible for deduction at 100 per cent rather than 150 per cent) is equal to twice the amount of the grant. Hence, for a grant rate of 50 per cent of project costs, this means that the whole of the project expenditure is deductible at 100 per cent and *none* is deductible at 150 per cent. The value of these tax deductions, as well as tax payable on the grant, are discounted at a 10 per cent nominal interest rate per year.
Source: IC estimates.

Providing an across-the-board 18 per cent non-taxable grant gives an immediate benefit to tax loss companies — similar in value to the ‘concessional’ element of the deduction for a tax profit company. However, the subsequent tax deductions (for the 100 per cent component of the tax concession) decline in value as the delay in moving into tax profit lengthens.

The 50 per cent taxable grant provides substantial up-front support, and the additional deductions allowed under the contamination provisions of the tax concession mean that the grant reduces the after tax cost by more than 60 cents in the dollar.

An advantage of the current selective 50 per cent taxable grant is its up-front nature. The Commission has also suggested that there would be benefits for recipients if the payment of the automatic grant could be conducted in a similar way — that would depend on whether it is administratively and practically feasible to do so.

Cost effectiveness and efficiency

As with the DGS and the GTGS, the broad question of whether or not the automatic grant is worth having can be examined in terms of whether the scheme is likely to generate a net social benefit for Australia. Using the same framework as applied previously, on the benefits side the key elements for consideration are:

- the extent to which the program induces *additional* R&D — ie. R&D which would not have been carried out in the absence of the program;
- the benefits to the wider community (spillovers) generated by the *induced* R&D.

On the costs side, the key elements are:

- costs of administering the scheme;
- the resource cost associated with the efficiency losses arising from having to raise a higher level of taxes to finance the program — the marginal excess burden of taxation (MEB) times the program and administration costs; and
- compliance and other costs incurred by applicants.

Rather than seek to estimate the net social benefit (which would require particular values for the spillover return to be assumed), the spillover return that would be needed for the scheme to break even in a welfare sense — such that the social benefits would be at least as great as the social costs — is calculated. The elements needed for this calculation are described in what follows.

Data required for the social benefit-cost assessment

Induced R&D among non-recipients of grants

For companies which do not currently receive a grant, the net value of introducing an automatic non-taxable grant of 18 cents in the dollar is to bring forward their claim for 50 per cent of expenditure on R&D. That is, instead of claiming 50 per cent of their total R&D expenditure in the future year in which they turn profitable, they claim it in the year of expenditure. If the grant is paid up front, they receive an additional benefit because they receive assistance as expenditure is made.

For these companies, the automatic grant is an additional inducement to undertake more R&D than their current level.

The largest group of companies in this category are the registrants for the R&D tax concession which are in tax loss. Their characteristics are that they are eligible for the 150 per cent deduction, cannot claim it now, but will claim it in due course.

In addition, however, non-registrants for the tax concession are, in effect, in the same position. Because claims for R&D may be made retrospectively, they can also expect to claim the 150 per cent deduction as they move into tax profit.

The base level of R&D from which inducement is measured therefore is the sum of the R&D currently performed by registrants and non-registrants for the 150 per cent tax deduction who are in tax loss and do not receive grants.

Generally, around one-third of companies that register for the tax concession are in tax loss (BIE 1993c). Concessional R&D expenditure of around $2 billion was carried out by companies registered for the concession in the most recent year available (1991–92) (IR&D Board 1994d). In that year, overall private sector BERD was around $2.1 billion, so that around 95 per cent was eligible for the concession. Therefore, applying this ratio to the most recent estimate of private sector BERD available (1992–93) of around $2.5 billion gives an estimate of concessional R&D expenditure in that year of around $2.4 billion. Hence, it is assumed that registrants for the tax concession who were in tax loss performed around $800 million of R&D in 1992–93.

In addition, an estimate is required of how much R&D was being carried out by tax loss companies that neither registered for the concession nor received a grant. In this respect, a survey of non-claimants undertaken for the BIE evaluation (1993c) revealed at that time around 150 eligible companies that neither registered for nor claimed the concession because they were in tax loss. Such companies were undertaking annual R&D totalling around $40 million in 1990–91.

However, as pointed out by the Fallon Group, this is likely to understate the amount of R&D in this group for two reasons: first, it was based on survey findings for which there was less than a complete response rate (53 per cent); and second:

> it is our experience . . . that the creation of a cash benefit program will generate an exploitation industry, and a growth in claims, in its own right (Sub. 312, p. 2).

Because some non-respondents were probably non-R&D performers, the incomplete response rate is taken into account by adjusting upwards the estimate of R&D carried out by respondents by 50 per cent (that is, to around $60 million). The second influence — that R&D would come 'out of the woodwork' in response to a cash grant — would be reflected in overall expenditure above that amount. Because of the uncertainty associated with these estimates, the R&D performed by tax loss companies which neither applied for grants nor registered for the concession might lie between $60 million and $100 million — here a mid-range estimate of $80 million is assumed for 1992–93.

To these estimates of R&D is applied an inducement rate. The rate of inducement is given by that determined by the BIE for the tax deduction, since both are automatic schemes. The BIE survey found that *without* the extra 50 per cent concessional deduction, companies in tax profit would on average carry out 10 to 17 per cent less R&D than they currently do — or, compared to the level of R&D that would have been carried out in the absence of the concession, an additional 11 to 20 per cent of R&D was induced.

Subsidy provided by the automatic grant

These inducement rates are scaled for the magnitude of the subsidy provided under the automatic grant relative to the tax concession. Those subsidy rates are calculated as follows.

The net cost to revenue per dollar of R&D of providing an across the board grant to tax loss companies is given by:

$$c = [\$1(1 + i)] - [\$1 / (1 + i)^{r}]$$

where i = nominal discount rate, and r = number of years before profitability.

That is, it is the difference between the cost of providing the equivalent of the 50 per cent tax deduction *now* (if the grant is provided up-front, each dollar is actually worth [$1(1 + i)] relative to the tax saving received by recipients of the tax concession), and the cost of the delayed tax deduction that companies would have received if they claimed the concession when they earned sufficient taxable profits. For this calculation, the future discounted values (assuming a nominal discount rate of 10 per cent) are weighted on the basis of the distribution of realisation lags experienced by tax loss registrants, drawn from the BIE survey (1993c).

The resultant average estimates of the subsidy provided by the 18 cents in the dollar grant are 7.4 cents in the dollar if the grant is paid up-front, and 5.6 cents in the dollar if it is paid at the end of the income year during which R&D was undertaken.

Hence, using these estimates to scale the range on the BIE inducement rates of 10 to 20 per cent results in inducement rates of 4 to 8 per cent if the grant is paid up-front, and 3 to 6 per cent if paid at the end of the income year.

Administrative costs under the automatic grant

Administrative costs under the automatic grant would be much lower than in the case of the former DGS. Companies incur little additional cost in registering their R&D, because they would in any case register to claim the concessional element of the tax deduction — if not now, at some time in the future.

Some additional bureaucracy would be needed to pay the grant as a cash amount, but because it is automatic for companies which have registered their R&D, this would be at relatively low cost. It would not involve complicated assessment procedures.

The estimate for administrative costs used here is based on scaling the costs used for the evaluation of the tax concession (BIE 1993c). Assuming that tax loss companies comprise one third of all tax concession registrants, this gives an administrative cost of about $0.5 million. As in the case of the DGS, this estimate does not include on-costs, and should be considered in the light of sensitivity analysis.

Compliance costs under the automatic grant

Again, compliance costs for an automatic program would be low because it does not involve discretion. There is no need to prepare submissions, other than the documentation that would in any case be required to have the R&D registered. An application would, however, be required to receive the grant.

Because companies in tax loss that currently register for the concession are already incurring the compliance costs, the only additional compliance costs to be considered are those incurred by companies in tax loss that do not bother to register, and companies that would otherwise receive selective grants. On the basis of an estimate for the last two groups of around 250 companies, and assuming that expenditure of around $2 000 each might be needed, this results in a total compliance cost estimate of around $0.5 million.

Induced R&D among selective grant recipients

As noted in section E.1, the value of grant payments under the former Discretionary Grants Scheme was $16.4 million in 1993–94. With a grant payment of 50 per cent of project costs, the overall R&D undertaken by grant recipients was therefore around $32.8 million.

The proportion of this which was induced by the grant is given by the inducement rate. In section E.1 several inducement rates were discussed, ranging from 35 per cent to 55 per cent. Applying these rates gives a base of R&D which would be performed in the absence of any support. This falls in the range of around $15 to $20 million. Here, the level corresponding to the lower inducement value is used ($20 million).

To obtain the R&D induced by the 18 cents in the dollar automatic grant, the same inducement rates estimated above for registrants in tax loss and non-registrants are used.

Estimated cost to revenue

The cost to revenue of the automatic grant in the case of non-recipients of DGS grants is calculated as the cost of bringing forward the deduction on the estimated base level R&D in 1992–93 multiplied by the amount of R&D.

In the case of grant recipients, there is a similar cost to revenue in respect of the base amount of R&D and the amount of R&D induced. The net cost to the government of substituting the automatic grant for the DGS is of the order of $50 million, allowing for the saving of the cost of the DGS.

Results of alternative scenarios

The key results when the grant is paid up-front are set out in Table E26.

The required spillover returns for the automatic grant are 65 per cent with a low inducement, and 34 per cent if the inducement is high. Thus, the automatic grant is in the same broad band of results as the tax concession, and also the DGS.

Again, the results are sensitive to changes in parameters. For example, if the cost of public funds were to be 50 cents in the dollar, the required spillover return for break-even would range from 97 per cent in the first scenario to 50 per cent in the second scenario. If, on the other hand, they were 15 cents in the dollar, the range would need to be only 31 per cent to 16 per cent.

Assuming that administration costs were doubled to include on-costs, the required spillover return would be affected to a much smaller extent than in the case of the DGS. For an automatic grant like that proposed by the Commission, the administrative burden is much less onerous and so administrative costs play a much smaller role. The range on the required spillover return if administration costs are doubled only changes slightly to between 67 and 35 per cent.

Table E26: **Spillover return required by the automatic grant to break even**

		Base level R&D	*Automatic grant*	*Automatic grant*	*Automatic grant*
[1]	Concession registrants in tax loss (1992-93 est) ($m)	800	833	849	866
[2]	Grant recipients (1993-94 est)[a] ($m)	20	21	21	22
[3]	Eligible non-registrants (1992-93 est) ($m)	80	83	85	87
[4]	Total R&D (est) ($m)	900	937	956	974
[5]	Inducement ratio for all registrants		0.10	0.15	0.20
[6]	Inducement ratio for automatic grant		0.04	0.06	0.08
[7]	Induced R&D ($m)		37	56	74
[8]	Cost of bringing forward tax saving (7.4 cents/$)				
[9]	Cost to revenue ($m) ([8]*[4])		69.3	70.7	72.1
[10]	Administration costs ($m)		0.5	0.5	0.5
[11]	Total program costs ($m) ([9]+[10])		69.8	71.2	72.6
[12]	Marginal cost of funds (33 cents/$)				
[13]	Social cost of funds ($m) ([11]*[12])		23.0	23.5	24.0
[14]	Compliance costs ($m)		0.5	0.5	0.5
[15]	Total social costs ($m) ([10]+[13]+[14])		24.1	24.5	25.0
[16]	Required spillover return (%) ([15]/[7])		65	44	34
[17]	Ratio of induced R&D to social cost ([7]/[15])		1.54	2.26	2.96

a The base level R&D for this group is the estimate of R&D that would have been carried out by receipients of selective grants in the absence of the grants.
Source: IC estimates.

Overall then, what the cost benefit results appear to show is that the three schemes reviewed here have broadly similar outcomes, and similar outcomes to the tax concession as found by the BIE.

One purpose of the analysis was to compare the outcome for the DGS and the automatic grant proposed by the Commission. What is clear is that neither scheme has clear advantages over the other in terms of estimated costs and benefits, though the automatic grant is shown to induce substantially more R&D. The Commission’s other concerns about selective schemes are discussed in part D.

APPENDIX F: SELECTED RURAL R&D PROGRAMS

This appendix describes in more detail the legislative arrangements under which the Research and Development Corporations (RDCs) operate. It also provides some information about other rural R&D related programs administered by DPIE, the Cooperative Research Centres (CRCs) involved in agricultural or rural-based manufacturing R&D, and the Australian Centre for International Agricultural Research.

F.1 R&D corporations and councils

The Meat Research Corporation (Meat RC) was the first of the commodity-based RDCs to be established. It was established under its own Act: the *Meat Research Corporation Act 1985*. Subsequently the Horticultural RDC was established under the *Horticultural Research & Development Corporation Act 1987*.

The *Meat Research Corporation Act 1985*, was largely used as a model for the *Primary Industries and Energy Research and Development Act 1989* (PIERD). Eight commodity-based RDCs have been established under this Act. These are the Cotton, Dairy, Fisheries, Forest and Wood Products, Grains, Grape and Wine, Pig, and Sugar RDCs. Funding for most of the commodity-based RDCs comes half from the relevant industry and half from the Commonwealth Government.

In addition there are three predominantly government funded corporations. These are the Energy Research & Development Corporation (Energy RDC), the Land and Water Resources Research & Development Corporation (Land and Water Resources RDC) and the Rural Industries Research & Development Corporation (Rural Industries RDC).

The ‘generic’ Rural Industries RDC was established to look after the R&D needs of small and emerging rural industries, as well as issues affecting all rural industries. For instance, it manages and funds research for the rice, deer, goat fibre and cashew industries, and addresses multi-industry issues such as climate change, agroforestry, sustainability, and pest and disease control. In addition there are five R&D councils under its umbrella. They are the Chicken Meat, Dried Fruits, Egg Industry, Honeybee, and Tobacco R&D Councils.[1] The latter represent those industries judged large enough to conduct their R&D in a relatively independent way, and to all intents and purposes, they operate identically to the commodity-based corporations.

On 1 December 1993, the Australian Wool Research and Promotion Organisation took over the responsibilities of the Wool RDC. On the recommendation of the Wool Industry Review Committee (Garnaut 1993), this new body has also taken on the promotion function previously carried out by the Australian Wool Corporation. The enabling legislation is the *Australian Wool Research and Promotion Organisation Act 1993*.

Functions and powers

Under the PIERD Act the main functions of an RDC are:

- to investigate and evaluate the requirements for research and development in relation to the primary industry in respect of which they are established;
- to fund that R&D, consistent with a five year R&D plan, and an annual operational plan prepared by the Corporation in consultation with its stakeholders; and
- to facilitate the dissemination, adoption and commercialisation of the results of research and development in relation to the primary industry in respect of which they are established.

To carry out these functions the RDCs have the ‘power to do all things necessary’, including:

- enter into agreements for the carrying out of R&D;
- make applications, including joint applications, for patents;
- join in the formation of a company; and
- do anything incidental to any of its powers.

The RDCs do not perform R&D themselves, although the Act makes provision for the corporations to carry out R&D ‘with other persons’. Many of the corporations interpret their role very widely, and are involved in funding basic, strategic, and applied research, market research, extension and technology transfer, commercialisation, and education and training.

[1] For convenience, the R&D Councils will, like the R&D Corporations, be referred to as RDCs.

Funding

Most of the commodity-based RDCs are funded through a statutory levy matched by the Commonwealth Government up to a maximum of 0.5 per cent of the gross value of production (GVP). GVP is calculated as the average GVP of the current ('relevant') year and two preceding years. Levies are generally based on units of production, for instance tonnes of sugar cane, but in a very few cases on the value of production, for instance for some of the grains. The size of the levy is determined each year by the relevant industry.

Expenditure on R&D by the RDCs is matched by the Government as it is spent. Any levy income set aside as reserves, is not matched until it is actually spent, and then only when industry expenditure is below 0.5 per cent of GVP.

Some rural industries contribute to research through voluntary levies. Both the Horticultural RDC and the Rural Industries RDC manage voluntary levy contributions, however, only those managed by the Horticultural RDCs are matched dollar for dollar by the Commonwealth Government.

The Fisheries RDC, in addition to receiving an amount to match levy receipts to 0.25 per cent of GVP, receives an unmatched amount equivalent to 0.5 per cent of GVP, on the basis that it is the Commonwealth's role to manage the fisheries resource (Kerin and Cook, 1989). The levy is compulsory for Commonwealth fishermen only.[2]

The Forest and Wood Products RDC receives $1 for every $2 raised by the industry, up to a maximum of 0.25 per cent of GVP.

The Energy RDC, the Land and Water Resources RDC and the Rural Industries RDC (other than the levy based Councils) are funded by direct Commonwealth appropriations because of the large public good component of the research they facilitate. These RDCs do, however, commission R&D in partnership with industry, with all industry contributions on a voluntary basis. In 1992–93 the Energy RDC received Parliamentary appropriations of around $11.6 million and the Land and Water Resources RDC $10.4 million. In addition to $763 1871 to match industry levies the Rural Industries RDC in 1993–94 received $10.46 million in Parliamentary appropriations.

In 1993–94, the Land and Water Resources RDC received a special appropriation of $2 million for drought related research which is managed with

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[2] Historically the States have managed fisheries within the three mile territorial sea, and the Commonwealth has managed fisheries in the ocean outside the three mile zone. Commonwealth fishermen are those who fish in that part of the ocean under Commonwealth jurisdiction.

the Rural Industries RDC and other RDCs in a cooperative program totalling in excess of $10 million.

Total expenditure for all RDCs in 1993–94 is estimated at $262 million, with around 55 per cent contributed by the Commonwealth Government. Individual expenditure ranged from around $300 000 by the Honeybee RDC to $51 million by the Grains RDC.

DPIE is responsible for the collection and administration of the levies, with the corporations being charged levy collection costs.

Administrative arrangements

The RDCs are headed by boards of directors which are appointed by the Minister on the recommendation of a selection committee, which in turn is appointed on the recommendation of the industry concerned. The function of the selection committee is to nominate persons who collectively possess an appropriate balance of expertise in a range of fields related to the particular industry, including production, processing, marketing, management and conservation of natural resources, science, technology transfer, economics, administration of R&D, finance and business management.

Accountability

The PIERD Act makes the RDCs accountable to both the Minister and the industry they represent. Like all statutory bodies the corporations and councils are required to prepare annual reports and submit them to their stakeholders, for instance their ‘representative organisation(s)’ and the Minister.

In addition, the Act requires both corporations and councils to prepare a five year plan in consultation with industry organisation(s) designated by the Minister as their ‘representative organisation’. The plan must include a statement of objectives and priorities and an outline of strategies to be used, and must be submitted to the Minister for approval. It must be reviewed annually and before varying the plan, corporations and councils must consult with their representative organisation(s).

To support the five-year plan, corporations and councils must prepare an annual operational plan, again in consultation with their representative organisation(s) and this also must be submitted to the Minister for approval.

The difference between the corporations and the councils in this context is that the councils are required to present their plans and annual reports to the Rural Industries RDC before submitting them to their stakeholders. Another difference is that the Councils do not handle money or contracts. The Rural Industries RDC manages and is accountable for all Council funds.

Priority setting, project selection, monitoring of progress and outcomes

In preparing their five-year plans and annual operating plans, the corporations are required to consult with industry. The corporations have developed a variety of ways of going about this process.

Generally on an annual basis, and on the basis of the R&D plan and annual operational plan, research providers are invited to submit proposals for research projects. Applications are assessed on the basis of the extent to which they address the objectives and priorities set out in the plans. In addition, the RDCs commission research from providers through tender processes.

Table F1: **Allocation of RDC expenditure**[a] **1992–93** (per cent)

Corporation/Council	*State Depts of Agriculture*	*CSIRO*	*Universities*	*Other*
Grains RDC[b]	54	13	25	8
Meat RC	16	20	11	54
Wool RDC	15	60	18	7
Horticultural RDC	60	7	9	24
Dairy RDC	33	14	19	34
Fisheries RDC	58	26	6	10
Sugar RDC	3	9	5	83
Pig RDC	35	12	41	12
Cotton RDC	29	48	19	4
Grape and wine RDC	23	7	6	65
Chicken meat RDC	20	22	52	5
Tobacco RDC[c]	97	0	0	3
Dried fruits RDC	44	38	16	1
Egg industry RDC	18	19	48	15
Honeybee RDC	30	10	51	15

a Commodity-based RDCs only.

b Entry for CSIRO includes all Commonwealth research organisations.

c Proposed 1992-93 expenditure.

Source: Commission estimates.

Who performs corporation research?

The corporations do not perform any R&D themselves. Most of it is contracted out to CSIRO, State Departments of Agriculture, universities and Federal research bureaux. Some small amount is conducted in facilities established by the corporations themselves and some in private laboratories. Table F1 shows

Commission estimates of who performed R&D for individual RDCs in 1992–93.

Clearly there is great variability between individual RDC funding allocations, but with the States receiving marginally more than CSIRO in total. Both the Sugar RDC and the Tobacco RDC stand out as exceptions with very high proportions of funding to one category. In the case of the Sugar RDC, more than $6 million, or 74 per cent of total research is carried out by the Bureau of Sugar Experiment Stations, a Queensland statutory authority established originally in 1901 under the Sugar Experiment Stations Act. Since 1991 its administration has come under the *Sugar Industry Act 1991*.

F.2 Other rural R&D related programs administered by DPIE

DPIE administers a number of programs which either involve an R&D component or aim to assist in the implementation of R&D outcomes. These are:

- The **Plant Variety Rights Scheme** which operates under the authority of the *Plant Variety Rights Act 1987* and which provides inducements for private sector plant breeding;
- Under the *Exotic Animal Disease Control Act 1989* payments are made to the **Exotic Animal Disease Preparedness Trust Account** for programs aimed at enhancing and improving Australia’s exotic animal disease preparedness;
- The **Rural Industries Business Extension Service** provides up to 50 per cent of the cost of employing a consultant or facilitator who can provide professional help on value-adding and/or technology transfer projects;
- The **World Best Practice Incentive Scheme** aims to assist farmers, processors and marketers of rural products to adopt best practice; and
- The **Innovative Agricultural Marketing Program** supports projects that focus on new agricultural, forestry or fishery products, new processes applied to existing products, or new elements in such processes.

DPIE also contributes to the operating costs of the Australian Animal Health Laboratory. There is also the National Landcare Program (with a budget of $78 million in 1993–94), involvement in the Murray-Darling Basin Initiative, the farm forestry program, and a range of forestry, fisheries, and energy related programs which contain elements of R&D.

Box F.1: **Agriculture and rural-based manufacturing CRCs**

CRC	*Core participants*	*Research focus*
CRC for Plant Science	CSIRO, ANU, Biocem Pacific Pty Ltd	Applying new technologies to problems in plant biology
CRC for Tropical Pest Management	University of Qld, Qld Dept of Lands, Qld DPI, CSIRO	Pests and pesticides in tropical Australia
CRC for Temperate Hardwood and Forestry	CSIRO, University of Tasmania, For. Commission of Tas, APPM, ANM, Forest Resources, APM	Genetic improvement, soil and stand management, resource protection
CRC for Legumes in Mediterranean Agriculture	WA Dept of Agriculture, University of WA, CSIRO, Murdoch University	Provide strategic & basic research and training for sustainable agriculture in mediterranean Australia on legumes
CRC for Tropical Plant Pathology	Uni of Qld, CSIRO, Qld DPI, BSES, Pacific Seeds, Qld Uni of Technology	Provide new and more effective ways of controlling plant diseases
CRC for Hardwood Fibre and Paper	Aus Pulp and Paper Inst., Monash Uni, Uni of Melbourne, CSIRO, Pulp and Paper Man Fed of Aus	Properties of hardwood fibres, relationships between properties and fibres, methods for evaluating fibre properties
CRC for Viticulture	Uni of Adelaide, Aus Wine Research Inst, Charles Sturt Uni, NSW Agriculture, CSIRO, SA Dept of Ag, Vic Dept of Ag, Phytotech Australia	Enhance the technical advantage of Australian grapes and grape products
CRC for Premium Quality Wool	UNE, CSIRO, WA Dept of Ag, Uni of WA, Uni of NSW, Wool RDC	Research and education to improve the quality and competitive position of Australian wool
CRC for Cattle and Beef Industry	UNE, CSIRO, NSW Agriculture, Qld DPI	Improve the quality & consistency of beef for export to Asia and domestic preferences
CRC for Aquaculture	University of Tas, Qld DPI, Tas DPIF, NSW Fisheries, James Cook Uni, Sydney Uni of Technology, AIMS, Uni of Central Qld, SA R&D Inst.	National research strategy, technological basis for sustainable, competitive and environmentally acceptable industry
CRC for Sustainable Cotton Production	CSIRO, UNE, Uni of Sydney, QLD DPI, NSW Agriculture, Cotton RDC	Develop and implement sustainable cotton cropping systems
CRC for Food Industry Innovation	Uni of NSW, CSIRO, Arnotts, Burns Philp Mauri, Goodman Fielder Wattle	Generate improved and novel natural food ingredients

Box F.1: **Agriculture and rural based manufacturing CRCs** (Cont.)

CRC	*Core participants*	*Research focus*
CRC for Quality Wheat Products and Processes	Arnotts, Australian Wheat Board, Bread Research Inst of Australia, CSIRO, Defiance Mills Ltd, George Weston Foods, Goodman Fielder, Grains RDC, NSW Agriculture, New Zealand Inst for Crop and Food Research, Uni of Sydney, WA Dept of Ag	Wheat quality and increasing value added at all stages in the production chain for wheat and wheat-based products
CRC for Weed Management Systems	Uni of Adelaide, NSW Agriculture, CSIRO	Sustainability and productivity of Australian agriculture, ecosystems at risk from invasive weeds
CRC for Sustainable Sugar Production	Bundaberg Sugar Company, BSES, CSIRO, CSR, James Cook Uni, Uni of Qld, Central Qld Uni, Mackay Sugar Coop Ass, NSW Sugar Milling Coop, Qld DPI, Sugar North, Sugar RDC	Fostering the international competitiveness of the Australian sugar industry

F.3 Cooperative Research Centres (CRCs)

Of the 51 CRCs in existence in 1994, fifteen were involved in agricultural or rural based manufacturing R&D (see box F1). All rank CSIRO amongst their core participants. Most of them also list one or more State government departments as members. While four CRCs list an RDC amongst their core participants, a number of the other corporations take part in CRC programs and provide funding.

Total resources committed to agriculture and rural based manufacturing CRCs are around $728 million. This includes $206 million from the Commonwealth Government. Industry participants have committed about $96 million, and other organisations, such as CSIRO, universities and the States about $426 million.

In general the comments received from participants on CRCs involved in rural research were favourable. However, there were some concerns. For instance, the Dairy RDC, while saying it is too early to assess the CRCs from the perspective of results delivered to industry, also said its observations were that the CRCs are science driven and might be differently structured if initiated by industry (Sub. 134).

F.4 Australian Centre for International Agricultural Research

The Australian Centre for International Agricultural Research (ACIAR) was established in 1982 under the *Australian Centre for International Agricultural Research Act 1982*. Following an amendment to its Act in 1992, its current functions are to:

- formulate programs and policies with respect to agricultural research for either or both of the following purposes:
  - identifying agricultural problems of developing countries;
  - finding solutions to agricultural problems of developing countries;
- commission agricultural research in Australia in accordance with such programs and policies;
- communicate the results of such research;
- establish and fund training schemes related to its research programs;
- conduct and fund development activities related to its research programs; and
- fund international agricultural research centres.

Like the RDCs, ACIAR does not itself perform R&D. Funding ($21.6 million in 1992–93) is by appropriation from the Commonwealth Government's official development assistance budget.

ACIAR is responsible to the Minister for Development Cooperation and Pacific Island Affairs, within the Foreign Affairs and Trade portfolio. Its efforts are focused in Southeast Asia and the Pacific, South Asia, China and Africa.

ACIAR said international cooperation in Australia's research and development programs is particularly important in agricultural R&D, and it has a mandate to promote international partnership programs in agriculture, forestry and fisheries. It said:

> International collaboration ... provides opportunities for sharing financial and human resources in research and development activities — which brings considerable benefit to Australian partners (Sub. 400, p. 6).

APPENDIX G: MAJOR LINKAGE PROGRAMS

This appendix provides information on the major linkage programs discussed in chapter F1. These programs are:

- the Special Research Centres and Key Centres of Teaching and Research funded under the ARC's Research Centres Program;
- the ARC's Collaborative Research Grants Program;
- the Advanced Engineering Centres Program;
- Australian Postgraduate Awards (Industry);
- the industry links subprogram of the National Priority (Reserve) Fund; and
- two IR&D Board programs — the Generic Technology Grants Scheme and the National Teaching Company Scheme — which since May 1994 are encompassed in the new Competitive Grants for Research and Development scheme.

G.1 Research Centres Program

The Research Centres Program consists of two elements:

- Special Research Centres (SRCs); and
- Key Centres of Teaching and Research (KCTRs).

The Research Centres Program was reviewed as recently as 1991 by a panel appointed by the ARC (Lazenby 1992). That review called for the continuation of both SRCs and KCTRs.

Special Research Centres

The SRC program began in 1981 with the announcement of the first ten Research Centres of Excellence, as they were then called. The Commonwealth is currently funding 17 centres mostly at a rate of between $400 000 and $800 000 a year (table G1). Expenditure totalled $13 million in 1994, and is expected to be $12.5 million in 1995.

The initial guidelines for the program stipulated that these centres were to be:

> ... special units within Australian universities ... established by concentrating research workers and resources, with the aim of pursuing research of outstanding quality within an international context likely to lead to a significant and major development of knowledge (cited in Lazenby 1992, pp. 4–5).

Table G1: **Special Research Centres**

Institution	*Funding began*	*Special Research Centre*	*Funding 1994*	*Funding 1995*
			$'000	$'000
University of Newcastle	1988	Industrial Control Science	814	833
Macquarie University	1988	Lasers and Applications Centre	780	747
University of New South Wales	1988	Membrane Science and Technology	486	497
	1991	Implementation of Corporate Change	na	460
	1982	Photovoltaic Devices and Systems (began as joint centre with RMIT, renewed at UNSW in 1991)	954	976
La Trobe University	1988	Protein and Enzyme Technology	136	
Flinders University of South Australia	1988	Electronic Structure of Materials	574	587
University of Melbourne	1988	Human Communications Research	610	624
	1982	Plant Cell Biology	954	976
	1991	Advanced Mineral Products	786	804
University of Queensland	1988	Vision, Touch and Hearing	728	745
	1991	Molecular Biology and Biotechnology	674	690
	1991	Software Verification	674	690
University of Adelaide	1991	Plant Molecular Biology	954	976
Murdoch University	1991	Asia Research Centre on Social, Political & Economic Change	841	861
University of Sydney	1991	Astrophysics	505	517
Royal Melbourne Institute of Technology	1982	Advanced Surface Processing	252	
University of Western Australia	1991	Advanced Mineral and Materials Processing	786	804
	1982	Environmental Fluid Dynamics	729	746
University of Wollongong	1991	Centre for Research Policy	na	
		unallocated	673	
		Total	**12 910**	**12 533**

Sources: Lazenby 1992, DEET 1993b and DEET 1994f.

The centres were to create a new focus for research activity that would make a significant contribution to the 'development of knowledge' and not merely be an extension of research within existing university departments. Following a review of the program in 1986, the Government agreed to a further selection round in 1987 at which time the ARC assumed responsibility for the SRC program from the Commonwealth Tertiary Education Commission. The selection criteria were also amended to give some priority to proposals of relevance to national economic development and international trade and that the centres promote interaction between universities, government and the private sector, especially industry.

The program objectives for the most recent selection round in 1991 were broadly as follows:

- to establish special units of concentration of research workers and resources in Australian higher education institutions;
- to promote research in areas of national importance which would enhance Australia's economic, social and cultural well-being;
- to encourage the pursuit of excellence in research, as measured at both national and international levels; and
- to establish centres of such repute that they would serve as points of interaction between higher education institutions, government, industry and the private sector generally (Lazenby 1992, appendix 6).

The SRC selection process is competitive — at least from within the higher education sector — and after a maximum of nine years, funding is contestable.

Higher education institutions which are members of the UNS, other than the IAS, are eligible for support as a SRC. The areas of clinical medicine and dentistry were excluded once responsibility for these fields of research passed to the NHMRC. The host institution is expected to provide the salary and associated costs of the principal researcher and essential infrastructure support.

Funding is awarded initially for six years, subject to a satisfactory review after three years. Funding may be extended to a maximum of nine years following a major review after six years. A centre's funding ceases after nine years and is made available for competitive bidding, although the centre can bid again for further funding.

For the 1991 selection round, the ARC sought a balance between centres focusing essentially on basic research and those which were 'mission-oriented' by being closely related to social, economic or industrial outcomes (Lazenby 1992, appendix 6). To reflect its view of the thrust of government policy, the ARC indicated its seven preferred areas for SRC activity (box G1).

Box G1: **Preferred areas for SRC activity**

For the 1991 selection round, the ARC expressed a preference for proposals in the following areas:

- fundamental and strategic research likely to give long-term benefits to agriculture, fisheries or forestry;
- research that underpins industrial research, particularly in chemistry, engineering, mathematics and physics;
- research that can contribute to the restructuring and competitiveness of Australian industry, especially in marketing, industrial relations and economics;
- research policy and management;
- research in information technology and communications;
- research which contributes to an understanding of Australia's Asian context; and
- research that contributes to the understanding and management of the Australian environment (Lazenby 1992, appendix 6).

However, no proposal was rejected solely on the grounds of its field of inquiry as demonstrated by the selection of the SRC for Astrophysics.

Although SRCs are engaged primarily in basic or strategic basic research, most also undertake research training although tending to concentrate on postgraduate research and postdoctoral training. SRC grants impose few constraints, so centres have considerable flexibility in setting their own priorities and developing their activities.

Notwithstanding their focus on basic rather than applied research, a number of SRCs have attracted 'considerable' external support. (Lazenby 1992, p. 12). These include the Centres for Advanced Surface Processing and for Photovoltaic Devices and Systems. Examples of other linkages reported in Lazenby (1992, p. 25) are:

- the Centre for Industrial Control science has undertaken a number of commercial projects, including a satellite tracking system;
- several companies have donated services and equipment to the Electronic Structure of Materials Centre and commercialisation possibilities have been discussed;
- the Protein and Enzyme Technology Centre collaborates in research with biotechnology companies in Melbourne and is associated with five companies in Japan;
- the Centre for Membrane Separation and Technology benefits from industry-sponsored R&D projects and outposts postgraduate students in industry; and
- the Centre for Lasers and Applications has undertaken cooperative projects with firms such as BHP, Gestetner Lasers, Telecom, and 3M.

Whilst acknowledging the paucity of hard data with which to assess the impact of the SRC program, the Lazenby review (1992, p. 20) assessed it as ‘an integral part of the research spectrum’ providing ‘some balance to the more applied objectives of the KCTR and CRC programs’. In particular, the SRC program had enabled:

> ... the building up of a ‘critical mass’ of staff especially suited to science-based experimental research. Such a concentration of staff, together with the necessary equipment, has allowed the development of research programs which are beyond the scope or individuals, or even groups of staff, working in a conventional department ... SRCs have also played a significant role in galvanising multidisciplinary research (p. 20).

In commenting on the draft report, the ARC suggested that SRCs not be considered as a major linkage program because, although linkages do occur, they are not given any prominence in selection criteria nor in the evaluation of outcomes (Sub 361, p. 12). Nevertheless, given a program objective of centres serving as ‘points of interaction’ and the range of business linkages described above, SRCs have been retained in the Commission’s listing of linkage programs.

Key Centres of Teaching and Research

The first seven Key Centres of Teaching and Research (KCTR) were established in 1985 on the advice of the then Commonwealth Tertiary Education Commission. By 1994 the Commonwealth was funding 30 centres for a total of \$6.7 million (table G2). Most centres are currently being funded at \$220 000 a year. The Government has agreed to the ARC recommendation of February 1994 that an additional eight centres be established for six years from mid-1995. Approximately \$2.4 million has been allocated to support these new centres.

Broadly, Key Centres are defined as:

> concentrations of high level activity within higher education institutions based on closely related research and advanced teaching programs. While the groups involved may already be operating at a high level they should, nevertheless, have the potential to develop increased capacity to attract high quality staff and students. Key centres are active in building linkages with industry and/or end user community groups (DEET, 1994c, p. 7).

The concept of Key Centres as originally developed emphasised teaching and learning as well as research but it was the teaching function which was to distinguish them from SRCs. KCTRs were primarily established to enhance the existing teaching expertise and build the research capability of the Colleges of Advanced Education: four of the first seven centres were in CAEs, two were joint CAE-university centres and one was established in a university (Lazenby 1992, pp. 6–7).

Table G2: **Key Centres of Teaching and Research**

Institution	*Initially funded*	*Key Centres of Teaching and Research*	*Funding 1994*	*Funding 1995*
			$'000	$'000
University of New England	1988	Agricultural Economics	215	
University of New South Wales	1988	Food Industry Development	215	88
	1988	School of Mines (Joint Centre)	215	88
University of Sydney	1989	Industrial Relations Research and Teaching	215	220
University of Technology, Sydney	1985	Advanced Computing Studies	215	
The University of Wollongong	1988	Advanced Manufacturing and Industrial Automation	215	88
	1988	School of Mines (Joint Centre, funds provided to the UNSW)		
La Trobe University	1988	Gerontology	215	165
Monash University	1988	Australian Studies	215	165
	1989	Industrial Relations	215	220
	1989	Advanced Materials Technology	215	220
Royal Melbourne Institute of Technology	1988	Toxicology	215	165
	1989	Design	215	220
	1989	Knowledge Based Systems (Joint Centre)	108	111
Swinburne University of Technology	1985	Computer Integrated Manufacture	266	51
University of Melbourne	1988	Women's Health in Society	215	165
	1989	Technology Management	215	220
	1989	Knowledge Based Systems (Joint Centre)	108	111
Griffith University	1988	Asian Languages and Studies (Joint Centre)	304	233
James Cook University of North Queensland	1989	Economic Geology	215	220

Table G2: **Key Centres of Teaching and Research** (continued)

Institution	*Initially funded*	*Key Centres of Teaching and Research*	*Funding 1994*	*Funding 1995*
Queensland University of Technology	1985	Land Information Studies (Joint Centre)	215	
	1989	Strategic Management	215	220
The University of Queensland	1988	Software Technology	215	165
	1985	Land Information Studies (Joint Centre, funds provided to QUT)		
	1988	Asian Languages and Studies (Joint Centre, funds provided to Griffith University)		
Curtin University of Technology	1985	Resource Exploration	215	
	1988	School Sciences and Mathematics	215	165
University of Western Australia	1988	Strategic Mineral Deposits	215	165
Flinders University of South Australia	1991	Centre for Education and Training on Addictions	286	293
University of South Australia	1985	Aboriginal Studies and Education	215	
University of Tasmania	1988	Aquaculture	215	165
	1988	Antarctic and Southern Ocean Studies	215	165
	1989	Ore Deposit and Exploration Studies	215	220
Other	1990	Languages Institute of Australia	294	301
Unallocated [a]				1 200
		Total	**6 741**	**5 809**

a to provide for new Key Centres from mid-1995

Sources: Crean 1994a, DEET 1994f.

The program has since expanded to cover any institution with broad research and teaching activities with links to industry. However, not until 1988 was it a requirement that teaching undertaken in a centre be additional to the host institution's normal undergraduate and postgraduate activities. In recent years, 'industry' has been more broadly defined to include government departments and community organisations. Responsibility for the KCTRs was transferred to the ARC in 1987.

The objectives of the KCTR program are:

- to significantly enhance the quantity and quality of teaching and research in higher education;
- to assist higher education to respond to demands for expertise in particular fields, especially through teaching and research in areas relevant to national economic, technological and social objectives;
- to strengthen and promote cooperation between higher education and industry and user groups and to encourage financial support for centres from these external agencies;
- to promote the interrelationship of teaching and research and develop interdisciplinary links in host institutions; and
- to promote teaching and a spectrum of research activities, including applied research, different from the basic research undertaken in SRCs and the large-scale industry-focused work of CRCs (DEET 1994c, pp. 4–5).

The KCTR selection process is competitive: all higher education institutions in the UNS, except the IAS, are eligible to apply for Key Centre funding. For the 1995 selection round, however, each institution has been limited to submitting a maximum of three proposals. Proposals can involve agencies outside the UNS but the main participant must be a member of the UNS.

KCTRs have been initially funded for three years and, subject to satisfactory performance, the funding continued for a further three years. It has been possible to extend funding to nine years. However, the 1992 Lazenby review recommended a maximum period of six years funding and this time limit applies to those centres being selected in the 1995 round. The 'general expectation' has been for KCTRs to build alternative sources of support and that they would be ineligible to apply for further Commonwealth funding after nine (now six) years. The activities of KCTRs are outlined in box G2.

Reviews of 13 Key Centres established in 1988 were carried out by specialist review panels appointed by the ARC in 1994 to assess the centres' achievements and determine whether Commonwealth funding should continue during 1995 and 1996, years eight and nine of funding for the 1988 cohort of Key Centres. The Minister approved continued funding for 10 of the 13 centres reviewed (DEET 1994f, p. 67).

Box G2: **Activities of Key Centres of Teaching and Research**

The activities of KCTRs have been described by DEET (1994c, p. 5) as encompassing

Research:

- carrying out research which is recognised as internationally competitive and which contributes to national objectives;
- research is expected to include the applied end of the spectrum and to underpin the Centre's teaching objectives; and
- where possible, focusing research on niche areas to provide a competitive edge both nationally and internationally.

Education:

- providing education at the advanced undergraduate and postgraduate level;
- providing short specialised continuing professional education courses to meet the needs of industry and other user groups; and
- providing specialised components of undergraduate courses.

Linkages:

- developing and maintaining cooperative links with industry and/or user communities relevant to the Centre's research and teaching activities;
- making a significant contribution to the commercialisation or utilisation of research; and
- acting as a resource for industry/users by providing both short and long term research consultancies, and by facilitating technology transfer.

Funding:

- actively seeking other funding sources with a view to becoming self sustaining, including applying for grants from other Commonwealth agencies, State Governments, and industry/users and by attracting operating grant funding (EFTSU) and student fees as appropriate.

In the 1995 selection round, a non-binding preference for three types of application has been stated:

- targeted areas — although no specific priorities have been identified, areas of national social, cultural, technological and economic importance are targeted;
- networking and joint applications which link academics on a number of sites; and
- applications to strengthen research and training in current areas of weakness.

Overhead costs in KCTRs are the responsibility of the host institution and significant other support is expected. This may entail provision of the director's salary, accommodation and other resources, and proportions of the institution's operating grant to reflect the students taught and research undertaken. The Lazenby review (1992, p. 39) found that a 'few' universities were 'budgetarily shy' in providing the level of support offered when applying for the KCTR grant. Like the SRCs, KCTRs have considerable discretion in how funds are used.

KCTRs are expected to establish an advisory board consisting of centre staff, industry/user community groups, academics from another higher education institution and senior university staff such as the Pro Vice-Chancellor (Research) and commercial arm representatives. The centres are required to report annually on their activities and submit audited financial statements covering expenditure and all sources of income.

According to the Lazenby review, some KCTRs have generated significant external funding from both private and public sector clients. One centre had attracted seven times its core ARC grant; several centres had generated at least four times as much; and most KCTRs had attracted external funding of at least twice their grant. While a significant number of KCTRs include doctoral and postdoctoral training in their activities, the main teaching activities are in undergraduate education, short courses, coursework Master's degrees and postgraduate diplomas. Although teaching and research are both compulsory, the balance varies between centres. The 1992 review of the centres considered that the KCTR program had provided the opportunity for post-1987 universities to develop research activities which previously had been the domain of the pre-1987 universities.

Overall, the review panel concluded:

> KCTRs link teaching, applied research and more basic research in ways that no other centres or industry-based research activities do. Significant numbers of KCTRs have had a positive impact on their related industries, providing trained personnel, raising the level of applied research skills, and undertaking some fundamental research on which the requests of industry for specific problem solving can be based (Lazenby 1992, p. 33).

G.2 Collaborative Research Grants Program

The CRG program was announced in October 1991 and is designed to:

> ... to support high quality research which has the potential for economic and social benefit to Australia and to encourage research collaboration between higher education institutions and industry (DEET 1994d, p. 1).

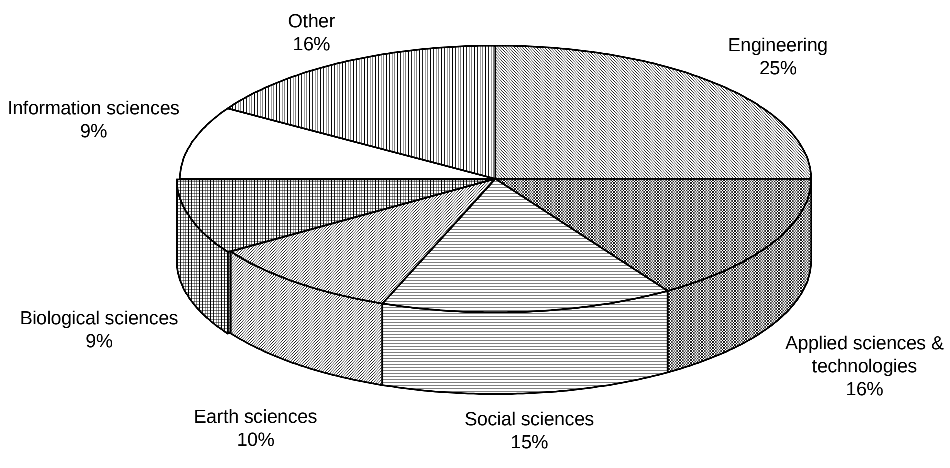
Project funding, which commenced in 1992, is allocated on the advice of the ARC and is provided on a dollar-for-dollar matching basis with industry. Commonwealth funding has expanded rapidly: from \$2.7 million supporting 41 projects in 1992 to \$6.7 million supporting 104 new and continuing projects in 1993. Commonwealth expenditure on CRGs was \$15.6 million in 1994 (180 projects) and is projected to be \$16.0 million in 1995 (225 projects).

CRG grants can be used to support basic, strategic, applied or developmental research in the social sciences, humanities, engineering and the natural sciences, but not clinical medicine and dentistry (figure G1). Awards have been in the form of grants, however, from 1995 awards can also include industry secondments and postdoctoral fellowships with industry partners, or any combination of all these elements, so long as the requirement for matching industry funding is met.

The CRG program's objectives are to:

- provide support for higher education researchers who wish to bring advanced knowledge to bear on problems or opportunities in order to obtain economic or social benefits for Australia
- develop cooperative links between higher education institutions, industry and public sector users of research; and
- develop within higher education institutions a greater understanding of industry's needs and how researchers may help to meet them (DEET 1994d, p. 2).

Figure G1: **Collaborative Research Grants: fields of research of all grants being funded in 1995** (by value)

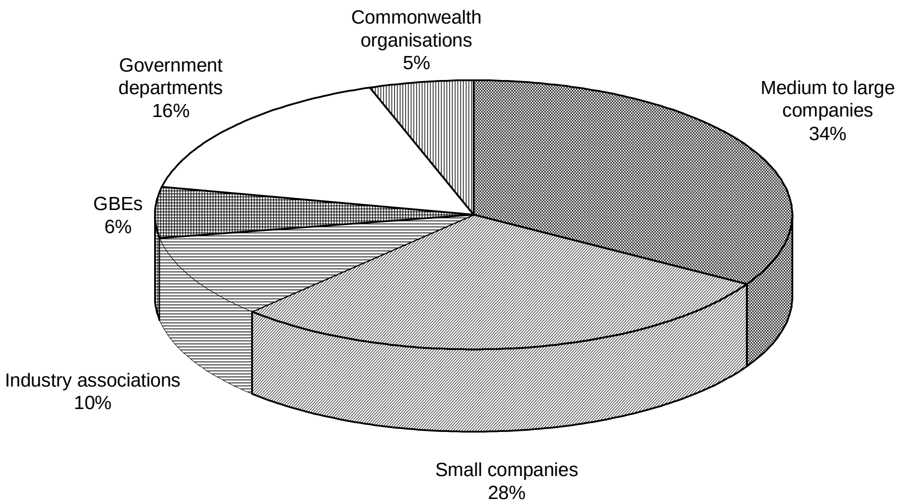


Source: DEET data.

Grants can be for up to three years: very few exceed $200 000 a year and most are between $50 000 and $100 000 a year. No more than four separate projects are supported simultaneously where the same researcher is the chief investigator on each. Institutions are expected to provide such infrastructure support as is necessary for the completion of the project, having regard to agreed industry contributions.

Industry support may be in cash or in kind (such as a contribution towards staffing the project, provision of equipment, or use of a laboratory). 'Industry' is broadly defined to include both public and private sector commercial enterprises, and State and Commonwealth agencies and private non-profit organisations which are research users; may include industry partners overseas; but excludes the commercial arms of the universities, rural R&D corporations, and public sector research agencies. Some indication of the source of 'industry' support is provided in figure G2. Industry contributions may attract the 150 per cent R&D tax concession.

Figure G2: **Source of industry support for new CRG projects funded in 1995** (percentage of organisations)



Note: Government department support is predominantly at the State level.

Source: DEET 1994f.

CRG selection processes are competitive. Members of the ARC's 1994 Collaborative Research Grants Panel were from higher education institutions (5), industry (5) and CSIRO (1). Applications are assessed against three equally-weighted criteria:

- the likelihood the research will lead to economic or social benefit for Australia;
- the research ability of the researcher or research group; and
- evidence that the project is 'truly' collaborative as evidenced by the joint development of the proposal, joint management of the collaboration and evidence of firm industry commitment to support the project.

CRGs are available to Australian higher education institution staff, though not to researchers receiving a salary from another Commonwealth research funding scheme (other than an ARC Fellowship) or IAS researchers. SRC and KCTR researchers are eligible so long as their salary is not financed by Commonwealth funds paid to those centres. Full-time researchers in CRCs are ineligible but part-time members are provided that they have the time and capacity to undertake their proposed project.

Restrictive commercial secrecy requirements do not preclude consideration for CRG funding. The applicant is required to ensure the collaborating company arranges all necessary secrecy agreements with the assessors chosen by the Panel. Industry bodies and institutions are expected to negotiate appropriate intellectual property arrangements at the outset but neither the Commonwealth nor ARC claims any proprietary interest in the intellectual property resulting from the CRG funding. However, the CRG program guidelines state that:

> It is expected that collaborating partners will respect the right of researchers, including postgraduate students, to publish the results of their work, subject to the terms and conditions of any formal agreement (DEET 1994d, p. 11)

Those awarded grants must submit yearly statements of income and expenditure and complete a final report after three years or earlier if project ends before then. These reports are made available to all interested parties, subject to delays in publication as agreed between the collaborating partner(s) and the higher education institution.

The CRG program only began in 1992 and no formal review of the scheme has been undertaken. However, some information is available from a survey of 90 1992 and 1993 CRG recipients (Adey and Larkins 1994). Some of the principal findings were that:

- the scheme is university-driven — in 93 per cent of cases, university researchers suggested the project and took the initiative in applying for the grant;

- 40 per cent of academic researchers had known their industry partner in the collaborative project for more than 5 years, and 60 per cent had collaborated with their industry partners on other projects;
- academic engineers often stated it was difficult to recruit engineering research students for CRG projects partly because CRCs and SRCs are often more financially attractive options; and
- program objectives in terms of publishing research results are being met — 48 per cent of projects employed students whose theses would be based on some aspect of the project research. Other survey information on expected outcomes revealed that 20 per cent of projects would lead to patent applications and in 8 per cent of projects the outcomes would remain confidential to the industry partner.

Some indication of purpose of new research projects being funded by CRG grants beginning in 1995 can be gleaned from project details released in October 1994 (Crean 1994c). Details were released on only 36 of the 98 projects, and about half of those involved single firms or GBEs as the industry collaborator. An examination of some of these raises a question about the extent to which benefits of the research would be appropriated by the single firms involved (table G3). Of course, this outcome has to be weighed against an assessment of the wider spillovers to the community from directly funding one-half of project costs and the additional support provided by measures such as the 150 per cent R&D tax concession and government contributions to university overhead costs.

G.3 Advanced Engineering Centres Program

The Advanced Engineering Centres Program was announced in the Commonwealth’s 1991–92 budget and, after a competitive selection process, three Advanced Engineering Centres were established within universities:

- the Advanced Engineering Centre for Manufacturing (University of Melbourne and RMIT)
- the Australian Graduate School of Engineering Innovation (University of Technology, Sydney and University of Sydney); and
- the Advanced Engineering Centre for Information Technology and Telecommunications (the universities of Adelaide and South Australia, Flinders University, and the South Australian Department of Technical and Further Education.

Table G3: **Expected research outcomes from selected 1995 CRG projects**

Industry collaborator	*Total grant $'000*	*Expected research outcome*
CSL Ltd	159.3	Develop vaccines for horses.
Voxon International Pty Ltd	380.0	Develop compression algorithms and hardware for videophones.
Johnson & Johnson Pty Ltd	203.4	Assess the amenability of the Gene-Shears technology owned by the industry collaborator to treat malaria and giardia.
BHP Research (Newcastle Laboratories)	179.3	Optimise blast furnace operations; enhance market access for Australian coals.
ABB Distribution Pty Ltd	210.0	Develop a new type of current limiting switching device.
Biomass Energy Services & Technology Pty Ltd	167.0	Develop modelling techniques to optimise and scale up existing BEST Pty Ltd prototype biomass gasifier.
Silicon Technologies Australia Ltd	358.7	Study selected aerogels which are leading contenders for the commercial removal of gaseous pollutants from industrial processes.
Gulf Rubber (Aust) Pty Ltd	164.3	Develop insulation foams for marine applications so providing a new manufacturing activity that will target high valued export markets.
Cyanamid-Websters Australia Pty Ltd	346.5	Develop a vaccine for blowfly strike in sheep.
Bonlac Foods Pty Ltd	326.0	Develop a process for the commercial production of food and toothpaste additives from casein to reduce dental decay; potential world market of $500 million a year.
CSR Sugar Mills Group	413.2	Sugar cane by-product recovery and utilisation.
Australian Sonar Systems Pty Ltd	240.0	Investigate flow over towed sonar detection arrays to improve the design and operation of company products and increase their competitiveness on world markets.

Source: Crean 1994c.

Total Commonwealth funding for the three engineering centres was $4.95 million in 1992, and $3.6 million in both 1993 and 1994. Of that funding, $4.2 million, $2.1 million and $2.1 million respectively were for establishment costs. Each centre receives the same level of Commonwealth funding. Operating costs are being funded at $0.5 million per centre in 1995 and 1996 (Cook 1994a, p. 64).

The objectives of the AEC Program are to:

- increase the contribution of higher education institutions to Australia's design and engineering capacities and to assist in the development of internationally competitive, value-added industries;
- increase industry's use of higher education as a source of advanced teaching skills and consultancy services to assist in the application and commercialisation of technology;
- increase higher education institutions' use of industry-based staff in the activities of engineering schools; and
- establish centres with potential to become international centres of expertise in their field (DEET 1992, p. 2).

The centres are established under the aegis of higher education institutions. They are governed by a joint industry/university board and could be located in a technology park or on an industry site. They were intended to focus on fields not adequately catered for at the time they were established.

The centres provide advanced education and/or short specialised courses to meet demands from industry or TAFE. They are to assist industry in the solution of immediate problems, including commercialisation of research. Industry contributes in cash or in kind resources and is involved in the centre management. Continuation of funding depends on whether program objectives are being achieved.

The Advanced Engineering Centres are due for review in 1995.

G.4 Australian Postgraduate Awards (Industry)

This scheme, until 1995 known as the Australian Postgraduate Research Awards (Industry), was introduced in the Government's 1989 Statement *Research for Australia: Higher Education's Contribution*. Its aim is:

> ... to build up long term relationships between higher education and industry through research students undertaking research projects which have been jointly developed by industry and a higher education institution (DEET 1993, p. 260).

APA(I) are awarded on the advice of the ARC. The program, which commenced in 1990, is yet another mechanism which draws together both the teaching and research elements of university-industry links. The awards for masters degrees (2 years) and doctorate degrees (3 to 3.5 years) are $18 866 for each year of the award, plus relocation, removal and thesis allowances. Industry partners are required to contribute $10 000 for each year of the award ($5 000 in cash and $5 000 in cash or in-kind).

The number of applications received for 1994 increased by 32 per cent over the previous year, when 125 APR(I)s were awarded (DEET 1993b, p. 260). A further 125 awards involving funding of $2.5 million have been announced for 1995. Of these 1995 awards: 45 per cent are classified to the manufacturing sector; and 22 per cent are in the field of engineering research, 18 per cent in applied sciences and technologies, and 12 per cent in earth sciences. The grants appear to encompass a wide range of generic industry and firm-specific projects, as well as environmental and social research projects.

Commonwealth funding in 1994 for the 284 continuing APRA(I) awards and the 125 new 1994 awards was $6.7 million (DEET 1993b, table 7.1). Projected spending for 1995 is $7.9 million (DEET, 1994f, table 5.1).

In addition to the former APRA(I) awards, the Australian Research Fellowships (Industry) Scheme was introduced in 1990 to provide replacement costs to higher education institutions for academics selected for short-term projects with industry. The Scheme has recently been discontinued: commencing in the 1995 grant year, support for activity of this type can be provided through the CRG Program (Sub. 361).

G.5 National Priority (Reserve) Funding

The National Priority (Reserve) Fund was established in 1988 to provide grants to higher education institutions in the UNS on the basis of their responses to specific Commonwealth initiatives or to identified areas of national priority. From 1989, the base operating grants for higher education institutions were set at a maximum of 99 per cent of the total operating grant for that year. The remaining 1 per cent of the total operating grant — the Reserve Fund — has over the years been used for a variety of purposes such as compensating for unplanned increases in enrolments, the costs of institutional amalgamations, and the promotion of multicultural and environmental curricula. Proposals to develop links between universities and business have been a specific priority area since 1991.

Funding for university-business links from the National Priority (Reserve) Fund grew from $233 000 in 1990 to around $2.1 million in 1994 but is projected to decline to $1.7 million in 1995 (DEET 1994f).

Since 1990, funding of $695 000 from the National Priority (Reserve) Fund scheme has been provided at five centres for the Cooperative Education for Enterprise Development (CEED) Program, a cooperative education program

(Baumgart et al 1994). CEED projects typically involve senior undergraduate students undertaking research projects identified by client organisations from industry (including the public sector). Commonwealth funding has been provided for two years to cover establishment costs of each centre. Firms contribute around $12 600 per project which can be claimed under the 150 per cent R&D tax concession. Once established, the program in each centre is expected to be self-funding.

A range of other business linkage have been supported under the links with industry subprogram of the National Priority (Reserve) Fund scheme. For example, in 1994 grants of $100 000 each were made available for the formation of industry-university consortia at the Australian Technology Park, the development of a joint venture training program in advertising, and a pilot project for providing research services to industry (DEET 1993b, pp. 24–5).

G.6 Collaborative schemes under the Industry Innovation Program

Although a number of the R&D programs that fell within the IR&D Board's Industry Innovation Program support linkages between business and public sector research institutions, two were specifically targeted at encouraging such linkages. These were the Generic Technology Grants Scheme (GTGS) and the National Teaching Company Scheme (NTCS) which, since May 1994, have been folded into the new Competitive Grants for Research and Development program. Both the GTGS and NTCS are discussed in part D and are only briefly summarised here.

The GTGS provided support for enterprises undertaking collaborative work with research organisations on projects in particular 'generic' or 'enabling' technologies. While it appears the GTGS is now to have a less prominent role in the suite of business R&D assistance programs, some broad pointers to its operation as a linkage mechanism are:

- the orientation of the scheme shifted somewhat over its life so that support came to be provided both for early-stage and product-oriented R&D;
- it provided high levels of support to projects — around 70 per cent of grant funds supported projects where the grant accounted for more than 50 per cent of project costs;
- GTGS grants typically only involved one commercial partner and one research organisation, and even where multiple commercial partners were involved they were the main players in those areas and few spillovers to other firms and industries and the community might have been generated;

- where commercial partners could largely appropriate the benefits of the projects funded they received high levels of assistance through the twin benefits of government funding of the research institution's contribution to the project and the eligibility of their own contribution for the 150 per cent R&D tax concession — this has been redressed in the new scheme by restricting collaborative projects to those companies unable to 'adequately' benefit from the tax concession;
- the GTGS was characterised by a high proportion of companies with involvement in multiple projects funded under the scheme; and
- allowing for respondent bias in survey results and given that projects were screened case-by-case, a relatively high proportion of projects would have proceeded without support.

The National Teaching Company Scheme (NTCS) was introduced in 1984–85, with the objective of enhancing the international competitiveness of Australian industry. This was to be achieved by fostering the development of new and longer term working relationships between public sector research institutions and companies in the manufacturing and services sector.

Under the NTCS the Commonwealth Government provided financial assistance for the employment of graduates working on company R&D projects for two years, under the joint supervision of senior members of the company and of a research institution. Up to $50 000 per grant could be provided over a maximum of two years. The scheme was available only to manufacturing and services sector companies, and NTCS projects could incorporate work not eligible for the tax concession such as management information systems and market research.

Up until February 1991, 205 projects had been funded or been committed to be funded by the Commonwealth. A further 66 projects were funded by the States. The cumulative financial commitment by Commonwealth was $7.8 million. Projects rejected by the Commonwealth were referred to the States (BIE 1991).

The Queensland Government has supported eleven projects (one of which is yet to be completed), at a total cost of $550 000 (Sub. 258). Of the completed projects, 70 per cent resulted in an ongoing relationship between the firm and the tertiary research partner. The Queensland Government said overall the outcomes had justified the investment in the program.

In its Science and Technology Statement delivered in May 1989, the Government said some of the priority objectives of the NTCS were to increase industry's use of technology and investment in R&D, to overcome information gaps and to strengthen links between research organisations and industry.

However, the objectives changed after the scheme's inception. Innovation rather than R&D per se became the aim of the scheme, with less emphasis on training and enhanced employment prospects. The aim of fostering new and longer term working relationships remained.

The NTCS was evaluated in BIE (1991). The Bureau found the scheme to be flexible, and initially increasingly used by small and medium sized firms. However, since 1989–90 there had been a shift away from very small firms.

The BIE also found that 74 per cent of projects led to the development of a new product or process, but a crucial factor in whether participation in the scheme had improved company performance was whether the company had prior experience in working with institutions.

The BIE said the scheme could be seen as a mechanism primarily designed to overcome the information gap concerning the benefits of collaboration; and it seemed to have been successful in affecting the pre-conditions for increased working relationships between industry and institutions. However, the increased awareness was greater among companies with prior links and among large companies. It was less successful in leading to the development of continuing working relationships between companies and institutions.

APPENDIX H: GOVERNMENT RESEARCH AGENCIES IN SELECTED COUNTRIES

This paper discusses how government assistance to research and development is organised and funded through government research agencies in a sample of countries. Where information was available to the Commission, it covers the following topics:

- the size of government expenditure on R&D relative to the total R&D expenditure in the country;
- the main government agencies performing the research and their sponsorship arrangements;
- the functions, activities, funding, and links with industry of government research agencies.

The Commission visited most of the countries examined in this review during the course of its inquiry, and has drawn on the information collected during those visits, as well as other sources. The countries covered in this review are the United States, Japan, United Kingdom, Germany, Canada, New Zealand, Taiwan, Korea, South Africa, and India.

H.1 United States

In the United States, science and technology policy is characterised by pluralism in priority setting, funding and the conduct of R&D. This:

> ... enhances the ability of the Federal Government to 'buy' the best research available from many sources and to support R&D for many different reasons. It also facilitates the access of non-government scientists to advise in the priority-setting process (CRS 1994, p. CRS-2).

The US Federal Government has used a wide range of methods to support R&D. Some allow private organisations to make all the important decisions about size and scope of the research projects. Examples include R&D tax incentives, institutional support for universities, and the Independent Research and Development (IR&D) program for contractors of the Department of Defence. Other support is more targeted, managed by government agencies and financed by project-specific appropriations and authorisations.

Funding of R&D

In 1993, US expenditure on R&D was about US$161 billion. Industry funded about 52 per cent of this, and the Federal Government about 42 per cent. The remaining 6 per cent was supported by universities and colleges, State and local governments, and non-profit institutions (NSB 1993, pp. 91–2).

Although government support for R&D represents the spending of 25 Federal agencies, 95 per cent of the funding is channelled through just six, with the Department of Defence dominating:

- Department of Defence (DOD) — 51 per cent;
- Department of Health and Human Services — 15 per cent;
- National Aeronautics and Space Administration (NASA) — 13 per cent;
- Department of Energy — 11 per cent;
- National Science Foundation — 3 per cent; and
- Department of Agriculture — 2 per cent (NSB 1993).

Although DOD remains the largest focus of the 1994 Federal R&D effort, government funding priorities are shifting. Since 1987, DOD funding has decreased while health and space research have increased.

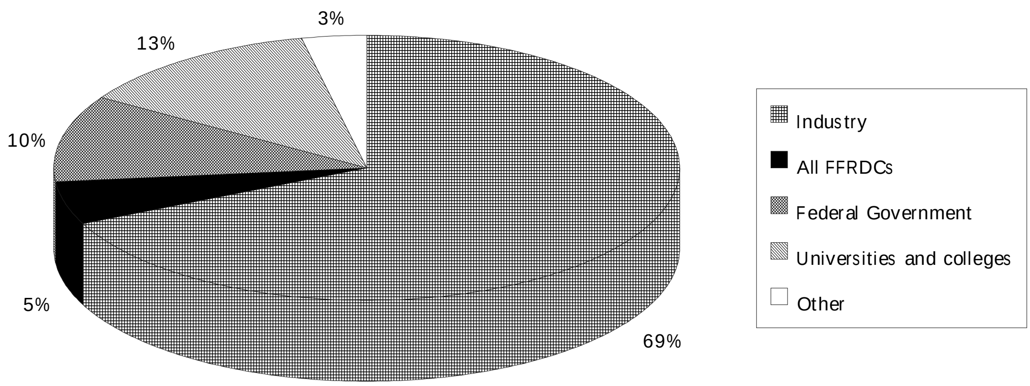
The National Science Board (NSB) has observed that Federal support for science and technology R&D is in a period of reexamination. Public debate has now focused on how best to reorient the federal effort away from traditional, primarily defence-related science and technology concerns, toward more commercial technology support. Defence conversion, dual-use technology, technology transfer, and research partnering, although not new concepts, have become more prominent as components of current technology policy. Much DOD funding is devoted to defence-wide initiatives, including dual-use technologies.

Performance of R&D

In contrast to Australia, industry is the largest performer of R&D in the United States. In total, companies performed R&D valued at about US$110 billion, or about two thirds of the national R&D effort (see figure H1), while universities and colleges (exclusive of Federally Funded Research and Development Centres (FFRDCs)) performed 13 per cent.

FFRDCs are key organisations in the performance of government-funded research. An FFRDC is an organisation exclusively or substantially financed by the Federal Government to meet a particular requirement or provide major facilities for research and associated training purposes. Each centre is administered by an industrial firm, an individual university, a university consortium, or a non-profit institution.

Figure H1: **US R&D by performing sector** 1993



Source: NSB 1993, p. 93

Total Federal R&D expenditures reached an estimated US$68 billion in 1993. This was allocated as follows:

- 46 per cent to industry (including industry-administered FFRDCs);
- 24 per cent to Federal in-house R&D performance;
- 17 per cent to universities and colleges;
- 8 per cent to FFRDCs administered by universities; and
- 5 per cent to institutions in the non-profit sector, including FFRDCs administered by non-profit institutions (NSB 1993, p. 92).

The Federal laboratories are an important part of the national science and technology infrastructure. There were about 700 federal laboratories in 1991. They are very diverse in character, and their primary mission is the fulfilment of traditional, agency-specific R&D objectives:

> It is misleading to characterize this diverse set of facilities as a federal laboratory 'system'. The laboratories include single-office facilities operated by a handful of

> people, as well as large organizations with thousands of researchers, such as the Brookhaven National Laboratory in New York. Most ... are relatively small, staffed by five to ten full time equivalent employees ... (National Academy of Sciences 1992, p. 68).

Laboratories owned or principally funded by the government received $23 billion of the $70 billion R&D spending by government in 1993. Of this, $16.6 billion went to intramural laboratories, and $6.6 billion to FFRDCs.

All FFRDCs, whether administered by university, industry or non-profit institutions, conduct R&D almost exclusively for the Federal Government. The Departments of Defence and Energy provide most of the funding for FFRDCs administered by firms and non-profit organisations and, along with NASA, provide most of the university-administered FFRDC R&D funds (NSB 1993, p. 110).

Three federal agencies account for about 80 per cent of the work of the intramural laboratories — the Department of Defence (50 per cent), the Department of Health and Human Services (15 per cent) and NASA (15 per cent). Of the basic research undertaken in government in-house laboratories, 38 per cent is funded by Health and Human Services, and 21 per cent by NASA.

A very significant proportion of R&D funded by the Federal Government is performed outside government laboratories. This is said to allow the Government to contract with the best performer available, and to encourage the development of more private research capabilities, both in terms of skilled scientists and infrastructure facilities. In this context, CRS said:

> ... almost 76 per cent of the federally funded research and development is performed not in Government laboratories or facilities, but extramurally (outside the funding agency), via grants and contracts. The pattern of pluralism in the performance of R&D funded by Federal Government enhances the government's ability to 'buy' the best performer for its research and development funds and to develop extramural research infrastructure, including the training of scientists and engineers (CRS 1994, p. CRS-12).

About 74 per cent of the industry R&D performance was financed by industry itself, while the balance (26 per cent) was financed by the Federal Government, mostly by the Department of Defence. The industry-administered FFRDCs receive substantial funding from government departments. They performed an estimated $2.7 billion of R&D in 1993, and received the bulk of their funding from the Department of Defence and the atomic energy defence programs of the Department of Energy.

Universities account for an increasing proportion of R&D performance. The share of all R&D conducted in academic institutions — excluding their associated FFRDCs — grew from 9 per cent in 1985 to 13 per cent in 1993.

Over the same period, the share held by industrial firms fell from 72 per cent to 69 per cent.

Priority setting

Federal agencies determine their budget priorities based on their mission needs, and on broader Presidential priorities. In addition, there are negotiations between agencies or departments and the Office of Management and Budget. The Office gives final approval to the Federal R&D budget, and Congress then decides whether to appropriate dollars for these or other science and technology activities.

However, with the creation of a new cabinet-level National Science and Technology Council (NSTC) (see box H1) both OMB and the Office of Science and Technology Policy (OSTP) will share power in guiding federal agencies' R&D budgets. For example, they are to collaborate in helping agencies develop R&D budgets that accord with national goals.

Each agency submits its budget to the Congress, where it is examined in both the House of Representatives and the Senate by authorising committees, for program and policy direction, and by appropriations subcommittees, which recommend funding levels to the full House and Senate for agencies, programs and sometimes specific projects.

This also enables non-government scientists to participate in the priority setting process, as non-government scientists are members of advisory panels, program planning and priority-setting groups, peer review panels, and of groups which advise the Office of Science and Technology Policy on R&D issues (see box H1).

Federal R&D support is increasingly tied to specific multi-agency initiatives. As part of an overall strategy to use science and technology to achieve national goals, the 1994 budget targeted US$12.5 billion for six Presidential initiatives, ranging from global environmental change research to science and mathematics education (NSB 1993, p.38).

Box H1: **Priority setting in the United States**

In the United States lists of ‘critical technologies’ have been compiled by several government and business organisations. These have been developed largely in-house, and there has been little community consultation associated with these studies. They appear to have had little impact on government funding of R&D.

In July 1994, the Clinton Administration released a formal statement on science policy: *Science in the National Interest*. In this statement, five broad goals were announced for US science and technology. These were maintaining leadership across frontiers of scientific knowledge; enhancing connections between fundamental research and national goals; stimulating partnerships that promote investment in fundamental science and engineering and effective use of physical, human, and financial resources; producing the finest scientists and engineers for the twenty-first century; and raising the scientific and technological literacy of all Americans. The extent to which there was public consultation in the development of these goals is not clear. A National Science and Technology Council was created to consider science and technology policy making, and the *Government Performance and Results Act* of 1993 requires agencies to develop strategic plans consistent with the national goals as well as performance reports.

National Science and Technology Council (NSTC) was established through an executive order signed by the President in November 1993. The principal purposes of the NSTC will be to establish clear national goals for federal science and technology investments and to ensure that science, space and technology policies and programs are developed and implemented to effectively contribute to those national goals.

One of NSTC’s main functions is to develop, for submission to the Director of the OMB, recommendations on research and development budgets that reflect national goals. The Council will also provide advice to the OMB Director concerning the agencies’ research and development budget submissions.

The NSTC has nine committees, which in turn break into sub-committees. The Council and its various committees are made up of Cabinet secretaries and agency heads with responsibility for significant R&D programs (such as the heads of NSF, NASA, EPA, NOAA) and key White House officials.

Sources: CRS 1994, CSIRO 1995b.

H.2 Japan

In 1991, Japan spent the equivalent of about US$102 billion on R&D. Of this, 81 per cent was funded by Japanese industry, 11 per cent by universities (virtually all government-funded research), and 8 per cent by other government agencies.

Van der Staal (1992) said that the role of the government funding has decreased as a result of budgetary restrictions and declining political support. He added that:

> The most important role the Japanese bureaucracy actually plays is the creation of networks for the exchange of information of different aggregation levels between different segments of society (p. 88).

Nevertheless, Japan operates an extensive range of laboratories through its government ministries. Many ministries are actively involved in science and technology, but in terms of available budget or influence, the most important are:

- the Science and Technology Agency (STA);
- the Ministry of Education, Science and Culture; and
- the Ministry for International Trade and Industry (MITI).

In developing policy, the Prime Minister’s office is advised by the Science Council of Japan and the Council for Science and Technology, the supreme advisory body for the formulation of policies for the promotion of science and technology, and the coordination of the policies of the relevant administrative agencies.

There are over 100 national laboratories in Japan — national research institutes (attached to government ministries and agencies), semi-government research organisations (legally distinct, but affiliated with government via budget allocations and appointments of directors), and non-profit organisations. They are very diverse, serving traditional government objectives in agriculture, defence, health, science etc. About 30 are associated with industrial technology.

Papadakis, Coker, Wang and Bozeman (1993) said that the national laboratories are ‘overwhelmingly concerned’ with providing technical assistance to their parent agencies. They add that:

> ... we must be cautious about oversubscribing to generalisations about the industrial orientation of the Japanese laboratory system ... Japanese labs are not uniformly devoted to the creation of industrial technologies or the commercial advancement of industry (p. 4).

Rather, the major emphasis is on basic research, and to a lesser extent, precommercial applied R&D. Commercial applied research receives the least attention:

> ... basic research is the highest research priority among Japanese government labs, and to the same degree as the United States. One quarter of the Japanese government labs reported basic research as their singlemost important mission, and another one-third gave it the next highest possible rating in terms of importance (p. 5).

The laboratories are funded largely by their parent agencies. However, some limited funding can also be obtained through competitive grants processes — from, for example, the STA and the Environment Agency.

The two most important agencies that control large numbers of industrial research laboratories are MITI and the STA.

Ministry for International Trade and Industry (MITI)

While the laboratories associated with MITI have long had roles in the promotion of industrial technologies, support of basic research is also an important objective for MITI, which sees this as part of its industrial technology policy. MITI seeks to increase Japan’s effort in basic research and to promote international research cooperation. In its visit to Japan, the Commission was also told that MITI is moving out of applied research, and fostering basic research which industry is unwilling to undertake.

MITI encourages interaction between industry and academia, but its emphasis is on national laboratories rather than universities. Interaction is mainly through the Agency for Industrial Science and Technology (AIST) and the 15 national laboratories attached to it, and the Japan Industrial Technology Association. A parallel system is operated by MITI with the Ministry of Education for research contracts, collaborative research and industry secondments (Phillips 1989, p. 73).

AIST was established in 1948 as a division of MITI. CRS (1994) noted that AIST programs are usually in those areas where Japanese industry is considered weak, or where no company would sponsor the research alone, or where there is an identifiable public good aspect to the research.

The Commission was advised that the programs of the AIST research institutes are about 50 per cent driven by researchers’ own proposals and 50 per cent by MITI, following consultation with industry.

Another important agency of MITI is the Japan Key Technology Centre (JKTC). The Commission understands that the purpose of the Centre is to encourage firms to undertake research which will enable them to undertake ‘frontier development’ related to these technologies. Particular areas of interest are electronics and communications technologies.

JKTC’s principal activities are of a venture capital nature, including investment in and lending to companies. JKTC lends to individual companies up to 70 per cent of eligible research outlays.

The Science and Technology Agency (STA)

The STA was established in 1956. It frames national science and technology policy, runs large-scale R&D projects, and coordinates inter-agency policies and programs. Overall, STA serves in an important advisory capacity for the government.

The STA operates under the Prime Minister's Office, and provides the secretariat to the Prime Minister's Council for Science and Technology, the leading organ for science and technology policy making. In this role, STA compiles and submits the national science and technology budget, serving both budget-setting and policy-making functions (CRS 1994).

The STA promotes industry-academic interaction through:

- the Research Development Corporation of Japan (JRDC), a special STA corporation;
- research contracts and trial manufacture contracted by STA corporations to private corporations; and through
- systems of contract and collaborative research organised by STA corporations and laboratories (Phillips 1989, chapter 3).

The JRDC is a public corporation of the STA. It initiated the Exploratory Research for Advanced Technology (ERATO) program in 1981 to foster the creation of advanced technologies and advance future interdisciplinary scientific activities.

The JRDC deals with research in the fields of biological, physical and chemical science. Research is usually carried out at the interface of science and technology. Fifteen ERATO projects had been completed by 1993 with a further 18 in progress. Each project was funded over a 5-year project lifetime. Members of project teams, who are usually university professors or research institute directors, are employed by JRDC on a renewable yearly contract basis. ERATO teams tend to be relatively youthful — the average age of directors is 42 years and that of the scientists, 30 years. About half come from industry.

All results from projects are the common property of JRDC and the project team, with patent rights being shared equally. JRDC holds between 600 and 700 patents in Japan and between 200 and 300 foreign patents.

The JRDC also supports basic research through the Precursory Research for Embryonic Science and Technology program (PRESTO). This was set up in 1991 to enable creative individuals to conduct basic research around their ideas. While the research fields to be supported are selected by the JRDC, these are very broadly specified. If research undertaken under PRESTO appears promising, it may subsequently be taken up under ERATO.

JRDC also serves as a broker between researchers (at universities and national laboratories) and industry. The Commission understands that it first collects research results and then assesses development (essentially technical) risks associated with developing each result in industrial contexts. If the risk is low, technology transfer facilitation occurs with the JRDC playing an intermediary role and helping prepare development contracts. In this case the company develops the project, with the researcher providing guidance.

However, if the risk is considered to be high, the research results end up in the JRDC's Cooperative Technology Development unit, which then publicly seeks corporate interest in developing and selecting suitable candidates, and offering development funding. The development funding takes the form of an interest-free loan. If projects are not technically successful, the development funds loaned do not have to be repaid, otherwise the loan is repaid in instalments over 5 years plus royalties (but how stringently this requirement is enforced for cooperative Japanese subsidy programs is unclear — see Mowery 1993, p. 27). The success rate of the projects has been very high, with 90 per cent being technically successful. Commercial success is harder to judge, but short-run initial profitability is achieved in about 20 per cent of cases.

H.3 United Kingdom

Funding of government research

In 1991–92 UK expenditure on R&D was about £12 billion. Business expenditure was about two thirds of this.

The UK Government funded over £5 billion on R&D in 1991–92: 45 per cent of this was spent by the Ministry of Defence. Of the rest, 20 per cent was spent by civil departments, 19 per cent was channelled through the higher education funding councils for block funding of tertiary institutions, and 17 per cent was allocated to research councils to be spent by them on programs of research in particular areas of science and technology.

The government sector *performed* about £1.6 billion of the research, much of it in a large number and wide variety of government research agencies. Most agencies are affiliated with either a departmental 'customer' or one of six Research Councils. Some receive funding from multiple sources.

A brief history of arrangements for government research agencies

The methods of funding of research performed in the government sector reflect a number of key historical developments.[1]

Research agencies were first grouped together in 1916 when the Department of Scientific and Industrial Research (DSIR) was set up. Its purpose was to undertake research which was the responsibility of no single existing Ministry. Ministerial responsibility was taken by the Lord President of the Privy Council, allowing greater independence than for normal departments.

The DSIR had its own laboratories for performing research, set up cooperative laboratories with industry and provided research grants to students and staff. Staff were employed as civil servants.

In 1920, the Medical Research Council (MRC) was established under similar arrangements and with its own employees. This was followed by the establishment of the Agricultural Research Council (in 1931) and the Nature Conservancy (in 1949). Together with the DSIR and the MRC, these bodies became known as the four 'research councils'.

At the same time departments were also conducting their own research on matters which concerned them exclusively. Large performers included the Ministries of Agriculture and Fisheries, Health, Fuel and Power, the Post Office, the Colonial Office and the Service Departments.

A significant reorganisation of the performance of R&D in the government sector occurred in 1964. The research councils were brought under the direct control of the Secretary for State for Education and Science. A Natural Environment Research Council (NERC) was set up, based on the Nature Conservancy, but with some functions of the DSIR. DSIR was divided, and a new Science Research Council established out of one part, with the rest of the laboratories going to form a new Ministry of Technology.

The new Ministry of Technology was initially small. It comprised mainly the Atomic Energy Authority, the National Research Development Corporation, and the so-called industrial research establishments of DSIR; it also had responsibility for the industrial research associations for the machine tool, computer electronics and telecommunications industries. The inclusion, over the next few years, of researchers from other areas (including the old Aviation Department) increased its size substantially, adding (among other things) sixteen research establishments, two factories and establishments concerned with shipbuilding and motor vehicles.

1 This section is based on Gummett (1980).

As arrangements for the machinery of government changed, establishments initially in the Ministry of Technology became, in turn, part of the Department of Trade and Industry, the Department of Industry and eventually the Department of Trade and Industry again.

The Report of Lord Rothschild in 1971 (Rothschild 1971) marked the next policy turning point. He made two major recommendations that affected the operation of government research agencies:

- departments with a significant interest in science and technology should appoint Chief Scientists to advise on scientific matters and a Controller R&D to administer and execute policy; and
- a customer-contractor relationship should be set up for applied research conducted in government.

For laboratories attached to departments, the Rothschild report lent strong support to moves that were already underway to make them more accountable. For research councils, Rothschild recommended a transfer of 25 per cent of their budgets — the amount identified as funding applied research — to departmental 'customers' to purchase research from the councils.

Although the transfer of funds was implemented, departments had some difficulties initially in specifying their requirements. In the case of medical research, some funds were eventually returned to the MRC by the Department of Health and Social Security.

The customer-contractor principle has continued, however, to guide the performance of government research. In its recent White Paper, entitled *Realising Our Potential*, the Government concluded that the 'Rothschild principle' remains as valid today as 20 years ago.

So far as research commissioned by departments is concerned, the Government now sees the principle being implemented in the form of a completely competitive processes:

> ... the utility and quality of research needed by civil Government Departments are best guaranteed by leaving them free to determine their own needs and commission the work from suppliers who compete to meet their specifications (White Paper 1993, p. 42).

For Research Councils, the Government appears to have moved away from relying on Departmental customers as the main customers for applied research. It now stresses the Councils' own responsibility to identify the needs of users and to support research which contributes to wealth creation.

The current structure of research arrangements

Research councils

Research Councils vary significantly in their functions, funding levels and relationships with other entities. Many maintain substantial responsibilities for funding laboratories and institutes in which they directly employ researchers. Others contract a great deal of research to university researchers and institutes. Some Councils have an important role as funders of the higher education system.

All Councils receive significant block funding grants from the Office of Science and Technology. However, they vary in the extent to which they rely on income from external sources such as departments, industry and other Councils.

The extent of variation among Councils is illustrated by the following observations about funding sources and expenditure:

- the Economic and Social Research Council (total expenditure £35.6 million in 1991–92) received almost all its funding as a block grant and distributed almost all of it to higher education institutions;
- the Agricultural and Food Council (total expenditure £110.1 million in 1991–92) received forty per cent of its funding from external sources and spent nearly 80 per cent of its total funds in its own institutes;
- the Medical Research Council (total expenditure £221.3 million in 1991–92) received less than 10 per cent from external sources and spent about 60 per cent in its own institutes and about 30 per cent in higher education institutions;
- the Natural Environment Research Council (total expenditure £160.1 million in 1991–92) received over one quarter of its funds from external sources and spent over 80 per cent in its own laboratories;
- the Science and Engineering Council (total expenditure £458.0 million in 1991–92) received less than 10 per cent of funds form external sources and spent about half in higher education institutions, about one quarter in its own laboratories, observatories and institutes, and about 20 per cent in international science programs.

A number of Councils participate in the LINK program which sponsors pre-competitive research in cooperation with industry. Following the White Paper, Councils will be expected to look more closely at the needs of users in framing research programs.

Civil departments and agencies

Consistent with the customer-contractor principle, research agencies which have been affiliated with departments are increasingly being established at arm's length. Box H2, taken from the White Paper, lists agencies which are now expected to cover their costs with charges which they make to their customers. These agencies are also encouraged to compete for business from other public sector customers.

The White Paper summarised the relationship between departments and agencies in the following way:

> Since 1989, the Government has taken a number of measures to strengthen the customer-contractor relationship. Responsibility for commissioning research and development has generally been placed with the relevant policy divisions of Departments tapping into the intelligence built up by the Chief Scientists' groups and equivalent arrangements within Departments. These divisions hold a budget, which they use to implement their decisions on the research and development they need to meet their policy objectives. They draw up specifications and enter into contracts with the suppliers whom they judge can best deliver to specification. The divisions are expected to mount competitive tenders wherever practicable, and to seek value for money. In addition, Chief Scientists take a strategic overview of the contribution of science and technology to policy development over both the long and short term.

The Government has stated its belief that 'privatisation is a realistic prospect for a number of [government research] establishments' (White Paper p. 46). However, it recognises that there are other establishments for which privatisation is not currently feasible.

Contributions to Research Councils by Departments now appear generally to be a relatively small proportion of their expenditure. Exceptions include the Ministry for Agriculture, Fisheries and Food (which contributed £40 million out of a total budget for research of £140 million in 1991–92) and the Department of the Environment (which contributed £7 million out of a total budget of £94 million in 1991–92).

Defence research

Defence research is commissioned mainly from the Defence Research Agency (DRA). The DRA is expected to earn sufficient revenue to achieve a real return on assets of 6 per cent.

The customer-contractor principle is followed consistently in Defence. Each of the two main defence research programs has a nominated defence customer: in the case of the Strategic Research Program, the Deputy Chief Science Adviser fills this role and in the case of the Applied Research Program, it is the Deputy Chief of the Defence Staff (Systems). Both are advised on future needs and evaluation of programs by an extensive committee system involving both military and independent advice.

Box H2: **Science and technology agencies expected to cover their costs from customer charges**

Agency	**Department**
Central Science Laboratory	Ministry Of Agriculture, Fisheries And Food (MAFF)
Central Veterinary Laboratory	MAFF
Agricultural Development And Advisory Service	MAFF/Welsh Office
Scottish Agricultural Science Agency	Scottish Office
Transport Research Laboratory	Department Of Transport
Defence Research Agency	Ministry Of Defence (MOD)
Chemical And Biological Defence Establishment	MOD
Meteorological Office	MOD
Building Research Establishment	Department Of The Environment
Forensic Science Service	Home Office
Natural Resources Institute	Overseas Development Administration
National Engineering Laboratory	Department Of Trade And Industry (DTI)
National Physical Laboratory	DTI
Laboratory Of The Government Chemist	DTI
Warren Spring Laboratory	DTI

Source: UK White Paper 1993

In the White Paper the Government indicated that industry would be expected to play a greater part in meeting defence research needs in the future as more competition is introduced into the spending of defence research funds. It anticipated that the proportion of research performed in the private sector would rise from one quarter in 1992–93 to about two-thirds by 1997–98.

The Ministry is said also to be making defence technologies more available for civilian use and to be encouraging the use dual technologies in defence applications.

Priority setting

The UK's foresight program is discussed in part G of this Report. The process is intended to bring together those with a stake in science and technology and to inform the government's decisions and priorities.

A central purpose of the foresight program is to make government a better purchaser of research so that research will have a greater pay-off for the community. Among other things Foresight is intended to inform purchasers in departments and Research Councils about how funds should be allocated.

The proposed annual Forward Look will assess the type of work best suited to the longer term needs of the country and the extent to which current publicly supported R&D meets these needs. It will assist allocation among and within programs.

H.4 Germany

In 1992, the German national R&D budget was DM80.7 billion. Of this, 59 per cent was funded by industry, 22 per cent by the Federal Government, and 16 per cent by the States.

The German science and technology (S&T) policy making system reflects the impact of the independent, laboratory system (the National Laboratories and the research institutes of the Max Planck and Fraunhofer Institutes) and the strong involvement of the German States in research. A cooperative structure exists to guide the R&D process. It is directed at the ministerial level by the Ministry of Science and Technology.

Current policy emphasis is on applying R&D to enhance Germany's economic and competitive standing while protecting its environment and health (CRS 1994, p. CRS-17).

The German States are significant funders of R&D, and national S&T policy is a cooperative effort between the Federal Government and its ministries, the States, universities, industry and independent research societies and institutes.

As in the United States, industry in Germany funds and performs more than half of the nation's R&D. In 1992, about 66 per cent of German R&D was *performed* by its industrial sector and 16 per cent by universities (CRS 1994,

p. CRS-20). R&D is conducted by industry, universities, and the Federal Government and also by some State research institutes and a number of important independent research agencies (such as the Max Planck Institute and the Fraunhofer Institute).

The Government's S&T policy is carried out primarily by the Federal Ministry for Science and Technology through a range of Federal, State, and independent organisations. The Ministry conducts no R&D itself. However, it funds about 51 per cent of Federally-funded R&D, with most of the remainder accounted for by the Ministries of Defence (17 per cent), Education and Science (9 per cent), and Economics (7 per cent). Much of the R&D financed by the Ministry of Defence is performed by industry.

Government-supported research institutions

Research institutions supported by the Federal Government cover the whole range of research from basic to applied research. The 16 National Research Centres are a central element of the German strategic research scene (German Ministry for Research and Technology 1993, pp. 32–3). These are funded on a block basis, and:

- provide large-scale equipment for research;
- manage technical infrastructure; and
- provide concentrated capabilities for handling complex interdisciplinary issues.

They cooperate with universities in important areas of basic research, handle national programs in international cooperative projects, investigate central issues of environmental and 'preventive research', and contribute to technology development focusing on issues of public interest.

The Max Planck Institute for the Advancement of the Sciences concentrates on basic research in selected areas of the sciences and humanities. It is funded on a block basis, and currently operates 62 research facilities in the States of the former West Germany and 39 research facilities in the States of the former East Germany. It is funded both by the State and Federal governments.

Fraunhofer Institutes

The Fraunhofer Institutes are the main facility for applied research in Germany and the primary vehicle for Germany's contract research system. In jointly funding the Fraunhofer Institutes (FhG), the Federal and State governments aim to promote the practical application of scientific findings in the area of applied research. FhG covers some 50 institutes of varying size and has 8 000 employees. It is managed by an Executive Board, advised internally by a Scientific and Technical Advisory Board and externally by a Board of Trustees.

The institutes are an important partner of industry, performing contract research, offering information and services relating to new technologies, products and processes and providing training courses for qualified personnel. To maintain strong links between business and academia, directors of the FhG are business managers with proven entrepreneurship who often, at the same time, occupy the position of professor at regional universities.

The FhG receive institutional funding from government sources, under long term contracts either for the government or the private sector, and under short ‘problem solving’ contracts with individual companies or industry associations. About one third of the FhG budget is public ‘basic funding’ and the remainder comes from contract research. (ASTEC 1994e).

The FhG provide an example of a publicly supported research agency that is reliant on contracts for a majority of its funding. In this way, the priorities of the FhG are mainly driven by their funders — an average of 70 per cent comes in payments for technology by industry or in directed grants from government.

ASTEC noted that a 1992 government review of FhG funding stressed the need for a stronger orientation to industrial demand and reduction of the proportion of public funding for the institutes in Western Germany. The responsible Minister commented that:

> ... the success of the FhG is measured in terms of the application if its results in industry and ... income from industrial contracts is the most important parameter of success (Reisenhuber 1992).

On average the institutes for industry-related contract research in western Germany are expected to increase their income from industry from 35 per cent in 1991 to at least 40 per cent by 1995.

Priority setting

Germany has taken three major steps in the development of a research foresight policy. The first was in 1990 when, faced with the high costs of reunification, the Ministry of Research and Technology set up a committee to analyse the balance of ministry spending on basic science, and determine whether new priorities were needed, taking account of increasing collaboration within Europe (Cabinet Office 1993, ch. 9).

One reason for establishing the committee was a rapid rise in the proportion of the ministry’s budget devoted to basic science. Another was that the heavy investment in 'big science' areas of physics had peaked several years earlier, allowing for consideration of other priorities.

The committee drew up a list of research topics to be given greater priority. These included seven topics in life sciences, five in environmental and earth sciences, two in information technology and computing, and none in physics. While the committee's approach could be characterised as more 'science-push' than 'demand-pull', it provides an example of priority setting at the national level.

In a second initiative, the Fraunhofer Institute for Systems and Innovation Research (FhG ISI) is collaborating with the National Institute for Science and Technology (NISTEP) of Japan in a DELPHI process. FhG ISI conducted an identical survey to Japan's Fifth Technology Forecast Survey in 1992–93. It has agreed with NISTEP to exchange the German responses in return for using the Japanese questions. This exchange will enable comparisons to be made between the views of German and Japanese experts and determine whether the answers depend on national research and innovation systems.

H.5 Canada

In 1992 Canadian expenditure on R&D was about C$10 billion. About 40 per cent was financed by business, 45 per cent by government and about 10 per cent was financed from abroad.

The Department of Industry plays an important role in science and technology (S&T), as several research and funding agencies report through it to Parliament. Influential national organisations are the National Advisory Board on S&T, Parliamentary Committee on S&T, Governing Council of NRC and private groups including Business Council and Chamber of Commerce (CSIRO 1995b).

National Research Council of Canada (NRC)

The NRC is the principal research agency of the Canadian Federal Government. In 1993–94, it had a budget of about C$467 million. The NRC accounts for about 10 per cent of federal expenditures on science and technology.

It carries out a wide spectrum of activities which include the performance of scientific and engineering research in response to national, economic and social needs; the provision of financial and technical assistance to industry; the establishment and maintenance of standards; the provision of national scientific and technological facilities for industry and the universities; and the operation of a nationwide network of scientific and technical information services. About 40 per cent of NRC's research is focused on applied areas.

While NRC is block funded through a Government appropriation, its activities are guided by the needs of external clients. It is involved in many collaborative research agreements.

The NRC carries out the bulk of the research in its own laboratories. For example, in 1993–94, research projects undertaken by the Council laboratories accounted for about 76 per cent of expenditure while industry performed 12 per cent.

Industry links and dissemination of research findings

NRC promotes partnerships and collaborations to ensure that its research programs complement those of other R&D performers. In 1992–93, NRC's research institutes reported 1400 interactions involving more than 1800 partners and clients (such as representatives of the key sectors of the Canadian economy). These collaborations contributed over C$50 million to NRC funds in the same financial year (NRC 1993). Interactions ranged from informal collaboration and formal joint venture agreements, to the provision of R&D services. The percentage distributions are as follows (NRC 1993, p. 8):

- collaborative R&D projects — 59 per cent;
- provision of R&D services by NRC staff — 18 per cent;
- the use of testing facilities and analysis — 14 per cent; and
- long term strategic research and activities related to facilities — 9 per cent.

NRC disseminates its research findings in a number of ways, including publications, reports, and presentations to professional organisations. The NRC said that its research productivity is represented by its performance in terms of number of publications, reports, and presentations to professional organisations. In 1992–93, NRC's researchers produced more than 1700 publications, reports, and books. NRC staff made some 1400 presentations to conferences and participated in over 900 national and international committees. NRC believes that presentations and conference participation can be seen as indicators of the relevance of NRC's work, the external interest in NRC's achievements and recognition of its value (NRC 1993, p. 6).

H.6 New Zealand

Compared with other countries, a large proportion of New Zealand's total R&D expenditure is funded by the public sector. Of the total R&D expenditures of

NZ$640 million in 1990–91, about 64 per cent was expended by the public sector (including the Public Good Science Fund, higher education and government departments).

The management and organisation of government-funded science has changed considerably in New Zealand over the past five years. A key element has been the organisational separation of government's involvement in science and technology policy, science funding and the carrying out of R&D.

Prior to these reforms, most of the scientific and industrial research was done in the science divisions of the Department of Scientific and Industrial Research (DSIR), Ministry of Agriculture and Fisheries, Ministry of Forestry and the Meteorological Service. The Crown Research Institutes (CRIs) which now do most of the scientific and industrial research, and were formed from the science divisions of these bodies, are discussed below.

Policy making

Science policy is decided by Cabinet based on the recommendations of a Cabinet Committee. The Cabinet Committee, in turn, is advised by:

1. the Ministry of Research, Science and Technology, whose function is policy advice and funding (or the purchase of science),
2. the Royal Society of New Zealand (representing individual scientists), and
3. the Foundation of Research Science, and Technology (the Foundation is an independent statutory authority established in 1990 whose primary function is the allocation of funds for R&D which falls within the definition of 'public good science and technology[2]'). Universities get their funding for research separately, mainly through the Budget Education Fund.

The Government has two Ministerial portfolios with specific responsibilities for science and technology. These are Research, Science and Technology (RS&T) and the CRIs. The CRI portfolio covers the Government's ownership interest in

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2 New Zealand defines public good research as producing outputs that:

- are likely to increase knowledge or understanding of the physical, biological or social environment; or
- are likely to develop, maintain or increase research skills or scientific expertise that is or are likely to be of particular importance to New Zealand; or
- may be of benefit to New Zealand, but unlikely to be funded, or adequately funded, from non-government sources (*Foundation for Research, Science and Technology Act 1990*).

CRIs. Both these portfolio responsibilities fall to the Minister of Research, Science and Technology.

Certain other Ministerial portfolios have a minor, and indirect, advisory role, as has the Ministerial Advisory Group, whose members are appointed by the Minister of Research, Science and Technology.

Setting research priorities

The Government is required by law to set priorities for public good science and must issue a priority statement at least once every three years. The current priority statement sets out 5-year funding targets for each of 24 science areas.

In 1992, the Government approved the first long term priority statement for public good science. The statement has bipartisan support.

> It sets out a series of strategic goals that include establishing a balanced research portfolio, in terms of both short term and long term research and research areas; promoting value added in New Zealand's productive sectors; and the interlinking of public good science funding (PGSF) with private sector funding to maximise mutual (and thus national) benefit (Ministry of Research, Science and Technology 1993).

The Science and Technology Expert Panel (STEP), a group of 15 people representative of a diversity of interests and science and technology related skills, was central to the process of priority setting in the first round in 1992. STEP, in a process of extensive consultation produced a *Statement of Science Priorities* in 1992 (Minister of Research, Science and Technology 1992, p. 4).

The *Statement of Science Priorities* in 1992 included the setting of priorities for research by groups of output classes, funding levels by output class and establishing priority research themes. Priority themes were developed at three levels:

- generic themes, such as sustainable development, applicable to a large number of output classes;
- cross-output themes, such as climate change, on specific topics and naturally linked groupings of outputs; and
- specific output class themes of key importance which have not been considered elsewhere.

On 10 May 1994, the Minister of Research, Science and Technology announced a review of government priorities for investing in science and technology for the second priority statement (for 1995–2000). The review, which will identify the level of funding for different areas of research, began in June 1994 and ends in mid-1995.

The review process is being carried out in several phases by different independent Ministerially-appointed panels with overlapping membership. The Minister will appoint a Strategic Consultative Group (SCG) to develop the Strategic Statement, in consultation with key stakeholders (users, providers, funders and policy makers). A New Priorities Panel was to produce a final report to the Government by April 1995, and the Government is to release its final priority statement a month or two after that, identifying the amounts of funding to be distributed to different areas of science and technology. The priorities will guide FORST as it develops strategies for funding research at a more detailed program level.

In October 1994, the SCG released a strategic statement *For the Public Good, Directions for Investment through the Public Good Science Fund*. The Strategic Statement represents the SCG’s vision of where New Zealand’s long term economic, social and environmental interests lie. It was developed through the SCG’s own analysis, discussion and reading of over 80 submissions on a draft statement.

After the SCG statement has been agreed to by the Government it will be submitted to a New Priorities Panel, which, using a consultative process as well as panel members’ judgment, will develop the new Priorities Statement. This statement will contain recommendations for specific amounts of funding for each of 17 output classes (fisheries, agriculture etc). The Foundation for Research, Science and Technology will then develop a research strategy for each of the output classes.

Contestable funding

The Foundation is the Government’s agent for the purchase of public good science outputs. It is the task of the Foundation to allocate the Public Good Science Fund (PGSF) so that the Government’s strategic intentions for science as set out in the priority statement are most efficiently and effectively met.

The PGSF is the largest source of public research funding in New Zealand and is the primary means whereby the government invests in science. About 60 per cent of the Government’s total research expenditure is channelled through the PGSF and allocated by the Foundation.

For 1993–94 the Government budgeted $NZ275 million for the PGSF. Total government spending on R&D&T in 1990–91 was around $NZ400 million.

A key element of the new system is the way funds are allocated through the PGSF. After communicating priority themes to the Foundation, the Government expects the Foundation to translate these into research strategies. C*ompetitive* proposals in the different output classes are invited, that is, *funding is contestable*. All eligible research organisations or researchers seeking to carry out public good research can apply for funds. The PGSF is accessible to all comers within New Zealand, including, progressively, the universities.

The Foundation is required to consult extensively with a wide range of stakeholders in this task and advise the content of each strategy to the Government prior to implementation. Information and technology transfer should be important considerations in every research proposal funded through the PGSF. Each strategy should include a consideration of the level of private sector and non-PGSF funding proposed or expected in that area of science.

The PGSF is required to categorise funded programs into fundamental, strategic and applied research, and experimental development in each output class and the results are to be made publicly available.

The PGSF provides the interface between all those carrying out, or involved in some way in, public good research, including the private sector.

PGSF also allocates funds for the Technology for Business Growth[3] scheme and for Science and Technology Fellowships.

Criteria for the selection of research proposals

In selecting research proposals the PGSF has to ensure amongst other things that the proposals:

- comprise priority public good science outputs that can be monitored;
- have scientific and technical merit;
- include collaboration between scientific providers (where practicable and appropriate); and
- that the proposed science output has a reasonable chance of being delivered to the standards required.

3 This scheme is administered by the Foundation for Research, Science and Technology and consists of four interlinked programs: Cooperative Research Program, Technology Joint Venture Program, Technology Transfer Program and the In-House R&D Program. These programs are all based on joint government-private sector funding arrangements. The Technology for Business Growth Program invests a total of about NZ$11 million in research and technology projects with commercial outcomes. The program's preferred investment in individual projects ranges from NZ$8 000 to NZ$500 000.

R&D operations

Crown Research Institutes

On 1 July 1992, 10 CRIs[4] were established under the *Crown Research Institutes Act 1992*. The CRIs are owned by the Government, and have a 'scientific purpose', that is, the Government expects a 'science dividend' (net benefits from science) rather than a 'financial dividend'. CRIs are limited liability companies, each having a Board of up to nine directors appointed by the Government. The shareholders are the Minister for CRIs and the Minister of Finance. The company structure allows CRIs to borrow funds, to form joint ventures and subsidiary companies.

Each CRI is based around a production sector of the economy or a grouping of natural resources, to enable a clearly defined purpose and client base. The groupings are sector based CRIs (five CRIs covering research in agriculture, horticulture and food, crop and food, forest, and industrial research and development), resource based CRIs (three CRIs covering research in landcare, water and atmosphere — now to include fisheries, and geological and nuclear sciences), and one CRI to cover environmental health and forensic sciences.

Funding is allocated through the PGSF. The development of research strategies by the Foundation helps the CRIs orientate their research plans and make bids for research work such that they can try to maximise their revenues from the PGSF.

Government departments and universities

Some departments still carry out their own research. This occurs where such research 'supports the development and effective implementation of policy and research that contributes to the performance of a regulatory function' (Ministry of Research, Science and Technology 1993). This research is funded through departmental appropriations. Departments with substantial research capabilities are the New Zealand Defence Force, the Department of Conservation and the Ministry of Agriculture and Fisheries.

Tertiary education research are participants in the PGSF on a limited basis only, but the aim is full participation by 1996–97. However, the majority of funding for university research will continue to come from sources other than the PGSF.

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4 The number of CRIs has now been reduced to nine with the closure of the CRI on social research and development.

Some views about the New Zealand reforms

The New Zealand model has been controversial within New Zealand and Australia, and the Commission visited New Zealand to review its effects. Much of the controversy is linked with the effects of splitting the activities of the Department of Scientific and Industrial Research (DSIR) and some departmental research arms into the Crown Research Institutes (CRIs).

Over the decade prior to these changes being implemented, government expenditure on science had fallen by about 30 per cent. This was said to have reflected a large and growing national debt, loss of confidence in the value of government science, and dissatisfaction with the perceived scientist-driven nature of the output.

Critics argued that the current process of research priority setting (which includes industry and other user groups) is unduly driven by market opportunities, and does not give sufficient weight to scientific or technical opportunities. Others argued that consultation had been limited and that the review panel was insufficiently representative of the interests of scientists and consumers.

There is also concern that basic research is being under-funded relative to market-driven research, that the emphasis on applied R&D has led to a significant fall in the acquisition of new knowledge, and that there is an undue emphasis on short term, low risk projects. However, the counter view put to the Commission was that funds are allocated to areas of national research priority, on the basis of what will generate the best net value to the community. The priority system could be designed so as to achieve a balanced research portfolio.

Allocation of funds to priority areas *per se* says nothing about the relative merits of funding basic versus applied research. The need for basic or applied research may be judged in terms of the potential to benefit New Zealand. The Chief Executive of the New Zealand Institute for Crop and Food Research said that under the new system there is support for strategic basic research of relevance to the industry he serves.

Several of the heads of CRIs with whom the Commission met also said that the CRIs had strong incentives to undertake public good research that was useful to industry, and to quickly transfer to industry any new technology developed. They said that more technologies are transferred to industry now than previously. By serving users, they can also obtain funding from FORST because their research is seen to be ‘relevant’. In addition, they receive payment (and further work) from users.

While some argue that having separate CRIs has made cooperation and collaborative research more difficult than when they were part of a multi-disciplinary organisation, FORST said it encourages cooperative research proposals where this is beneficial to the community. In some research areas, the CRIs themselves seek to collaborate with others, including other CRIs, to generate better research proposals (which are more likely to be funded).

The costs of the new system, which requires bidding for funding, assessing, reviewing and auditing research proposals, and establishing contracts with FORST, have been alleged to be very high. Some have argued that it generates more costs than benefits — especially given the administrative burdens of the bidding and reporting process. This was said to have undermined staff morale, especially as some scientists have lost portability of benefits, rights of appeal and in some cases, their jobs. And it is alleged that less science is being undertaken.

Some have cited an additional cost of about 25 to 30 per cent of PGSF funds (NZ$85 million a year), which is alleged to be spent largely on additional bureaucracy (to make bids, assess the bids, administration and auditing costs). The Commission discussed these costs with officials and others in New Zealand, and it became clear that there are no reliable estimates of the actual costs of either the current or the previous arrangements. It was also stated that the first year's costs were more than usual because of the quick adjustment path to reforms chosen and the learning costs involved.

That said, it does appear likely that the new assessment system is more costly than the less formal system of allocating funds which it replaced. Previously, block research funds were allocated to DSIR and the Ministry of Agriculture and Fisheries. But there were difficulties with this approach, and supporters of the new system argue that the higher administrative costs are justified by the sharper focus the process has brought to tailoring research programs to actual priority needs. The broader costs of allocating research funds badly can be very high.

It is difficult making judgments about the success or otherwise of the New Zealand experience because of the short time it has been in existence. It has generated much public debate. Some adjustments are already occurring — for example, one of the CRIs (New Zealand Institute for Social Research and Development Ltd) has since closed down. While criticisms continue to be made of particular changes, almost everyone the Commission spoke to did not wish to return to the previous arrangements. The reforms enjoy bi-partisan support and Government funding for science is now increasing again.

H.7 Taiwan

Total expenditure in Taiwan in 1990 was US$2.5 billion, of which business undertook slightly more than half.

The Taiwanese government has set up two institutions to assist firms in a range of industries to overcome problems associated with conducting R&D, training, and marketing: the Industrial Technology Research Institute (ITRI) and the Institute for the Information Industry. Of the two, ITRI is the closer to CSIRO in its organisation.

Industrial Technology Research Institute (ITRI)

ITRI was set up in 1973 under the direction of the Ministry of Economic Affairs. It has five major divisions to support the development of various industrial technologies (Industrial Technology Research Institute 1992). ITRI has over 6000 staff, organised in five major divisions and some eleven laboratories and technical centres.

Funding and the bidding process

ITRI is funded by government on a project/program basis rather than through a block allocation. In theory, ITRI has to compete for funding from the government. However, in reality, ITRI has little competition in supplying research of the kind funded by the Government.

In addition, ITRI competes for money for research projects funded by industry. Competition is more vigorous in this area because industry often has its own research facilities as alternative sources of supply.

R&D projects contracted by the government totalled 69 per cent of operating revenue for the year. The balance of revenue came from industrial services and technology contracts with private industry. ITRI however aims to achieve half its funding from the private sector.

Technology transfer and links with industry

ITRI usually takes the initiative in working with industry to form R&D consortia with private sector companies already in the field.

ITRI encourages spin-off companies — the Commission understands that ITRI has spun-off 12 new companies (of which two subsequently failed). ITRI has a very applied research orientation and implements charging/royalty practices for technology transfers to private firms. It is common for ITRI to develop significant contract research activities with private enterprise.

Boxes H3 and H4 provide some information about ITRI's intellectual property, technology transfer (including dissemination) and other linkages with industry.

Box H3: **Industrial Technology Research Institute, Taiwan**

In 1992, ITRI was granted 274 domestic and foreign patents, transferred 143 technologies to 217 companies, carried out 419 contracts or joint research projects with 691 companies, and provided many industrial technical services. ITRI also contributed to 11 major investment projects involving 36 participating companies in the following industry sectors: computers and computer peripherals, communications, machinery, materials and chemistry.

ITRI set up two task force groups in 1992 in accordance with government initiatives. The objective of the first group was to establish manufacturing capacity for key components and devices to narrow the trade deficit with Japan. A total of 29 key components were targeted for development. The objective of the second group was to assist a total of 67 technical service companies by enhancing their capability to offer assistance to the 80 000 SMEs throughout the country. Service companies operating in the fields of automation, energy conservation and environment protection have been targeted for assistance in the first phase of this program. ITRI operates a total of 11 laboratories and technology centres, as well as an industrial technology investment centre.

Source: Industrial Technology Research Institute 1992.

Box H4: **Electronic Research and Service Organisation (ERSO)**

ERSO is one of the laboratories operated by ITRI. It has two major tasks to perform in its role of facilitating the transfer of technology: to develop needed technology for the industry; and to diffuse the developed technology among the industry's firms. There are various mechanisms that ERSO can use to diffuse new technology, including issuing technical documents and organising conferences for electronic firms in Taiwan.

Furthermore, the new technology can be transferred to individual firms through licensing agreements where royalty charges are levied on recipient firms, once they employ the technology. If, however, the developed technology has marketing potential and there is the desire to set up a new joint venture to disseminate the technology, then a new spin-off venture company would be established by ERSO.

It is important to note that although the spin-off company is supported by ERSO's engineers and its funding is provided by the government, the venture company is cautiously organised as a privately owned company. Both the technology endowment received from ERSO and the capital endowment supplied by the government are aimed at attracting investment from the private sector. It is hoped that the private sector can account for at least 60 to 70 per cent of the total shares of the newly established venture company.

Source: Nelson 1993, p. 397.

The Commission understands that ITRI charges very little for its research outputs, emphasising the public good nature of its research, and a preference for a more indirect return on taxpayers' funds through job creation and income generation (and consequent taxation revenue).

One of the laboratories operated by ITRI is the Electronic Research and Service Organisation (ERSO). ERSO has a critical role in the technological development of the electronics industry (see box H4).

In setting up technology transfer companies, ERSO provides strong incentives for the new company to develop new technologies. Since the companies' new technologies will be supported by the same group of engineers who developed them within ERSO, the companies can be in full operation within a very short period of time, and they can respond rapidly to changes in the external environment. Thus privately owned venture companies can serve as conduits to diffuse new technology.

Priority setting

For projects funded by government, research ideas tend to originate within ITRI These projects however are subject to rigorous screening both internally — President and Vice-Presidents provide something close to peer review — and externally through the Ministry of Economic Affairs (MOEA).

In its visit to Taiwan, the Commission was told that ITRI Board has recently set broad directions for the Institute, emphasising:

- that ITRI works for the benefit of the industry;
- the need to serve SMEs; and
- the need to develop breakthrough work — developing advanced technology not in wide use even in advanced countries (the plan is to allocate 10 per cent of ITRI's resources to this objective within 3 years).

The Board has also decided to quickly reduce the emphasis given to technologies now widely used in advanced countries and already in use by technological leader firms in Taiwan.

ITRI's work relates largely to industry, and aside from public good work in this area, it appears to do little broader public good research in other areas such as those relating to the environment.

The Commission understands that in the Ministry of Economic Affairs, Review Councils of 15–20, comprising half from industry and half from university professors, review proposals in specific areas (such as mechanical or chemical engineering). The Ministry then makes recommendations to the Minister, based heavily on the recommendations of the Review Councils. After approval by the Minister, it is scrutinised by the legislature which has the power to cut funding.

Within this process, ITRI absorbs 70 per cent of the MOEA's R&D budget (currently $US220 million) and consequently, MOEA is very influential in determining directions at ITRI. However, ITRI's President and Chairman appear to have direct access to the Minister, so that if they feel strongly about particular projects or issues and they can try to have the Ministry's recommendations overturned.

MOEA tends to put more funding into projects related to industries which it wishes to promote, such as industries making components critical to reducing the trade deficit with Japan, from which Taiwan imports many components.

H.8 Korea

R&D expenditure by (South) Korea amounted to US$5.3 billion in 1990. Business expenditure was almost three quarters of this.

The Korean Institute of Science and Technology (KIST)

KIST was established in 1966 as the first government funded multi-disciplinary research organisation (it was originally modelled on Australia's CSIRO). It has largely done applied research under contract, mainly to Government but also to industry.

KIST originally covered a wide range of research activities, but has since been separated from the Korean Advanced Institute of Science and Technology (KAIST). It is now expanding its basic research capacity and has recently received $6 million from the Government under the 'KIST 2000' program to enhance basic research, and is now:

> ... committed to distinguishing itself as a revamped research institute dedicated to basic research of science and to the development of future-oriented 'cutting edge' technologies (KIST 1993, p. 4).

Block funding from the Government does not cover all research projects. Typically KIST puts up proposals for such projects to Government which decides whether to fund them. KIST must compete against other, more specialised, research institutes for Government funding.

Diffusion of research results has generally been via the sponsoring firm or agency. KIST would hand over the research outputs and the intellectual property to the firm, in exchange for the firm paying back to KIST the direct Government financial contribution to the projects (which in turn funds further work by the research team involved).

Priority setting

A new organisation for Korean R&D planning, management support and evaluation was set up at the Science and Technology Policy Institute (STEPI) in 1992. STEPI stated that it is the only institute in Korea in charge of science and technology policy research and national R&D management. STEPI has established the Division of National R&D Planning and Management consisting of five functional sections for technology forecasting, R&D planning, management support, evaluation and cooperation among industry, academia and research institutes to carry out this role. The Division deals with the management of the Highly Advanced National programs and other national R&D programs such as the core technology development program to support various national research institutes, and international cooperation programs (Science and Technology Institute 1992).

H.9 South Africa

The closest parallel to the Australian CSIRO in South Africa is the South African Council for Scientific and Industrial Research (CSIR). The Council is the largest of the seven government research agencies. It has 2800 staff divided into 13 business units.

Historical background of CSIR

The CSIR is a statutory research council involved in research and development, and the implementation of research findings. It was established in 1945 and, like CSIRO, was based on the UK model (in CSIR's case, the National Physical Laboratory). Between 1945 and 1985, it operated as a national laboratory predominantly funded by Government.

For some time, CSIR's culture was that of a 'super-university', with a primary focus on research and the publication of research findings. However, in 1985 a government White Paper on an industrial development strategy for South Africa identified the need for a *technology provider* to industry, and CSIR was called upon to provide this service to industry on behalf of the government. Two significant changes occurred since then:

- CSIR became a market-oriented provider of technology, increasingly operating as contract research organisation;
- in 1993, the Council increased its emphasis on technology for development, jobs and wealth creation as part of its commitment to the new South Africa.

CSIR's mission and research focus

CSIR's current mission, which was approved by the CSIR Board in November 1993, is to:

- be the technology partner of South African industry (in both the formal and informal sectors) to promote economic growth — under its *Technology for Competitiveness* objective;
- provide technology solutions that improve the quality of life in urban and rural developing communities — under its *Technology for Development* objective; and
- provide scientific and technological support to enhance decision-making in the public and private sectors — under its *Technology for Decision-making* objective.

CSIR focuses on applied research on behalf of government departments; endeavours to solve technological problems and to help improve competitiveness in industry. It also delivers technology as part of an integrated package containing information, finance, management and network access on behalf of small and medium enterprises.

Funding

CSIR receives some block funding from government under a 'Framework Autonomy' policy, intended to provide longer term stability in the government funding stream.

However, there has been the assumption that some external income would/may be generated through contract work, with government departments forming the major client group. Although no formal target was set by the South African Government for the amount of research to be commissioned by external clients, there was some tacit understanding that external income should not be more than 45–50 per cent of total income for CSIR.

CSIR is one of 7 Science Councils in South Africa[5]. Government funding of the Science Councils has fallen in real terms (from 0.9 per cent of the Government Budget in 1990–91 to 0.65 per cent in 1992–93) forcing them to downsize. CSIR considered that the only way for it to counter this was to increase income from contracts with the private sector, and where possible, counter the

[5] There are 7 Science Councils in South Africa at present: CSIR, MINTEK (Mining beneficiation technology), SA Bureau of Standards, Medical Research Council, Foundation for Research Development (agency functions), Agricultural Research Council, and Human Sciences Research Council.

downward trend in government contracts. By 1994 external income comprised about 54 per cent of total income compared with about 38 per cent in 1988 (the balance in each of these years was provided by Government through parliamentary grants).

CSIR does the bulk of its research in-house. It also provides some funding on an ‘agency’ basis to external ‘centres of excellence’.

CSIR is permitted to compete for outside research work against other institutions and private sector companies. Government departments are not obliged to contract CSIR exclusively. Where the departments decide to invite other bids, CSIR has to submit tenders along with other potential contractors. Nearly half of external contract income is won on a contestable basis from as many as 14 government departments (by far the biggest source being Defence). Appropriation funds are allocated on merit and used for positioning work, to build skills and facilities, to protect intellectual property and develop future business (CSIRO 1995b). However, CSIR is not permitted to subsidise its bids for external work by drawing on its parliamentary appropriations.

Priority setting

A board of directors appointed by the Minister of Trade and Industries has the responsibility to interpret the mandate of the CSIR, and to guide corporate portfolio investment. The Board determines policy objectives for the organisation. Priorities for each strategic business unit are determined by negotiation with the Executive.

A senior Executive Group of the Executive Board plus 13 directors meet weekly. The top 500 managers (project leader and above) meet the group each quarter to discuss current events and emerging issues. This is an important forum for promulgating change (CSIRO 1995b).

In November 1993 the CSIR Board adopted the new Government’s special priority of assisting developing communities with technology.

H.10 India

In 1992, the total R&D investment in India was nearly US$1.4 billion. The Indian Government funded 87 per cent of this, with private industry funding 13 per cent. Of the Federal Government’s R&D spending, the Defence Department accounts for 27 per cent (CRS 1994, p. CRS-35).

Council of Scientific and Industrial Research (CSIR)

The CSIR was set up in imperial times and is the closest parallel to Australia's CSIRO. It is the largest civilian R&D organisation, and has 42 national laboratories and institutes working in many different fields of applied research and development (CRS 1994).

Funding

The CSIR receives a single line budget appropriation from the Federal Government (that is, it is block funded). But CSIR is now expected to get an increasing proportion of its funds from external sources. The proportions differ in different areas of research — for example, the National Chemical Laboratory is expected to earn 70 per cent of its operating budget from commissioned research, while the Microbiology laboratory earns almost nothing from contracts.

CSIR institutes and other research organisations have been expected to obtain at least 30 per cent of their income from contract research for industry or other organisations. With recent cuts in government support, they are expected to raise as much as 50 per cent of their budgets from non government sources by 1996. Institute directors feel they have no choice but to drop long-term research projects and look for short-term projects backed by clients (CRS 1994, p. CRS-36).

Priority setting

CSIR priorities are set now by a Council of prominent academics, industrialists and Government representatives (with the Prime Minister in the Chair), but with input from CSIR. In the past, when budget constraints were less tight, CSIR used to set its own priorities according to what the researchers assessed was important, but increasingly they have had to respond to what is demanded by industry and Government.

More broadly, the science policymaking agenda is generally set by the Ministry of Science and Technology in consultation with other ministries and departments. Advisory bodies are also available to advise on areas pertaining to their fields. Universities and government laboratories are also effectively involved in the science and technology policy-making process. Representatives of universities and laboratories are invited to S&T policy-making meetings (CRS 1994).

In addition, in 1994 (for the first time in India), several standing committees of the Indian Parliament have begun to examine the budgets of departments and agencies within its jurisdiction. The Committees will issue reports and non-binding recommendations regarding these departments and agencies.

H.11 Summing up

Government research agencies operate in a diversity of science and technology policy environments. The policy environments in different countries vary in a number of ways, including the separation of the function of funding and performing, the type of government funding mechanisms (for example, block or project funding), the extent of private sector involvement in the performance of the research and the way priorities are set by or for the government research agencies.

Most overseas governments reviewed (including the governments in the United States, United Kingdom, New Zealand, Japan, and Taiwan), do not allocate the bulk of their research funds as block grants to their government research agencies for the latter to use as judged to be best by them. Most have to compete for government R&D funds on a project or program basis. While government research agencies in some countries, such as India and South Africa, used to rely primarily on block funding for research funds in the past, they are now under increasing pressure to earn more of their income from commissioned research projects or programs.

Even when governments financially support R&D in significant ways, most endeavour to allow the private sector to perform the research as much as feasible. The bulk of the research in the United States, Germany and Japan is carried out by industry. In the United States, almost 76 per cent of the Federally-funded R&D is done extramurally via competitive grants and contracts. In countries such as South Africa, Canada, and India (all of which were former British colonies and established CSIRO-type organisations based on the parent model in the United Kingdom) a significant proportion of research is still performed internally by their key government research agencies. Where external research is undertaken, CSIR in South Africa charges full cost prices. In the United Kingdom, the trend is towards more contracting out of research.

Countries which used to allocate appropriation funds on an exclusive basis to their government research agencies without outside competition are now separating funding from performance and inviting bids on a project/program basis in an attempt to get more value for their R&D investments. Both the United Kingdom and New Zealand, in particular, are putting considerable emphasis on the separation of funding from research performance and inviting competitive bids from the private sector to also undertake contract research. The

UK Government is going further and examining options for privatising more of its government research agencies and/or their activities.

National priority setting is increasingly becoming important in setting a framework for subsequent prioritising of government assistance for R&D. In some countries (for example in New Zealand) the link between priority setting and funding allocations from Government is fairly tight. In others, the national priorities setting exercise is intended to be used more generally to guide likely future areas for research.

QUANTITATIVE

APPENDICES

APPENDIX QA: QUANTIFYING THE RETURNS TO R&D: THE EVIDENCE TO DATE

Government involvement in research and development (R&D) is generally justified on the grounds that the incentives to the private sector to invest in R&D do not adequately reflect the value that society derives from that R&D. The larger the divergence between the social and private returns on R&D, then the stronger the case for government involvement is seen to be:

> Spillovers (the divergence between the social and private rates of return) are of interest to governments because their existence represents the strongest justification for subsidisation of private industrial R&D (BIE 1994b, p. vii).

Whilst highlighting the argument, the above quotation does not necessarily hold. In many cases the social benefits would have accrued anyway, even without government involvement, because the expected private returns are high enough to ensure private sector provision. What is important is the social return from the R&D that the private sector does not undertake because it is unable to appropriate all of the social benefits. This 'marginal R&D' may not take place because the private returns are too low, even though the social returns are high enough to warrant provision. This 'market failure' occurs as a result of the fundamental characteristics of the knowledge generated by R&D and differentiates it from most goods and services. *However, the studies reviewed here are incapable of distinguishing the benefits from this 'marginal R&D' as they look at the returns accruing to all R&D, rather than that occurring at the margin.*

Arguments for government intervention also need to take into account the costs of that involvement, including the forgone alternatives on which the funds could have been spent, and the costs of raising those funds. However, the argument highlights the need to gain a detailed understanding as to the magnitude of social benefits from R&D.[1]

The extent to which private and social benefits differ is an empirical question. This appendix reviews a range of studies that have attempted to estimate the private and social returns to R&D. They predominantly focus on business R&D at the firm or industry level (mostly for agriculture and manufacturing). The studies use a variety of techniques, including both econometric techniques and case studies of individual projects, and are predominantly North American

1 Even if the private and social returns do differ then the appropriate policy response is an entirely different question. These issues are discussed in greater detail in part A of this report.

(from the United States and Canada). The Commission has found a number of Australian studies, but they are mostly case studies.[2] Given the lack of Australian econometric studies, the Commission has undertaken its own econometric work to assess the importance of R&D for the Australian economy (see appendix QB).[3]

Little empirical work appears to have been done to assess the social benefits flowing from public sector R&D (including that undertaken by Commonwealth and State Governments, other government agencies such as the CSIRO, and by higher education institutions). The few studies that have been undertaken tend to focus on individual projects, rather than all public sector R&D.

This review does not make any attempt to assess the theoretical literature relating to R&D, ancillary R&D issues (such as patents and intellectual property issues) or the determinants of economic growth (the so alled ‘new growth’ theories) (see Dowrick 1994). However, it does draw on the theoretical literature to clarify the empirical estimates of the social returns from R&D. It focuses on those empirical studies dealing with R&D at the economy-wide, industry and firm level and extends earlier survey work by Dempster (1994), Griliches (1979), Mairesse & Sassenou (1991), Mohnen (1990a) and Nadiri (1993).[4]

Box QA1 presents a glossary of the terminology used in this review of the empirical literature. In accordance with its widespread use in the empirical literature, this review uses the term *spillover benefits* to describe the difference between the private and social benefits, or *spillovers* for short. Through the use of an example, box QA2 illustrates these definitions.

2 The Commission did not explicitly look for case studies conducted overseas. Those it did encounter have been included.

3 The only other economy-wide study for Australia that the Commission is aware of was the consultancy report for this inquiry by Dowrick (1994), who extended an earlier paper by Coe & Helpman (1993). In their paper, Coe & Helpman include Australia with the other non G7 OECD countries, but do not publish their results separately for each country within this group. Dowrick (1994) uses their Australian data to estimate a similar TFP relationship for Australia.

4 This review does not attempt to cover those firm level studies that assess how the stock market values R&D, such as Cockburn & Griliches (1988), Griliches (1981), Johnson & Pazderka (1993) and Pakes (1985).

Box QA1: **Glossary of R&D terms**

Applied R&D	Original R&D undertaken in order to acquire new knowledge with a specific application in mind.
Basic R&D	Experimental and theoretical R&D undertaken primarily to acquire new knowledge without a specific application in mind.
Depreciation of knowledge	The rate of decline over time in the value of a given stock of knowledge to either private agents (private rate) or society (social rate).
Experimental development	Systematic work using knowledge gained from research to create new or improved products or processes.
Diffusion	The process whereby new private knowledge, know how and innovations spread from an innovating organisation to the general community.
Direct returns	The returns to R&D that accrue at the lowest level of data aggregation. For firm level studies, the direct returns measure the private returns and, for industry level studies, the direct returns measure the industry return.
Disembodied knowledge	Knowledge that is not embodied in equipment or materials (eg patented knowledge).
Embodied knowledge	Knowledge that is embodied in equipment or materials. An example is the technological knowledge contained in a new computer.
Extramural R&D	R&D activity funded by an organisation, but carried out by other organisations.
Industry returns	Private returns to the firm undertaking the R&D plus those external returns accruing to other firms within the same industry (intra-industry spillovers).
Intra-industry same spillovers	Spillover benefits (or costs) that accrue to (or are born by) firms within the industry as the firm spillovers undertaking the R&D (excluding the private return to the firm).
Intramural R&D	R&D carried out by an organisation on its own behalf or on behalf of other organisations.
Intra-industry spillovers	Spillover benefits (or costs) that accrue to (or are born by) firms outside the industry of the firm undertaking the R&D.
Knowledge spillovers	Refers to the uncompensated flow of new private knowledge and know how from the innovating firm to competitor firms and/or firms in other industries (see *Spillover*).

/continued overleaf

Box QA1: Glossary of R&D terms (cont...)

Pecuniary benefits	Those benefits that arise through the operations of the market place. An example is the return to R&D when knowledge is purchased through the market place.
Private returns	The returns appropriated by the firm undertaking the R&D. It includes not only the resulting profits from the marketing of any products, but also other factors such as the receipt of any royalties from any patents that result.
Product R&D	R&D directed towards the introduction of new or improved products to the market.
Process R&D	R&D directed towards the introduction of new or improved methods of production.
Research & Development (R&D)	Refers to creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications.
Rate of return	The flow of benefits expressed as the average annual benefit accruing in perpetuity as a proportion of the cost of the asset (the stock of knowledge) generating the benefit. Where the stream of future benefits varies over time, it can be expressed in turn as an equivalent average annual benefit flow in perpetuity.
Social return	The flow of benefits accruing to society expressed as the average annual benefit accruing in perpetuity as a proportion of the cost of the asset (the stock of knowledge) generating the benefit. Where the stream of future benefits varies over time, it can be expressed in turn as an equivalent average annual benefit flow in perpetuity (also known as *Total return.*).
Spillover	Refers to any unpaid benefit or unrecompensed cost that flows to any agent other than the institution undertaking R&D. It is the difference between the private and social rates of return.
Total factor productivity (TFP)	Is a measure of the impact of all the other factors, including R&D, on output other than changes in the quantities of physical capital and labour used in production. It represents the residual of output in excess of the quantities of physical capital and labour used.
Total return	See *Social return*.
Type of R&D	Comprises basic R&D, applied R&D and developmental R&D.

Source: Industry Commission; ABS 1990a, p. 25; and OECD 1981, p. 25.

Box QA2: **A hypothetical example of spillovers at work**

The purpose of this hypothetical example is to illustrate the different rates of return to R&D and how knowledge spillovers occur.

Suppose, that a small private firm *XYZ* invents a new way to miniaturise electronic circuitry. It patents this new technology and incorporates this invention in a new smaller computer that it retails. The sales of the computer and returns from the use of the patent constitute the *private returns* to R&D.

A larger rival Australian computer manufacturers *ABC* buys a copy of *XYZ*'s new computer and its research engineers pull the new computer apart to see how it works (reverse engineering). In doing so, they too discover how to miniaturise electronic circuitry but at a fraction of the cost that it took *XYZ* to obtain that knowledge. *ABC* decides to use this miniaturisation technique to make their own computers smaller. *ABC* is aware of *XYZ*'s patent, but decide to copy the process because they believe that *XYZ* does not have sufficient financial resources to take them to court to defend their patent. The sales of *ABC*'s new smaller and cheaper computer constitutes part of the *intra-industry spillovers* and occurs at the expense of *XYZ*'s profits. The R&D undertaken by *XYZ* has benefited *ABC*.

Consumers benefit by having a range of better and cheaper computers available to them.

Another Australian company, *DEF*, who develop medical products, learns that *XYZ* has patented the miniaturisation process. Their research engineers read *XYZ*'s patent application and discover some information about the miniaturisation process. They combine this information, with their existing knowledge and other publicly available knowledge, to develop a similar, but yet different, miniaturisation process that they use to make their range of bionic ears even smaller and cheaper. As *DEF* are in another industry, the sales of their new smaller bionic ear constitute part of the *intra-industry spillover* benefits. Although *DEF* is in an entirely different industry, it has also benefited from *XYZ*'s R&D.

Consumers benefit by having a range of smaller and cheaper bionic ears available to them.

One of *XYZ*'s major overseas rivals, *QRS*, learn that *XYZ* has just produced a new range of smaller computers. Through reverse engineering, they too learn how to miniaturise electronic circuitry. They use this knowledge to make their own computers smaller. *QRS*'s larger production volumes enable them to export their computers into *XYZ*'s traditional export markets at a lower cost. The sales of *QRS*'s computers constitute an *international spillover* that is detrimental to Australian producers (through lost profits) They too have benefit from the *XYZ*'s R&D.

Consumers benefit from having a range of better and cheaper computers available to them

The intra, inter and international spillover effects can be broken down into a *pecuniary benefit* (benefits to consumers and profits of competitors) and the *knowledge spillover* or *external benefit* (learning about the miniaturisation process and the increase in profit to the firm that learn about it). In this case, the international spillover involves a both pecuniary and spillover cost to Australia because of the loss of export sales.

The empirical studies are incapable of distinguishing between those benefits that result from market transactions and those unrecompensed benefits that occur from knowledge spillovers. In addition, the econometric studies do not pick up any welfare gain or loss to consumers, aside from any transfer to or from producers. However, a number of the case studies take into account some of the impacts on consumers.

QA.1 Methodologies

The empirical studies reviewed here use either statistical (econometric) techniques or case studies to estimate the social returns to R&D.

Econometric analysis

In the private sector, firms undertake R&D in order to gain a competitive advantage over their rivals. This advantage can take a variety of forms, from lowering production costs to developing new or improved products to gain market share. Econometric analysis uses statistical techniques to explore the relationship between R&D and the production process for individual firms, industries or the entire economies, in so far as they impact on production costs, output or productivity.

Most econometric studies estimate the relationship between R&D and either output (the production function approach) or production costs (the cost function approach).[5] Both methods treat R&D just like any other factor of production, like labour or physical capital. A third method often used is a variant of the production function approach and relates R&D to total factor productivity (TFP).[6]

Econometric analysis captures spillover benefits in two principal ways, through aggregation and through the inclusion of specific terms designed to measure the spillover benefits. Consider, for example, the estimation of a production function for the mining industry. The function might relate the output of the mining industry to, amongst other factors, two or more terms designed to

5 Under duality theory, these two approaches are related to each other. In theory at least, you can derive a cost function from a given production function and vice versa. In practice direct estimation of a production function suffers from problems of simultaneity bias that are avoided when estimating cost functions. However, cost function estimation has different data requirements, which may or may not be easily met.

6 A limited number of studies employ other approaches. For example, Jaffe (1986) uses a model that is related to production and cost functions — the profit function. As there are only a minority of these studies and a variety of techniques used, this review does not summarise all of these methodologies.

measure the benefits to R&D. One term would represent the aggregate stock of R&D capital in the mining industry. It represents the aggregation of the R&D capital stock of all firms within the mining industry. Thus, the relationship between the output of the mining industry and this aggregated term would indicate, not only the private returns to the firm undertaking the R&D, but also the returns to all other firms within the industry (intra-industry spillovers). One or more terms may measure the aggregate R&D capital stocks in other industries, such as agriculture and manufacturing. This has the primary advantage of enabling the source and receiving industries of these spillovers to be easily identified. Its principal drawback is that it requires more data. Alternatively, a single term measuring the aggregate stock of R&D capital in all other industries could be used to measure the benefits accruing from all other industries in the economy. Some studies just aggregate the R&D capital stocks of all industries, while others allow for the fact that firms using similar knowledge or processes to the firm undertaking the R&D would be better placed to use any resulting knowledge than would firms from another industry. Some of the empirical studies attempt to make allowances for this 'technological proximity'.[7]

If sufficient data exist, firm level studies are capable of distinguishing between the private and intra-industry returns through the inclusion of separate terms reflecting the firm's own R&D capital stock and the R&D capital stock of all other firms in the same industry.

In theory at least, it is possible to extend this approach, of using additional terms to identify the contribution of specific pools of knowledge, to establish the importance to industry of public sector R&D (the Commonwealth and State Governments, CSIRO and higher education), as well as for that conducted overseas (international spillovers). Their inclusion would also increase the data requirements. Such an approach would not measure the extent to which overseas firms benefit from Australian R&D.

Unlike most of the case studies, the econometric studies incorporate unsuccessful R&D projects in their expenditure or stock figures. Thus, if these expenditures do not generate financial benefits, there will be a lower rate of return to aggregate R&D than if they had been omitted.

The use of econometric techniques, however, has numerous limitations. Many relate to the availability of suitable data and these are discussed in greater detail in section QA.2. In addition, most econometric studies do not adequately

[7] These include Goto & Suzuki (1989), Griliches & Lichtenberg (1984a), Jaffe (1986, 1988), Mohnen & Lepine (1991), Scherer (1982, 1983, 1984, 1993), Sterlacchini (1989) and Terleckyj (1974, 1980).

explain the real world interaction between R&D and other factors of production, most notably the stock of physical capital. R&D may make physical capital more productive, but this may be measured as a return to physical capital, rather than to R&D itself. Likewise, it does not measure the extent to which research may alter the rate at which other inputs can be substituted in the production process. At least conceptually, some of these limitations could be overcome through the use of interactive terms in more sophisticated models. However, to do so would require more data to maintain the power of the econometric tests.

Production functions

R&D may be viewed as a means of increasing productivity, or the amount of physical output produced from a given level of 'traditional' inputs such as labour and physical capital. Some researchers try to estimate this relationship empirically using a production function, which relates the quantity of output of a particular firm, industry or economy to its usage of inputs in the production process (see figure QA1).

Whilst it is possible to extend production functions to allow for changes in the input mix and the fact that undertaking R&D may actually lower the cost of producing knowledge to the firm, the empirical studies do not take this into account.

Figure QA1: **Diagrammatic representation of a production function**

Output of the firm, industry or economy (quantity)	*is a function of*	Quantity of inputs: - labour used in production - physical capital used in production - materials used in production **- own R&D capital** (aggregation of inputs used in R&D) **- R&D spillover pool** (external stocks of R&D available) - etc.

Source: Commission adaptation of Dempster 1994, p. 12.

The returns to R&D are measured through at least one, possibly more, terms representing specific pools of R&D that the industry or economy may draw upon. One variable that is always included is the aggregate stock of R&D capital in the particular industry for which the production function is being estimated. Such a term measures the collective private and intra-industry spillover benefits from R&D. Other terms may represent the aggregate stock of

R&D capital in other industries or for the entire economy. These terms measure the intra-industry social benefits that occur. Similar approaches can be employed at the firm or economy-wide level.

To estimate production functions, output needs to be measured independently of the inputs used (labour and physical capital). For most industries this is not a problem. However, for some service industries the official measures of output are calculated on the basis of the inputs used, along with some assumption about the rate of TFP growth in the industry (normally assumed to be zero).[8] This relationship between measured output and inputs will only hold given the rather unrealistic assumption that there is no productivity growth in these industries. To overcome this, production functions should only be estimated for those industries where output is clearly measurable. These arguments are equally applicable to the TFP studies, such as Englander et al. (1988), discussed later.

Examples of studies that estimate 'traditional' production functions include Coe & Moghadam (1993), Cuneo & Mairesse (1984), Griliches & Mairesse (1984), Hall & Mairesse (1993), Lichtenberg (1992), Nadiri (1980a) and Schankerman (1981) for industrial R&D and Bredahl & Peterson (1976), Cline (1975), Griliches (1964), Huffman & Evenson (1989), Knutson & Tweeten (1979), Peterson & Fitzharris (1977) and White & Havlicek (1982) for agricultural R&D. The Commission's own modelling work at the economy-wide level (see appendix QB) extends the 'traditional' production function approach to cover public and foreign R&D.

Cost functions

Cost functions are very similar to production functions in that they relate R&D to the production process (see figure QA2). Instead of estimating the relationship between R&D and output, cost functions explore the link between R&D and production costs on the premise that successful R&D should lower the costs of production. In addition, they will also pick up the impact of new products and the gain in market share on production costs. They are estimated at either the firm or industry level and the studies reviewed here relate only to industrial R&D.[9]

Unlike production functions that relate output to the quantities of inputs used, cost functions relate the cost of production to input prices (where inputs vary with production) and the quantities of inputs (where inputs do not vary with

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8 For example, the ABS measures the output of the *Finance, property and business services* and *Public administration and defence* industries on the basis of the aggregate number of hours worked (ABS 1989, pp. 128–9).

9 Mullen & Cox (1994b) estimate a translog cost function for Australian broadacre agriculture but do not include any variables relating to R&D.

production). In some models, the production costs measure variable production costs, while others measure total production costs. This distinction in the definition of production cost implies a slightly different treatment of R&D. In the variable cost functions, the *stock* of own R&D is treated as a quasi fixed input, whereas in total cost functions R&D is treated like any other variable input by including the *price* of R&D.[10] In all cases, the spillover pool enters as a quantity. Thus, different data are needed to estimate a cost function.

In the articles reviewed here, there is another major distinction between the way the cost functions and their production function counterparts are estimated. The cost function studies measure the extent to which all industries benefit from the R&D undertaken by the current industry (that is, the industry that is the source of the spillovers), while the production function studies measure the extent to which the current industry benefits from all R&D, including the R&D undertaken by other industries (that is, the industry benefiting from the spillovers).[11]

Whilst in theory cost functions are interchangeable with production functions, those empirical studies that estimate cost functions are considerably more complex than their production function counterparts. They typically estimate both the cost function and its associated factor demand equations as a full system. This increases the efficiency with which individual parameters are estimated. The more sophisticated dynamic adjustment models add extra realism by allowing expectations, adjustment costs and the length of the planning horizon to differ.

Examples of studies using the cost function approach include Bernstein (1988, 1989), Bernstein & Nadiri (1988) and Mohnen & Lepine (1988, 1991), while Bernstein & Nadiri (1991), Mohnen et al. (1986), Nadiri & Prucha (1990), Mohnen (1990b) and Suzuki (1993) are examples of studies that estimate the more sophisticated dynamic models.[12]

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[10] Indices of average R&D prices can be obtained through a variety of means — from published sources, if they exist; calculated as the weighted sum of the input prices used in R&D; or derived from the value and quantity of R&D undertaken. For example, Bernstein (1988) calculates 'a Divisia price index (the second method described above) of the prices, and the labour, material and physical capital shares of R&D expenditures' (p. 5).

[11] Despite the apparent similarity in the way the equations are specified, the way the rate of return is actually calculated for cost and production functions are quite different.

[12] Bernstein & Nadiri (1989a, 1989b) employ similar techniques, except they relate R&D to value or output instead of variable or total costs and both studies estimate dynamic models.

Figure QA2: **Diagrammatic representation of cost functions**

Variable cost function:

Variable cost of production

is a function of

Prices of inputs that vary with output
- labour used in production
- physical capital used in production
- materials used in production

etc

Quantities of factors that do not vary with output:
- own R&D capital (aggregation of inputs used in R&D)
- R&D spillover pool (external stocks of R&D available)

Total cost function:

Total cost of production

is a function of

Prices of inputs that vary with output
- labour used in production
- physical capital used in production
- materials used in production

etc
- own R&D capital (aggregation of inputs used in R&D)

Quantities of factors that do not vary with output:
- R&D spillover pool (external stocks of R&D available)

Total factor productivity (TFP) studies

TFP studies are a variant of the production function approach described earlier and, as a result, much of that discussion is relevant here.[13] Instead of relating R&D to output, many TFP studies relate R&D intensity (the ratio of R&D expenditure to value added (output) or sales) to the rate of growth in the residual of output over the labour and physical capital used in production, or the rate of total factor productivity growth.[14] In its most common form, R&D intensity is related to the growth in TFP, although some studies regress knowledge stocks

13 Terleckyj (1974, pp. 3–8) provides an excellent, yet very readable, discussion of how the equation that these studies estimate is derived from the underlying production function and the assumptions adopted.

14 Instead of estimating a production function that includes R&D directly (a ‘one step approach’), TFP studies estimate the relationship between output and R&D in a ‘two step approach’ by firstly estimating total factor productivity and then by estimating the desired relationship between TFP (or TFP growth) and R&D.

on the level of TFP.[15] Alternatively some studies, for example Scherer (1982, 1983, 1984, 1993), relate R&D intensity to the growth in labour productivity or output per worker. The methodology used by TFP studies are represented diagrammatically in figure QA3.

Figure QA3: **Diagrammatic representation of TFP studies**

Growth in TFP	*is a function of*	R&D intensity (ratio of total R&D expenditure to output)
Level of TFP	*is a function of*	own R&D capital (aggregation of inputs used in R&D)
Growth in labour productivity	*is a function of*	R&D intensity (ratio of total R&D expenditure to output)

Mairesse & Sassenou (1991, p. 18) note that, in principle, those studies using labour productivity should calculate their R&D intensities using the value of sales and those using TFP should use value added. Instead, the literature seems to use an ad hoc approach but, as Mairesse & Sassenou note, it has little effect on the final result:

> However, there is no evidence of the large discrepancies that one might expect to find between studies in which R&D intensity is measured with respect to sales and those in which it is measured with regard to value added (Mairesse & Sassenou 1991, p. 22).

TFP studies attempt to measure the effects of embodied R&D. To account for the effects of disembodied R&D, they assume that the underlying production function contains a time trend variable (see Terleckyj 1974, p. 4). The time trend supposedly represents the cumulative increase in knowledge (that is disembodied R&D) over time.[16] The interpretation of the R&D variable as representing embodied R&D ignores the productivity improvements embodied in capital and labour that result from technological progress.[17] In short, if they correctly interpret the R&D variable to be a measure of embodied technical change, then they only measure some of the returns to embodied R&D, as it

[15] Examples of the latter approach are Coe & Helpman (1993), Englander *et al.* (1988) and the econometric estimates contained in appendix QB of this report.

[16] Whilst this interpretation of the time trend variable as a measure of disembodied R&D may be criticised, it is commonly used in econometric studies.

[17] This interpretation equally applies to production and cost functions as well.

ignores the effect of R&D embodied in capital and labour that cannot be accurately measured.

The assumptions underlying TFP studies include that output is a constant returns to scale function of capital and labour, that the productivity rate of return on R&D capital is estimated as a component of productivity growth, that inputs used in production (including R&D) are substitutes and not complements, equilibrium in output and input markets, and that the benefits of R&D occur immediately and not over time.[18] Studies that seek to explain TFP growth additionally assume that the value of knowledge does not decline over time (that is the rate of knowledge depreciation is zero) or that R&D intensity approximates the underlying net growth in the stock.[19] Although none of the studies do so, in theory it is possible to relax some of these assumptions.

Where the TFP equations seek to explain productivity growth in terms of the R&D intensity, the estimated coefficient represents the marginal product and is often termed 'the excess gross rate of return to R&D'.[20] However, Sterlacchini (1989) points out that:

> …, the coefficient δ cannot be a rigorous measure of the R&D marginal productivity for, at least, two reasons. First, the above approach holds only if the rate of depreciation of R&D investments (that is, the degree of obsolescence of the stock of technological knowledge) and the lag over which such investments affect output and productivity are small enough to be neglected (cf Mansfield 1980, p, 864). Second, the production function framework implies the concept of separability between different classes of inputs while R&D expenditures (and, in general, innovative activities) should be regarded as complements rather than substitutes for capital and labour inputs (see Nelson, 1981, pp. 1053–54). In light of these arguments … it is preferable to consider the R&D coefficient a simple measure of statistical association (Sterlacchini 1989, p. 1550).

Technically, Sterlacchini's interpretation of the coefficient as a measure of statistical association is correct. But as most studies interpret the estimated coefficient as the marginal product of R&D, this review adopts this interpretation.

Examples of industrial TFP studies include Goto & Suzuki (1989), Griliches (1994), Griliches & Lichtenberg (1984a, 1984b), Griliches & Mairesse (1990), Sterlacchini (1989) and Terleckyj (1974, 1980), while Evenson (1980, 1992),

[18] The inclusion of lagged R&D intensities would measure the benefits over time. However, the Commission has not been able to find any such studies. Griliches & Lichtenberg (1984a, pp. 473–4), Nadiri (1993, p. 9), Sterlacchini (1989, p. 1550) and Terleckyj (1974, pp. 3–8) discuss the assumptions underlying TFP studies in greater detail.

[19] Various authors, for example Terleckyj (1974), demonstrate this mathematically.

[20] The term gross relates to it including the return required to cover depreciation.

Mullen & Cox (1994a, 1994c) and Thirtle & Bottomly (1988, 1989) are examples of agricultural TFP studies.

Coe & Helpman (1993) and Englander et al. (1988) also conduct TFP studies, but do not use the above approach. Rather, their methodology relates TFP levels to the stock of R&D capital. The main advantage with this approach is that it explicitly takes depreciation into account and therefore, to some extent, the dynamic aspects of R&D as the stock of R&D provides benefits over time. Their R&D coefficients can easily be converted from an elasticity into a *net* rate of return (see Coe & Helpman 1993, p. 18).[21] Their approach overcomes both aspects of Sterlacchini's first concern about the use of a zero depreciation rate and that R&D expenditure provides benefits over time. It does not, however, overcome his second concern, which can be equally applied to the less flexible forms of production and cost functions as well. Additionally, Coe & Helpman (1993) and the Commission's own modelling work at the sectoral level (see appendix QB) are the only TFP studies that attempts to measure the returns to public and/or foreign R&D.

Case studies

An alternative way of assessing the social returns to R&D is through the use of case studies. Unlike the econometric work that focuses on the returns at a more aggregated level (firms, industry or economy), case studies focus on identifying the benefits and costs accruing to both the firm and to society from a particular individual innovation that flows from the R&D process. The Bureau of Industry Economics provides a good overview of the methodologies that case studies use in their report *Beyond the Innovator: Spillovers from Australian R&D* (BIE 1994b).

Case studies have been a popular way of assessing the benefits from R&D and have contributed much to the understanding of spillovers. Numerous studies have been undertaken to assess the social benefits resulting from agricultural R&D, primarily that undertaken by public sector research organisations, such as the CSIRO. Despite this, there appears to have been few case studies measuring the social benefits flowing from industrial R&D. In part, this reflects the fact that manufacturing case studies are more likely to focus on the benefits accruing to the firm undertaking the R&D (private benefits), coupled with the fact that they may be less likely to be published for competitive reasons. If all factors are correctly taken into account, case studies can provide valuable information to complement the econometric studies.

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21 However, Englander *et al.* does not provide sufficient information to enable their elasticities to be converted into rates of return (marginal products).

Case studies involve trying to identify all the benefits and costs that flow from a particular innovation. Whilst the net benefit (or cost) to a firm can be easily identified from its financial records, identifying the extent to which other parties benefit is more difficult:

> Unfortunately the practical impediments to rigorous measurement of social returns to industrial R&D are very severe, especially problems of corporate memory and confidentiality, and inherent difficulties in tracking knowledge flows between firms to link R&D causes with economic effects. No doubt that is why so little empirical work has been published in the mainstream economic literature (BIE 1994b, pp. 12–13).

Many of these difficulties are shared by the econometric studies. To overcome this, the case studies only measure the direct impact of R&D on output, costs or profit and not the indirect effects. In this respect, the econometric approach has two advantages over the case studies. The higher level of aggregation at the industry or economy-wide level, coupled with the use of statistical techniques to measure the association with R&D, as opposed to actually identifying the extent to which each party benefits, makes it easier to take some of these factors into account.

As the BIE (1994b, p. 1) notes, the particular advantage of the case study approach is its transparency. Its methodology is readily understandable and it enables the beneficiaries to be clearly identified.

However, the use of case studies has a number of disadvantages. Firstly, case studies are typically only undertaken for selected successful projects. They are unlikely to be representative of all R&D. Case studies of unsuccessful R&D are unlikely to be published. The ACIAR, for example, stated that:

> The 12 chosen projects areas were judged in advance to have been 'successful', and no pretence is made that they were randomly chosen (ACIAR 1991, p. 3).

Some authors also raise the question of a 'publication bias' where studies that do not produce significant results are not published. This raises the question: what conclusion can be drawn from case studies? Despite this possible bias, the Commission has found a number of case studies indicating low returns to R&D (tables QA14 and QA15).

Methodological approaches may distort the findings of case studies. Where case studies do not factor in all the relevant benefits and costs, their findings are likely to be inaccurate. Where outside agencies undertake research on behalf of another organisation, there is a danger that the organisation conducting the case study may not take into account the full cost of the other agency(s). Omitting these costs will underestimate the true costs to society and lead to an overestimate of the benefit cost ratio or the rate of return.[22] For example:

> In 1989, the (Meat Research) Corporation commissioned a study to determine the benefits to industry from a sample of successful R&D projects funded by the Corporation. The results indicate a substantial return on the investment of funds in those projects. This table presents only the Corporation's share of R&D costs and subsequent benefits. It should be noted, however, that substantial funding for those projects was also provided by research organisations (MRC 1991, p. 8).

Similarly, when the ACIAR (1991, p.3) included the cost of all R&D projects, rather than just the twelve successful ones, the benefit cost ratio fell from 31 to 2.7 as to 1.[23]

Additionally, a limited number of studies estimate some of the future benefits that will flow from the R&D undertaken. In conducting its own review, ACIAR said:

> In any economic assessment, especially one in which some of the benefits lie in the future, it is necessary for the analyst to make assumptions. This introduces an element of subjectivity into the calculations (ACIAR 1991, p. 7).

Where the actual stream of benefits differs from those estimated, the true rate of return will differ from the published results. Whilst it is unclear as to which way these estimations will bias the results, there may be an incentive to overestimate to present their findings in a more favourable light.

Some of the studies are undertaken prior to actually commencing the R&D, for example, BIE (1992), IAC (1975, 1985), Page et al. (1991) and Parham & Stoeckel (1988). These studies should be viewed as project feasibility studies, rather than a rigorous assessment of the benefits that actually accrued. Nevertheless, they may give some indication of the magnitude of the possible benefits.

Griliches, who himself had previously undertaken case studies, said:

> There have been a number of detailed case studies of particular innovations tracing out their subsequent consequences … Much can be and has been learned through such studies. They are, however, very data and time intensive and are always subject to attack as not being representative, since they tend to concentrate on prominent and successful innovations and fields. Thus, it is never quite clear what general conclusions one can draw on the basis of such studies (Griliches 1979, p. 92).

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22 The rate of return is equal to the benefit cost ratio multiplied by the discount rate (see Trajtenberg 1990, p. 166).

23 In this case, the ACIAR did not include any benefits from the unsuccessful projects, despite including their costs.

The Commission has found two broad categories of case studies that attempt to measure the broader social benefits from different types of R&D – agricultural and industrial. The Commission has primarily focused on Australian case studies, although some American studies are included (eg. Griliches (1958) and Trajtenberg (1990)). Examples of agricultural case studies include ACIAR (1991), Griliches (1958), Parham & Stoeckel (1988) and several done either independently or jointly by the IAC and the CSIRO. The Commission has only found a limited number of industrial studies, including BIE (1992), McLennan et al. (1988) and Trajtenberg (1990).[24] The BIE (1994b) conducted another series of case studies for Australia, but did not provide quantitative estimates of the magnitude of the benefit cost ratio or the social return from these projects, except to say that ‘1 project had very low spillover benefits, 10 had low spillover benefits and 5 had moderate spillover benefits’ (BIE 1994b, p. 68).

General methodological issues

Irrespective of the methodology used, there are a number of important methodological concerns that are applicable to most studies.

Valuing the benefits to the firm undertaking the R&D

Firms undertake R&D in the hope of gaining a competitive advantage over their rivals. To gain this advantage, they must spend money on physical capital (laboratories, computers etc), human capital (labour), energy and other materials so that they can undertake R&D. Over time, these expenditures contribute to a firm’s ability to undertake its own R&D, and possibly its ability to benefit from the work of others. It is assumed in the econometric studies that this aggregation of R&D expenditures over time constitutes the stock of R&D capital available to the firm and that, without additional R&D expenditure, its value to the firm declines over time.

The empirical studies attempt to measure the impact of R&D on the firm undertaking it. This represents the net flow of benefits over time from lower production costs, quality improvements, increased market penetration and payments made for use of any patents. The literature terms this value to the firm as the private returns to R&D.

[24] Case studies by Mansfield *et al.* (1977) and Tewksbury *et al.* (1980) have not been included in this review as they do not present sufficient information to enable comparable rates of return to be calculated. The internal rates or return presented by these studies are not strictly comparable with the estimates reported in table QA15.

Valuing the benefits to society from R&D

In the econometric studies, society is defined as the sum of all other firms. Benefits or costs incurred by other parties, for example consumers, are not taken into account. That is, they do not measure the effects on consumer well being. To some extent, the case studies capture these by including consumers in their definition of society. Neither approach explicitly incorporates the less tangible forms of benefits and/or costs, such as the benefits of cleaner air.

The empirical literature labels the value of these benefits that accrue to other parties as external benefits or spillovers. When the private return is included, it reflects the return to 'society' and is called the social or total return to R&D.

As Griliches (1979, p. 99) notes, the private rate of return may exceed the social rate of return, if it occurs at the expense of another firm. In this case, the private return merely reflects a transfer from one producer to another (pecuniary effect), rather than an increase in society's economic well being. In most cases, the social rate of return is likely to exceed the private return.

Complementary nature of R&D

The theoretical literature talks about the complementary nature of R&D — to benefit from another firm's R&D you must have sufficient expertise in your own firm. This implies that resources must be spent to maintain the capability of benefiting from spillovers, irrespective of whether actual benefits occur, and has widely different policy implications. Without undertaking its own R&D, a firm is incapable of benefiting from the spillover pool. Aside from the Commission's own modelling work (see appendix QB), Jaffe (1986) is the only empirical study that the Commission has come across that has tried to test this argument. In two of his three stage least squares (3SLS) equations, the R&D variable that can loosely be interpreted as measure of the complementary nature of R&D was found to be statistically significant.

R&D provides benefits over time

The benefits from R&D are dynamic in the sense that they provide benefits over time and not just in the period in which the expenditure occurs. In addition, it takes time for knowledge to transfer between firms, industries and countries. Griliches says:

> … it is unlikely that real technological spillovers are contemporaneous. One would expect them to be subject to quite long lags. … While there is a literature on both spatial correlation and on dynamic factor models, it is doubtful that we can estimate today convincing models of overlapping, shifting relations of mutual causality, given the poorness of the underlying productivity measures (Griliches 1992, p. S41).

A detailed analysis of the dynamic effects of R&D requires considerable data that is often not available. As a compromise, some studies lag some, or all, of their R&D variables to represent the dynamic aspects involved.[25] Whilst being imperfect, their inclusion is marginally more realistic, given that a complicated lag structure is not an option with the present data restrictions.

The agricultural econometric studies model the dynamic effects of R&D differently to their industrial counterparts in that they use annual R&D expenditure figures instead of stock figures. To incorporate the dynamic aspects of R&D into their models, they are required to make some assumptions about the structure of the lags involved.[26] The literature seems to offer little justification as to why the exact the lag structure used was chosen. For example:

> … the dozen or so lagged values of R are likely to be highly correlated and to use up too many degrees of freedom, so a distributed lag structure is often assumed (Thirtle & Bottomly 1988, p. 102).

Aside from possible econometric problems associated with the use of lagged expenditure figures, the rate of return estimate appears to vary considerably with the choice of lag structure:

> Shifting the lag structure does affect the output elasticity and the MIRR (marginal internal rate of return) considerably, but the model continues to fit equally well, regardless of the lead time (Thirtle & Bottomly 1988, p. 108).

Identifying other growth factors

Apart from labour, capital and R&D, numerous other factors may account for productivity or output growth. If appropriate measures of these variables are not included in the model then the results may be biased because of the omission of key variables. The economy-wide studies are particularly susceptible to this. Coe & Moghadam (1993), for example, found that European trade reform was a significant determinant of productivity growth in France.

Most non agricultural studies do not take these additional factors into account. Coe & Moghadam (1993) and the Commission's own modelling work are notable exceptions. Given that some of these factors are critical in agriculture (eg. the weather), most studies include additional variables representing these factors, including the weather, the educational status of farmers, the terms of trade and the use of fertilisers. In most agricultural studies, extension services

[25] For example, Bernstein (1988), Bernstein & Nadiri (1988) and Coe & Helpman (1993) lag their external stocks of R&D by one year, while Englander *et al.* (1988) incorporate a three year lag between R&D stocks and TFP. In a similar vein, Clark & Griliches (1984) lag R&D intensity by one year.

[26] Despite tending to have longer time series available than the industrial studies, it is still not long enough to enable the exact profile to be estimated econometrically.

that disseminate the findings of research amongst farmers are included with R&D.

QA.2 Data issues

The usefulness of a particular study depends, not only on the methodology it employs, but also on the quality of the data being used. Insufficient data of a suitable quality restricts the sophistication of the methodology used and, hence, the questions that the empirical work are capable of answering. Due to many conceptual and definitional problems, even the best overseas studies use less than perfect data.

Where are the actual gains measured?

Griliches (1979, 1980a, 1992) and Dempster (1994) argue that some of the gains from R&D attributed to a particular industry may actually originate in another industry. This problem occurs as the official statistics do not adequately reflect changes in quality that are likely occur as the result of R&D. Griliches comments:

> This is a problem of measuring capital equipment, materials and their prices correctly and not really a case of pure knowledge spillovers. If capital equipment purchase price indices reflected fully the improvements in their quality, ie were based on hedonic calculations, there would be no need to deal with it. As currently measured, however, total factor productivity in industry i is affected not only by its own R&D but also by productivity improvements in industry j to the extent of its purchases from that industry and to the extent that the improvements in j have not been appropriated by its producers and/or have not been incorporated in the official price indices of the (i) industry by the relevant statistical agencies (Griliches 1992, p. S36).

These measurement problems affect where the gains are measured as occurring. Quality improvements that occur in one industry may be attributed to another. For example, productivity improvements in the computer industry may make computers more powerful, but if these quality improvements are not reflected in the official statistics, then these productivity improvements will be attributed to those industries using the new, more powerful computers.

Dempster (1994, p. 13) terms this mismeasurement of where the actual productivity gain occurs as a ‘productivity transfer’ and it reflects the fact that quality improvements are not fully reflected in the official price indices.

Availability of consistent data

For econometric estimation, data needs to be collected in a consistent manner, either over time for time series analysis or across firms, industries or economies for cross sectional work. For example, the ABS surveys institutions undertaking R&D every second year. To overcome these restrictions, econometricians have resorted to statistical techniques to estimate data for the years that are not reported. Two such techniques are common — interpolation and extrapolation. Interpolation involves imputing values for observations that are missing from a series, while extrapolation involves extending a series forward or backward in time. For both interpolation and extrapolation, the techniques used may vary from a simple linear approach to those using more sophisticated econometric techniques.

For example, Coe & Helpman (1993) published indices of domestic and foreign R&D capital stocks covering the period 1971 to 1990 for 22 countries, including Australia. Given the irregular nature of R&D surveys within a number of the smaller countries, including Australia, Coe & Helpman used econometric techniques to interpolate and extrapolate R&D expenditures for the years that were not surveyed.

> For a number of smaller countries, R&D expenditure data are not available over the full 1970 to 1990 period, in which case an estimated equation relating real R&D expenditures to real output and investment (all in logarithms) were used to "predict" the missing R&D expenditure data (Coe & Helpman 1993, p. 21).

Whilst being far from satisfactory, the use of these techniques enables estimation to occur where it would otherwise not. When used judiciously, they may not influence the findings significantly.

It is difficult to ensure consistency, especially over time. More recent ABS publications are far more frequent and comprehensive than they used to be. However, much of this higher quality data can not be used on its own for time series work as it has only been collected for a limited number of years. In an attempt to alleviate some of these limitations, the ABS publishes a less comprehensive inter year survey for some of its publications.

Since the 1978–79 survey, the ABS uses the survey definitions and practices recommended by the Organisation for Economic Co-operation and Development in their *Frascati Manual* (OECD 1981). This will aid in the collection of internationally consistent R&D data.

How should the contribution of R&D be measured?

Many authors have tried to grapple with the issue of how knowledge, or R&D as a proxy for knowledge, should be measured. This issue has yet to be satisfactorily resolved.

The official statistics measure the annual expenditure on physical capital (laboratories, computers, etc), human capital (labour), energy and other materials used in R&D. They include the full cost of those long lived assets purchased during the year, such as buildings, rather than the contribution that the assets make in that year.

Bernstein & Nadiri, amongst others, raise the concern that:

> …, spillovers are intertemporal externalities because the transmission of R&D spillovers arises from R&D capital stocks. R&D capital stocks exist because current expenditures on R&D give rise to a stream of future benefits (Bernstein & Nadiri 1991, pp. 2–3).

From a practical viewpoint, not all researchers agree with Bernstein & Nadiri:

> Despite some impressive efforts to grapple with these measurement problems, it remains unclear whether a meaningful index of a firm's or an industry's knowledge stock can be constructed. … In any event, it is clear that — to the extent that depreciation rates, lag structures, and spillovers differ systematically across industries — even a correctly measured flow of current R&D effort will not serve as an adequate proxy for the services of R&D capital in cross industry comparisons (Cohen & Levin 1992, p. 1065).

Instead of using a stock of R&D capital, many researchers use expenditure figures, including all of the studies explaining TFP growth.[27] For example, Johnson & Pazderka (1993) offer the following defence of their use of R&D expenditure:

> Our use of the R&D expenditures (flow) variable is also motivated by another consideration. Our data set includes only limited time series of R&D expenditures. This, together with the well known problem of establishing the economically correct rate of depreciation of knowledge, would make it difficult to construct a reliable measure of the R&D stock (Johnson & Pazderka 1993, p. 18).

Those studies using R&D expenditure figures assume, either implicitly or explicitly, one of two things: (1) that the benefits from R&D expenditure are used up entirely within the course of a year, or (2) that movement in the flows approximate movements in the underlying R&D capital stock.[28] The above quotation by Johnson & Pazderka indicates that when there is only a limited time series data available then it may be better to use the expenditure figures, as there may not be sufficient data to estimate an R&D capital stock. From a practitioner's viewpoint, their biggest advantage lies in their simplicity. By using

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[27] For the TFP growth studies, the use of R&D intensity (R&D expenditure divided by sales) is, given a number of assumptions, mathematically equivalent to using the growth rate in the stock of R&D (see, for example, Terleckyj 1974, pp. 3–8).

[28] The econometric term for a variable that represents another is a proxy. The use of proxy variables by definition involves measurement error and this biases the estimated coefficient. Omitting the underlying variable also biases the estimated coefficients. Kennedy (1992, p. 46) cites studies by McCallum (1972) and Wickens (1972) which show that using a poor proxy is better than omitting the unobservable (underlying) regressor.

expenditure figures, the empiricists assume away many of the difficult conceptual issues involving knowledge.

Many researchers, primarily those estimating production or cost functions, do however use stocks of R&D capital. Statistical organisations, such as the ABS, do not publish stocks of R&D capital because of the limited amount of data available.[29] To overcome this lack of an official R&D capital stock, many researchers construct their own R&D stocks using similar techniques to those used by the ABS to calculate their physical capital stock figures — the perpetual inventory method (PIM).[30] The major differences between the way the ABS constructs its stock of physical capital and the way the researchers construct their stock of R&D capital relates to their use of the available data. Unfortunately, most studies do not adequately describe how they derive their stocks of R&D capital.

Construction of data on R&D capital stocks

From a practical viewpoint, whilst being far from perfect, the notion of an R&D capital stock is a better way of dealing with the influence of R&D over time than expenditure figures given insufficient data. Complicated lag structures would compromise the econometric power of the tests involved.

Perpetual inventory method (PIM)

In an appendix to their paper, Coe & Helpman (1993) provide the most detailed explanation of any study as to how their stocks of R&D capital were derived. The four key steps in calculating the R&D capital stock figures are:

(1) establishing the rate of depreciation or obsolescence of knowledge;

(2) establishing the average annual growth rate of real R&D expenditure over the period for which data are available;

(3) calculating the initial capital stock figure; and

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29 For similar reasons, the ABS does not publish physical capital stocks below the ASIC (Australian Standard Industrial Classification) Division level. For it to commence publishing physical capital stocks at the ASIC Divisional level in 1966–67, the ABS required data dating back to at least 1948–49 and, in some cases, to considerably earlier periods. For example, to calculate the value of the stock of dwellings required data back into the nineteenth century (ABS 1989, p. 171). This lack of capital stock figures for industries below the ASIC divisional level would hinder any estimation of production or cost functions at this level of disaggregation.

30 For example, Bernstein (1988, 1989), Bernstein & Nadiri (1988, 1989a, 1989b, 1991), Coe & Helpman (1993), Coe & Moghadam (1993), Goto & Suzuki (1989), Jaffe (1986), Mohnen & Lepine (1991) and Suzuki (1993).

(4) calculating the remaining capital stock figures from the initial capital stock figure and the expenditure figures.

Under the PIM, the R&D capital stock in any period is a function of:

- the value of the R&D capital stock in the previous period, *net* of any depreciation that has occurred; and
- the level of R&D expenditure in the previous period.

Algebraically, this can be expressed as:

$$S_t = (1-\delta)S_{t-1} + R_{t-1} \tag{QA1}$$

where

S_t is the stock of R&D capital at the beginning of period t (in constant prices);

S_{t-1} is the stock of R&D capital at the beginning of period t–1 (in constant prices);

R_{t-1} is the expenditure on R&D during period t–1 (in constant prices); and

δ is the depreciation or obsolescence rate of knowledge.

Through equation *(QA1)*, the R&D capital stock in one period can be related to that in any other. However, equation *(QA1)* does not tell us how the initial, or benchmark, stock of R&D capital is constructed.

Calculating the initial stock of R&D capital

Coe & Helpman (1993, p. 24) state that their benchmark R&D capital stock was calculated according to the following procedure suggested by Griliches (1980b):

$$S_0 = \frac{R_0}{(g+\delta)} \tag{QA2}$$

where

S_0 is the stock of R&D capital at the beginning of the first year for which R&D expenditure data (in constant prices) is available;

R_0 is the expenditure on R&D (in constant prices) during the first year for which it is available;

g is the average annual logarithmic growth of R&D expenditures (in constant prices) over the period for which published R&D data were available; and

δ is the depreciation or obsolescence rate of knowledge.

Griliches (1980b, p. 346) uses the same approach, but with a zero rate of depreciation (that is $\delta = 0$).

Calculating the rate of growth in R&D expenditure

While most studies appear to calculate their growth rates (g) over the period for which R&D expenditure data is available, Bernstein (1989) uses the historical growth rate in physical capital over the periods prior to R&D expenditure data commencing.

Calculating the rate of depreciation

As new knowledge is created, the value of existing knowledge may decline or be rendered obsolete. This concept is relatively easy to imagine for industrial knowledge. For example, the development of transistors virtually rendered vacuum valves obsolete. However, it is equally applicable to other forms of knowledge as well.

It is conceivable that the rate at which private knowledge becomes obsolete, or depreciates, may well differ from the rate at which social knowledge depreciates. For example, industrial knowledge that may no longer be of use to the industry concerned, but it may still be of some benefit to other industries or society in general.

As Griliches (1979) points out:

> The question of depreciation is much more complicated for social research and development capital measures at the industry or national level. The fact that private knowledge loses its privacy and hence its value is a private loss, not a social one … The real problem here is our lack of information about the possible rates of such depreciation. The only thing one might be willing to say is that one would expect such social rates of depreciation to be lower than the private ones (Griliches 1979, pp. 101–102).

As little additional research appears to have been undertaken since Griliches comment, his observation appears to be still relevant today.

The few studies that have attempted to measure the rate at which knowledge depreciates deal with private knowledge, that is, the decline in value of the various components — specific types of physical capital, human capital, and materials — that constitute the R&D capital stock.[31] Numerous authors quote studies by Mansfield (1973) and Pakes & Schankerman (1978, 1984) to show

[31] Bernstein (1988, p. 5) argues that the concept of depreciation depends on the framework in which knowledge is being modelled. The interpretation of R&D as an input adopted in the studies reviewed here will not apply to all studies, such as those dealing with patents that treat knowledge as an output, not an input.

that industrial knowledge depreciates faster than physical capital, with little left after ten years.[32] Most empirical studies use depreciation rates in the order of 10 per cent per annum. To overcome any uncertainty regarding the rate of depreciation, many studies test the sensitivity of their results to changes in the depreciation rate.[33] There appears to be no discussion as to whether the rate of depreciation changes over time.

Sensitivity of the stock figures

The initial R&D capital stock figures are quite sensitive to the growth and depreciation rates used. Small variations can change the stock figures considerably. Coe & Helpman admit that:

> Our estimated rates of return are sensitive to the calculated benchmarks for the R&D capital stocks, because they are sensitive to the levels of the R&D capital stocks (Coe & Helpman 1993, p. 19).

Numerous studies have undertaken sensitivity tests to the rate of depreciation used. Bernstein (1989) found that his results were not sensitive to small variations in the depreciation rate used. However, Coe & Helpman (1993, p. 12, footnote 1) argue that their conclusions are strengthened by using a considerably higher depreciation rate. It appears that, in general, the R&D stock figures, and the estimated results, are fairly sensitive to the rate of depreciation used. However, small changes may make little difference. If the stock figures are indeed sensitive to the depreciation rate used then the initial R&D capital stock figure is also likely to be sensitive to the growth rate used, which will vary with the period over which they are estimated. However, its importance is likely to diminish over time. The Commission has not come across any study conducting sensitivity studies on the rate of growth used.

While the magnitude of the estimated stock may vary according to the depreciation rate, it does not follow that the elasticity estimates themselves are sensitive to the stock figure. Using a wide ranging sensitivity test on the rate of depreciation (from 0 to 100 per cent), Hall & Mairesse (1993) demonstrate that:

> … the choice of depreciation rate in constructing R&D capital does not make much difference to the R&D elasticity estimates, … although it does change the average level of measured R&D capital greatly, and thus the implied rates of return (Hall & Mairesse 1993, p. 22).

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32 See, for example, Bernstein (1988, p. 329) and Griliches (1979, p. 101).

33 For example, Bernstein (1988, 1989), Bernstein & Nadiri (1989a), Coe & Helpman (1993), Suzuki (1993) and Griliches & Lichtenberg (1984b). The depreciation rates used range from 0 per cent (Coe & Helpman 1993) to 30 per cent (Griliches & Lichtenberg 1984b), with most lying in the range of 5 to 15 per cent. The lower depreciation rates often reflect the social, as opposed to the private, rate of depreciation.

While they find that the elasticity does not appear to be sensitive to the stock figure, the estimated rate of return is.[34]

Conceptually, the PIM is a valid way of constructing capital stock figures. In practice, statistical organisations, such as the ABS, are reticent about its use as the stocks are sensitive to the data used. However, it appears to be the best way of constructing a R&D capital stock series.

Removing the effects of double counting

Irrespective of whether R&D is measured as a stock, expenditure or intensity figure, expenditure on labour and physical capital used in R&D should be removed from the measures of labour and physical capital used in production. Schankerman (1981) clearly demonstrates that the failure to remove this double counting, biases the estimated coefficients downwards.[35] That is, the true returns are likely to be *higher* than those estimated. When the coefficients (elasticities) are converted to marginal products, this difference is magnified even more.

Virtually all of the TFP studies, plus most of the earlier studies, do not adjust for this double counting and, based on Schankerman (1981), their estimates are likely to be lower than if they had done so (all other things being equal).[36] However, many of these studies are subject to countervailing biases, so the net effect is less certain. For example, by using R&D expenditure figures most of the TFP studies do not allow for depreciation. This would lead to an overestimate of the return to R&D when compared with the situation had depreciation been taken into account.

Identifying potential pools of spillover benefits

Most empirical studies implicitly assume that all knowledge is equally substitutable between all firms, irrespective of the industry they are in. This, however, is unrealistic. The more advanced studies attempt to make some allowance for this less than perfect substitutability of knowledge between industries, but not between firms in the same industry. Implicitly, they continue

[34] This flows from the procedure used to convert an elasticity into its marginal product where the elasticity is multiplied by the ratio of total output, costs or profit to the stock of R&D capital.

[35] This finding has been confirmed by a number of other studies, including Cuneo & Mairesse (1984), Griliches & Mairesse (1984) and Hall & Mairesse (1993).

[36] Examples of studies that do adjust for this double counting include Cuneo & Mairesse (1984), Hall & Mairesse (1993), Mairesse & Cuneo (1985) and Schankerman (1981). In its own modelling work, the Commission has adjusted its estimates of capital and labour to remove this double counting at the economy-wide level.

to assume that knowledge is still perfectly substitutable between firms in the same industry. In these studies, the R&D capital stock of an industry is merely the sum of the R&D capital stock of each firm contained in that industry.

Clearly the degree of substitutability of knowledge depends on the type of the knowledge and the industries involved. Insufficient data exists to adequately differentiate between intra-industry flows of embodied and disembodied R&D, and between process and product R&D. To deal with this, the researchers implicitly assume that all knowledge is embodied R&D or that the usage of knowledge between industries mirrors the usage of commodities between industries.

Instead of just adding together the stocks of R&D capital to derive a pool of potential spillover benefits, some researchers weight them according to their 'technological proximity' — a measure of how substitutable knowledge is between industries. The weights indicate how relevant the R&D of one industry is likely to be to the current industry, with a higher weight indicating that its R&D is likely to have greater relevance to the current industry. The weights are typically calculated using one of two approaches, although other methods may be used.[37]

The first method involves identifying those industries that are likely to benefit from patents taken out and those industries taking out the patents. The use of patents makes this approach more plausible for embodied knowledge than it is for disembodied knowledge, and for product R&D, as opposed to process R&D:

> … the availability of patent protection would be expected to have a stronger effect on product R&D than on process R&D (Cohen & Levin 1992, p. 1066).

The major drawback with this approach is that it is resource intensive, as it requires considerable information and is extremely time consuming. It also involves some subjective judgment. Cohen & Levin (1992, pp. 1063–1064) discuss in detail the problems associated with using patents in this manner. The major studies using patents as measures of technological proximity include Englander et al. (1988), Griliches & Lichtenberg (1984b), Mohnen & Lepine (1991), Scherer (1982, 1983, 1984, 1993) and Sterlacchini (1989).

The second method used to calculate the technological proximity weights is on the basis of input-output linkages. One justification of this approach is that the usage of commodities in production may reflect the usage of the knowledge associated with that commodity. This line of reasoning is more plausible for embodied knowledge than it is for disembodied knowledge, and for product R&D, as opposed to process R&D. Examples of studies using this method

[37] For example, through the use of innovation counts or on the basis of their statistical classification.

include Goto & Suzuki (1989), Sterlacchini (1989) and Terleckyj (1974, 1980).[38]

Whilst both methods of measuring technological proximity are open to criticism, they are an improvement on the assumption that knowledge is ‘homogeneous’.

In theory, these approaches could be extended to cover public and foreign R&D. Nevertheless, in practice, this would require considerably more detailed information.

Bernstein & Nadiri (1988) uses another method to identify appropriate spillover pools. In their study of five high technology industries in the United States, they include the knowledge capital stock of each industry separately. The main advantage with this approach is that it enables the source industries to be identified. It also enables the direction of the knowledge flow to be identified from the source to the destination industry. An additional advantage with this approach is that it overcomes the need to aggregate R&D stocks from different industries. However, the major drawback is that it requires considerable data.[39] While Bernstein & Nadiri (1988) had sufficient United States data to use this approach for the five high technology industries, there is currently insufficient data to use this approach for all industries. Whilst being preferable to the aggregation methods described above, this approach is seldom likely to be used for any more than a small number of industries because of insufficient data.

Data induced econometric problems

Econometric techniques rely on variations in the data to estimate statistical relationships. However, sufficient variation between R&D and other inputs may not be present, making reliable econometric results difficult to achieve:

> … there are two other serious econometric problems facing the analyst in this area: multicollinearity and simultaneity. Although both are common “garden variety” econometric problems, each has serious consequences. The problem of multicollinearity arises from the fact that many of the series we are interested in moved very much together over the period of observation. That being the case, it is then difficult (often impossible) to infer their separate contributions with any precision There are no cheap solutions to this problem. It requires either less collinear data, more prior information, or a reduction in the level in the aspiration level of the questions to be asked of the data (Griliches 1979, p. 106).

There may be a high degree of correlation between different types of R&D and between R&D and the quantity of other inputs used, most notably labour and

[38] Sterlacchini (1989) uses two different measures of technological proximity.

[39] Alternatively, the inclusion of so many R&D stock variables weakens the statistical power of the econometric techniques used.

physical capital. The problems are compounded when trying to identify the appropriate lag structure. For example, current levels of R&D may be related to past levels of R&D.

Another possible problem relates to identifying the direction of causality between variables (the simultaneity problem identified by Griliches in the quotation above). A production or cost function assumes that output or production cost is a function of R&D. However, R&D may be related to past output and profit levels. The econometric models used are not capable of separating out this bi causality.

Following the work on cointegration in the late 1980s, another possible problem emerges for time series studies, that of non stationarity. Engel & Granger (1987) demonstrate that traditional time series techniques can lead to spurious results if there is not a stable relationship between variables over time. For a stable relationship to occur over time, the variables must move about the same long term trend. This is referred to as stationarity, while non stationarity occurs when the variables deviate from the long term trend for a sustained period of time.[40] Thus, much of the earlier time series work may be unreliable, perhaps even spurious.

There are a variety of techniques that can be used to overcome some of these problems. For example, the effects of multicollinearity can be reduced through the use of principal component analysis and bi causality can be overcome through the estimation of simultaneous equations.

In most studies, these issues receive only limited coverage. Some studies, for example Coe & Helpman (1993), Coe & Moghadam (1993), Dowrick (1994) and the Commission's own modelling work are far more rigorous than others when it comes to testing for these econometric problems. Even after allowing for recent econometric advances, it appears that the testing in many studies is confined to whether the results are statistically significant, correctly signed and are of the same order of magnitude as to those already published. Issues such as multicollinearity receive little, if any, discussion.

Australian R&D data

Since 1978–79, the Australian Bureau of Statistics (ABS) has been the principal source of publicly available R&D data in Australia. Other sources include, the Department of Industry, Science and Technology (DIST) and the CSIRO.[41]

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40 These definitions are presented as lay interpretations of technical terms only.

41 The Department of Industry, Science and Technology (DIST) was previously known as the Department of Industry, Technology and Regional Development (DITARD) and, before that, as the Department of Industry, Technology and Commerce (DITAC).

Prior to the ABS commencing its R&D surveys in 1978–79, Australian R&D data was collected in 1968–69, 1973–74 and 1976–77 under the auspices of the then Department of the Science's Project SCORE (Survey and Comparison Of Research Expenditure). Prior to 1984–85, ABS surveys were conducted on an irregular basis. Since 1984–85, the ABS has conducted a regular survey of the research sector every second year. Less comprehensive surveys of some of the research sectors are conducted in the intervening years.

These surveys provide a limited coverage of Australian R&D. There are a number of problems, however. Due to the erratic and irregular nature of Australian surveys of R&D, it is impossible to obtain a sufficiently long series of data over time (time series) for some econometric techniques without recourse to interpolation and/or extrapolation. Insufficient industries are surveyed to conduct a cross sectional analysis at a given point in time.[42] It may, however, be possible to use panel (a cross section of industries over time) or pooled (a cross section of industries at different points in time) data for Australia. However, this would require the assumption that the sensitivity of output to R&D is the same across industries and over time, which is unlikely to be the case.[43]

One way to overcome the restrictions on cross sectional work is to seek access to more disaggregated data. The ABS collects this data right down to the individual firm level, but will only publish it at a more aggregated level to ensure confidentiality of individual survey responses. The ABS will not release firm level data under any circumstance.[44] However, many overseas researchers obtain access to detailed information for individual firms through private surveys and the financial market data services.[45] Stock exchange listing requirements in North America require companies to disclose details of their R&D activities. While the Australian Stock Exchange does not require this of Australian firms, a firm may voluntarily disclose details of its R&D activities.

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[42] The ABS R&D surveys do not include R&D undertaken by agricultural business enterprises (ASIC Division A). The ABS claims that this omission does not significantly influence their coverage of Australian R&D because most of the agricultural R&D is undertaken in other industries (for example, *Other Community Services*, which includes the CSIRO, and other agricultural research institutions).

[43] See, for example, Bernstein (1988, 1989), Bernstein & Nadiri (1988, 1989a, 1989b, 1991), Englander *et al.* (1988) and Mohnen & Lepine (1988, 1991).

[44] For an appropriate fee, the ABS will run an external organisation's model on its data, so long as the results do not disclose any confidential information. The principal drawback with this approach is that the external organisation does not have access to the underlying data to validate if the findings are indeed valid or if they are a product of spurious data.

[45] When publishing their results, the researchers take care not to publish data that will identify an individual firm. The most common technique is to pool the data of many different firms together and to report the pooled results.

Few, however, do.[46] Access to such detailed data at the firm level would enable more detailed analysis of the distinction between private and social benefits, especially intra-industry benefits, from R&D.

QA.3 Estimates of the returns to R&D

Over the last thirty years, considerable empirical research has attempted to quantify the extent of spillovers. Reviews by Mairesse & Sassenou (1991), Mohnen (1990a), Nadiri (1993), and others, have attempted to draw this considerable body of research together to enable conclusions to be made for policy. No one review covers all of the studies conducted. Most focus on the returns to manufacturing R&D, although similar studies have been undertaken for the agricultural sector (eg. Griliches 1992 and Huffman & Evenson 1993). Typically, such reviews of the literature include a brief discussion of some of the conceptual or methodological issues involved, before proceeding to draw conclusions from the empirical findings.

To enable valid conclusions to be drawn from these very different empirical studies, their results should be presented in a consistent manner. However, to do this requires a detailed understanding of each study. Sometimes, the reviewer is required to interpret the literature and present their findings in a very different manner to that intended by the original author(s).

Despite the best endeavours of the reviewer, it is virtually impossible to be entirely consistent between studies because of a wide variety of factors, including the use of different methodologies, a lack of clarity in the way findings are presented, the major structural differences in the countries covered, differing levels of aggregation (OECD, economy-wide or industry, a subsection of industries or individual firms), differences in the time periods covered, and whether the rates of return are estimated from specifications that use R&D stocks or flow expenditure figures.

Other reviews have had only limited success in standardising the results between studies. The Commission has attempted to standardise the results reported in this appendix to the extent possible using two approaches. Firstly, the Commission has interpreted a number of the studies first hand to ensure a consistent interpretation. Secondly, it has supplemented its own readings by drawing heavily on a limited number of high quality reviews that use a more or

[46] Personal communication with the Australian Stock Exchange.

less consistent approach.[47] Only those returns that are statistically significant at a 90 per cent level of confidence are reported. Where more than one model has been estimated, this review includes a range of results across all models, rather than making some subjective judgement as to which model to use. Those studies that estimate elasticities and do not provide sufficient information to enable rates of returns to be calculated have been excluded, unless there are no studies estimating rates of returns.[48] For these reasons, the results reported here may differ from other reviews.[49] In addition, this review attempts to cover more than just industrial R&D.

Where the econometric studies attempt to measure the existence of spillovers, they invariably identify the benefit accruing to receiving industry, but not necessarily the industry source of the spillovers.[50] Except in a very limited number of cases, the studies do not enable the bilateral flows of R&D between industries to be identified.[51]. These two severe limitations greatly reduce the policy relevance of these studies.[52]

Given the limited number of Australian studies, especially outside agriculture, the Commission has attempted to econometrically estimate the returns to Australian R&D at the economy-wide, as well as at the sectoral level for agriculture, manufacturing, mining, other services and wholesale & retail trade. This work is subject to many of the qualifications of econometric studies discussed here. As far as the Commission can ascertain, it represents the first significant Australian effort to econometrically assess the importance of private, public and foreign R&D. Appendix QB contains a more detailed discussion of the results and methodology employed, as well as its limitations. This review, however, seeks to put the Commission’s findings in context with the other studies reviewed here.

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47 Principally Mairesse & Sassenou (1991), Mohnen (1990a) and Nadiri (1993). An added advantage of these reviews is that the authors are bilingual and review a considerable body of Canadian and European literature written in French.

48 Examples of studies estimating elasticities that have not been reviewed include Griliches & Mairesse (1990), Hall & Mairesse (1993), Mairesse & Cuneo (1985), Nadiri & Bitros (1980) and Sassenou (1988) at the firm level and Nadiri (1980b) and Nadiri & Prucha (1990) at the industry level.

49 Numerous other factors may explain why the results of the same study are reported differently between reviews. The Commission has interpreted the studies using the definitions set out in the glossary (box QA1).

50 The cost function studies presented in tables QA10 to QA12 identify the industries generating the spillovers to be identified.

51 Bernstein (1989) is one such study.

52 The inability to identify the flow of R&D between industries could easily be overcome if sufficient data were available to allow the R&D efforts of individual industries to be included separately in the model.

The discussion that follows relates only to the findings of those studies reviewed here. Whilst being as comprehensive as possible, the list of studies contained in this review is by no means exhaustive.[53]

Measuring the returns to R&D

Most of the econometric studies surveyed measure the percentage increase in output, costs, profits, or total factor productivity that occurs in response to a one per cent increase in R&D (the elasticity with respect to R&D) or the change in total output, costs, profits, or total factor productivity that results from a one unit (dollar) increase in R&D (the marginal product of R&D). Although related, the concept of an elasticity is different from that of a marginal product. Given sufficient information, an elasticity can be converted into its equivalent marginal product. However, a number of reviews do not differentiate between the two. This appendix reports marginal products, except in isolated cases where the only studies that have been undertaken report elasticities.[54] These marginal products are loosely termed rates of return by the literature.

Unfortunately, the agricultural econometric studies present their findings differently to their industrial counterparts, in that they present marginal internal rates of return (MIRR), rather than marginal products.[55] Although related, it is not possible to easily convert between the two without recourse to the underlying data. Based on the limited number of studies that report both MIRRs and marginal products, the MIRR yields a significantly lower estimate of the rate of return than do the corresponding marginal products. For this reason, the returns to agricultural R&D are not strictly comparable with those of the industrial R&D.[56]

Case studies do not report marginal products. Rather, they usually present ratios of the total benefit to the total cost involved (benefit cost ratio), where all future

[53] For example, it does not include a number of French or Italian econometric studies that estimate cost functions.

[54] The marginal products have been converted to percentages by multiplying them by 100.

[55] Technically, the marginal internal rate of return (MIRR) is calculated as the interest rate required to equate the total value of the marginal product (TVMP) to zero. In each year, the value of the marginal product (VMP) is equal to the marginal product (MP) multiplied by the price level in that year. The TVMP is simply the sum of the various VMPs discounted back to the present.

[56] Thirtle & Bottomly (1988, pp. 108-109) raise an additional question as to what prices should be used to evaluate the rates of return in the presence of price distortions — the distorted or undistorted world price. This issue is likely to be more pertinent for the European countries subject to the Common Agricultural Policy (CAP), most notably for the United Kingdom, for which numerous studies have been undertaken, than Australia. It may be applicable to other countries, such as, the United States as a result of its Export Enhancement Program (EEP).

and past benefits and costs have been converted to current dollars (net present value).[57] However, benefit cost ratios are not the same as rates of return. To enable consistent comparisons to be made with the econometric studies, the benefit cost ratios have been multiplied by the discount rate used in calculating the net present values, giving a measure equivalent to an average annual rate of return (see Trajtenberg 1990, p. 166).

The rates of returns contained in this review indicate the total returns to R&D. They measure the flow of benefits expressed as a proportion of the cost of the asset (the stock of knowledge) generating the benefit. Where the stream of future benefits varies over time, it can be expressed in turn as an equivalent average annual benefit flow in perpetuity. To enable valid comparisons to be made, those studies whose estimates are net of depreciation have been converted to gross rates of return by assuming a depreciation rate of 10 per cent (see Mairesse & Sassenou 1991, p.18).[58]

Does the rate of return to R&D vary depending on the methodology used?

Before attempting to assess the policy relevance of their findings, it is worth considering whether the methodology that these empirical studies employ systematically influences their findings. On the basis of tables presented in this appendix, the rate of return to R&D appears to vary considerably depending on the methodology employed, data used (time series or cross sectional) and whether the analysis is at the firm, industry or country level.

In most cases, case studies of individual projects appear to yield considerably greater variation in their estimates of both the private and social returns to R&D than do the econometric studies. The upper bounds are often considerably higher, ranging in the case studies reviewed up to 2970 per cent (Grains RDC 1992), than the econometric studies whose upper bound is 329 per cent (Mohnen & Lepine 1991). The lower bounds of the case studies tend to be broadly comparable with the econometric studies. This highlights the extreme

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[57] Those studies that do not present their results as a ratio of total benefits to total costs have had their results converted to a total benefit cost ratio, prior to calculating the rate of return, to ensure consistency between studies (eg. Griliches 1958). Similarly, those studies that report only internal rates of return have been excluded (eg. Mansfield *et al.* 1977 and Tewksbury *et al.* 1980).

[58] However from their own empirical work, Hall & Mairesse (1993, p. 21) find the size of the small difference between the gross and net R&D coefficients ‘puzzling’. They discuss theoretical arguments as to why it should be either higher or lower, but cannot establish a case for why it should be similar. Despite their findings, the Commission has used the policy of Mairesse & Sassenou (1991) and Dempster (1994) because of its common usage in the literature.

variability in the returns to individual projects. Unlike the case studies that look at individual projects, the econometric studies look at all R&D, irrespective of whether it is profitable or not, and this is reflected in lower average rates of return to R&D.

Cross sectional studies tend to yield higher estimates of the rate of return to R&D than do time series studies. As Mairesse & Sassenou (1991, p. 9) note for firm level studies, this may reflect the absence of any variables representing the characteristics common to all firms within the industry. The inclusion of these variables yield lower estimates of the returns to R&D.

Similarly, TFP studies appear to be subject to more variation than do those estimating production functions. In part, this is likely to reflect the fact that there appears to be more subtle variations in the specification of TFP models (eg. whether the growth in labour productivity or TFP is being used) than in the other econometric models used.

As mentioned earlier, the TFP studies assume that output is a constant returns to scale function of physical capital and labour. By employing constant returns to labour, physical capital and R&D in their cross sectional work and not in their time series work, Griliches & Mairesse (1984) show that this assumption biases the estimated returns upwards.[59] While this difference may reflect other differences between time series and cross sectional techniques, Griliches & Mairesse demonstrate later in their paper that this bias holds using the same technique (p. 372). Cuneo & Mairesse (1984), Hall & Mairesse (1993) and Mairesse & Cuneo (1985) support these findings.[60] Mairesse & Sassenou note:

> … time series estimates of the R&D elasticity … generally tend to be lower than the corresponding cross sectional estimates. This phenomenon may be attenuated to a certain extent, by imposing *a priori* constant returns to scale. It becomes more apparent if this constraint is relaxed, implying estimated returns to scale which are sharply decreasing (whereas the cross sectional estimates of returns to scale are constant or weakly decreasing) (Mairesse & Sassenou 1991, p. 13).

Finally, the rate of return to R&D increases with the level of aggregation. Studies for entire economies tend to yield higher estimates than do those using data at the aggregate industry level. These differences are only partially

59 By converting their elasticities to rates of return, the return to R&D falls in one case from 62 to 42 per cent. Lichtenberg & Siegel (1991) derive similar estimates from the same study.

60 Hall & Mairesse (1993) demonstrate that the magnitude of this effect varies depending on the way in which the variables are measured (unadjusted, as deviations from the means, between successive observations, changes over time etc). They demonstrate that this effect is largest where the variables are measured as the difference between successive observations and small for unadjusted data (the most common method in the studies surveyed). In the remaining cases, they accept the assumption of constant returns to scale.

accounted for by the existence of spillovers between industries. Indeed, those industry level studies that explicitly take account of spillovers to firms in other industries (see table QA3) do not yield returns that are broadly comparable to those obtained from the limited number of economy-wide or international studies (table QA6). However, there appears to be little difference in the rates of return estimated from studies using firm (tables QA1 and QA3) and industry level data (tables QA2 and QA4). This, coupled with those few studies that attempt to estimate the spillovers between firms in the same industry (Bernstein 1988, Bernstein & Nadiri 1989a and Suzuki 1993), indicate that intra-industry spillovers may be fairly small.

What are the private returns to R&D?

Whilst still being subject to considerable variation, the econometric studies estimate that the return to the firm undertaking R&D expenditure (that is the private rate of return) is in the order of 10 to 55 per cent (tables QA1 and QA2). Only one West German study, Bardy (1974), has rates of return significantly outside this range with estimates in the range of 92 to 97 per cent.

At the industry level, the rate of return appears to be little different from those at the firm level, with most in the range of 10 to 50 per cent (tables QA3 and QA4). There are three notable exceptions: the upper estimates of Mohnen & Lepine (1988, 1991) exceed this range considerably with upper estimates of approximately 285 per cent and the lower bound of Odagiri (1985) is negative with a lower estimate of - 66 per cent

How large are the spillovers associated with R&D?

The spillovers associated with R&D are composed of two distinct elements: the extent to which firms in the same industry as the firm undertaking the R&D benefit from the R&D (intra-industry spillovers) and from firms in other industries (intra-industry spillovers).

As discussed previously, the spillovers between firms in the same industry appear to be fairly small. Direct estimates of their magnitude by Bernstein (1988), Bernstein & Nadiri (1989a) and Suzuki (1993) yield estimates in the range of 2 to 15 per cent. This would place them at the lower end of the estimates of the private returns to R&D.[61] Given the limited number of studies on which these estimates are based, these numbers need to be interpreted cautiously. The alternative approach of comparing the private returns from the firm level studies and the industry returns from the industry level studies

[61] These studies indicate that intraindustry spillovers range from 20 per cent of the private returns to R&D to an upper estimate of 130 per cent.

indicates that the net effect to society of intra-industry spillovers may be small, even possibly negative, reflecting the possibility that the pecuniary effects of intra-industry spillovers may actually erode the private returns.

Estimates of the intra-industry spillovers (tables QA3 and QA4) obtained from the industry level studies indicate that they appear to be more significant than intra-industry spillovers, with most lying in the range of zero to 150 per cent, with an average of return of approximately 75 per cent. Most of the outliers exceed the specified range by up to 40 per cent. One firm level study, Jaffe (1986), found that the cumulative effect of intra and intra-industry spillovers to be marginally negative.

However, a different conclusion about the relative magnitudes of intra and intra-industry spillovers is reached from the only firm level study undertaken that separately estimates both.[62] Bernstein (1988), found the converse — that intra-industry spillovers (ranging from 6 to 13 per cent) exceeded the intra-industry spillovers (2 per cent). However, his estimates of the extent of intra-industry spillovers are considerably smaller than those obtained from the industry level studies. This highlights the need for further research to establish whether intra or intra-industry spillovers are more significant.

From the industry level studies presented in table QA12, the ratio of total (that is private plus total spillover benefits) to industry (that is private plus intra-industry spillovers) benefits from R&D vary between 0.1 to 4.0 as to 1, with most lying in the range 1.2 to 2.0 as to 1 and a mean of approximately 1.6. This suggests that intra-industry spillovers are some 20 to 100 per cent of the industry rates of return.

Does the rate of return to R&D vary depending on the type of R&D?

A number of econometric studies explore whether the rate of return varies depending on the nature of R&D — applied R&D, basic R&D and, in one case, developmental R&D. Based on the limited number of studies, they tentatively indicate that the rate of return to basic R&D appears to be higher than that for applied R&D. Commenting on his 1980 findings, Mansfield notes that:

> These findings seem to indicate a strong relationship between the amount of basic research carried out by an industry and the industry's rate of productivity increase during 1948–66. However, one wonders whether, since the distinction between basic research and applied research is often nebulous, this relationship may not reflect the fact that industries that carry out relatively large amounts of long term R&D tend to

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62 Although Griliches & Mairesse (1983) also estimates both, their estimates have been excluded as they do not separately identify the private returns to R&D. Their estimate of the intraindustry returns may reflect some of the private returns involved.

> have relatively high rates of productivity increase. In other words, basic research may be a proxy for long term R&D[63] (Mansfield 1980, p. 866).

Mansfield (1988) found that the importance of applied versus basic R&D may vary between countries. He found that applied R&D was considerably more important to the Japanese economy than it was to the United States and, while both forms of R&D were important to the American economy, basic R&D was more important than that of an applied nature.

This tentative finding should be viewed cautiously. Apart from the difficult issue of classifying R&D expenditures between applied and basic research, the studies deal with the impact of R&D undertaken by the firm or industry on the firm or industry. They do not make any attempt to measure the return to other forms of applied or basic research (eg. that undertaken by universities or by the public sector), nor do they measure the wider benefits to society from firm or industry's R&D.

A few studies, Clark & Griliches (1984), Griliches & Lichtenberg (1984b) and Scherer (1982, 1984, 1993), have found that the rate of return to R&D designed to improve production processes (process R&D) yields higher rates of returns than R&D designed to improve existing, or develop new, products. However, these studies do not take into account the fact that some product R&D may go to developing new or better products to be used in the production process of other firms. Griliches & Lichtenberg (1984b) found that the return to process R&D was in the range of 58 to 76 per cent, while the return for product R&D was in the range of 21 to 30 per cent. Similarly, Scherer (1993) finds the return to product R&D to lie in the range of 26 to 30 per cent.[64] Based on the limited evidence from these few studies, it appears that the returns from process R&D may be different from those on product R&D.

The Commission has only found a limited number of studies that explicitly attempt to measure the returns to public research.[65] All are case studies of individual projects, with the exception of one econometric study, and cover agricultural R&D undertaken by public sector agencies (eg. CSIRO).

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63 Mansfield then proceeds to test this hypothesis and finds that 'much of the apparent effect of basic research may really be due to long–term R&D' (p. 866). After adjusting for this, he found that the effect of basic research 'becomes smaller and is often statistically insignificant' (p. 867).

64 In the text, Scherer states that process R&D is statistically significant but does not report the rate of return associated with it.

65 Econometric studies of the returns to Australian agricultural research have not been classified as public research, despite the high proportion of public funding to Australian agricultural research.

Lichtenberg (1992) includes a measure of all publicly funded R&D, whether or not it is undertaken by the public sector, in his econometric model. He found that publicly funded research generates a statistically significant lower rate of return than does privately funded R&D. The caveats discussed earlier about publicly funded R&D undertaken by private sector are equally applicable here.

The case studies (tables QA14) indicate that the returns to public R&D are generally subject to greater variability than are those for private R&D, particularly in relation to the maximum returns. However, those studies that indicate the most variability, particularly the upper estimates, are those undertaken by, or on the behalf of, industry research groups (eg. studies by the Grains RDC and the MRC). Notwithstanding the fact that individual projects may be highly profitable, this may well reflect the fact that all the benefits and, most probably, all the costs are not factored into account, especially where some or all of the research is undertaken by other organisations (eg. CSIRO). Nevertheless, it appears that public research is similar to private R&D in that the return to individual projects varies considerably. Many are highly beneficial, while others are not.

While not estimating the return to academic research, Jaffe (1989) found evidence of spillovers from academic research to a number of manufacturing industries in the United States. The effect varied between industries, with the effect being statistically strongest for the drugs, chemical and electronics industries. Jaffe (1989, p. 968) suggested that these results indicated that ‘the spillovers are limited to specific areas and not just the diffuse effect of a large research university’.

Some of the agricultural econometric studies have attempted to ascertain whether the returns to extension, or the dissemination of existing research findings amongst farmers, differs from that flowing from the original research. In their review of the American literature, Huffman & Evenson (1993, p. 246) find that a majority of studies (Evenson 1980, 1992 and Huffman 1976, 1981) yield higher rates of return to agricultural extension services than do other studies estimating the return to the R&D. However, Huffman & Evenson (1993, p. 245), Lu et al. (1978) and Lu et al. (1979) yield significantly lower estimates of the return to agricultural extension. Mullen & Cox (1994a) finds that extension is not statistically significant and Thirtle & Bottomly (1988, 1989) exclude it due to collinearity problems. Given the difficulties in measuring exactly what constitutes extension and how it is different to R&D, these results should be viewed cautiously.

Does the rate of return to R&D vary depending on the source of funding?

In a similar vein to those studies that attempt to differentiate whether the return to R&D varies depending on the nature of the R&D undertaken, a limited number of studies (see table QA9) attempt to explore whether the rate of return varies depending on the source of funding. The studies are all for the United States and differentiate between private and public funding of R&D undertaken by the firm. It should be stressed that these studies look at public funding of private R&D and not R&D undertaken by the public sector.

Most of the studies presented in table QA9 find that privately funded R&D has a positive and statistically significant effect on productivity. Only three studies (Link 1981b, Mansfield 1980 and Terleckyj 1980) do not find a statistically significant relationship. The average private rate of return to privately funded R&D appears to be in the order of 35 per cent and appears to be subject to less variability than for total R&D (tables QA1 to QA4).

Only one study, Mansfield (1980), has found publicly funded R&D to be statistically significant, yielding a 12 per cent rate of return. The four other studies found publicly funded R&D did not have any statistically significant impact on productivity growth.

Given that a firm's total expenditure on R&D can be funded from either private and/or public sources, it is not surprising that the return to all private industrial R&D lies, in all but one case, between the rates of return to private and public R&D. In essence, the return to total R&D appears to be a weighted average of that which is privately financed and that which is publicly funded.[66]

The studies indicate that the returns to private R&D exceed those to publicly funded R&D undertaken in private firms. Given that most studies find public funding of private R&D to be insignificant, this raises the questions as to its worth. It could be that this funding is directed towards areas providing broader society benefits of the type that cannot be detected using these techniques (eg. improving air or water quality, health standards etc).

Does the rate of return to R&D vary over time?

The studies are clearly divided as to whether the rate of return to R&D has changed over time. Englander et al. (1988), Griliches (1980b, 1986), Griliches & Lichtenberg (1984a), Nadiri & Prucha (1990) and Odagiri (1985) have found that the productivity of R&D has declined over time. However, BLS (1989), Clark & Griliches (1984), Griliches & Lichtenberg (1984b), Griliches &

[66] It is not clear from these studies the basis on which public funds are allocated, nor is there any indication as whether public funds are directed towards projects that have a higher level of risk than those funded by the company funds.

Mairesse (1984), Lichtenberg & Siegel (1989, 1991), and Scherer (1982, 1984, 1993) do not find any evidence of a decline over time. Griliches & Mairesse (1990) raises the possibility that the rate of return varies over the business cycle. The Commission's own work in appendix QB seems to tentatively support this conclusion.

Do the returns to R&D vary between countries?

The Commission has only been able to find a limited number of studies that seek to identify the importance of R&D at the national or international level. Most relate to the United States and Japan, but studies have also been undertaken for Canada, France, Italy, Sweden, the United Kingdom and West Germany. The study done for the Commission by Dowrick (1994) separated Australia out from an earlier aggregated study by Coe & Helpman (1993).[67] Given the dearth of Australian studies, the Commission has undertaken its own econometric work at the national level (see appendix QB).

Most of the national studies estimate elasticities of total factor productivity with respect to the stock of R&D, rather than rates of returns. Coe & Helpman (1993) and the Commission's own econometric work (see appendix QB) are the only exceptions. Using data from Coe & Helpman (1993), the Commission has calculated the rates of return implied by Dowrick (1994). Unfortunately, most studies estimate the effects for a single country or the average across a number of countries. Thus, it is hard to isolate country specific effects from those caused by differences in the data or methodology employed.

Patel & Soete (1988) is the only study that the Commission has found that estimates the importance of R&D at the national level for a number of countries – Canada, France, Italy, Japan, Sweden, the United Kingdom, the United States and West Germany. An added advantage is that they use the same methodology and cover the same period of time (1967 to 1985) for all countries. They found substantial variation in the elasticities between countries (table QA7), with the United Kingdom recording the highest elasticity (+0.82), and Canada the lowest (+0.26). High estimates were also obtained for the United States (+0.61) and Italy (+0.56). Unfortunately, they do not provide sufficient information to enable rates of returns to be calculated. Given that national income and the size of the R&D stock varies considerably between countries, the distribution of the underlying rates of return may not be distributed in a similar pattern to the elasticities. However, their estimates of the elasticities are substantially higher than those of other studies at the economy-wide level.

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67 The Commission has not included an international study by Marinova (1991) on the grounds that the methodology employed is inadequately explained and, in the absence of such an explanation, appears dubious.

In concluding their own work, Patel & Soete (1988) are cautious about their own findings. They identify that the small growth in the R&D capital stock in the United Kingdom had ‘little to do with the significant growth in total factor productivity’ and would ‘need to be explained in terms of other factors than growth in domestic R&D’ (p. 161). Conversely, over recent times Canada recorded the lowest growth in total factor productivity, despite being ‘accompanied by a very significant and rapid uptake in the growth in measured domestic R&D capital stock’ (p. 161). Rather than interpreting their Canadian result as ‘pointing towards a sudden highly inefficient Canadian R&D stock with regard to its presumed impact on productivity growth’ (p. 162), Patel & Soete conclude that:

> Econometric studies in this area need therefore to be interpreted and taken with a large measure of scepticism. They provide useful hints and indications of presumed economic relationships, which are however largely obscured by the difficulties in approximating some of the most crucial concepts (Patel & Soete 1988, p. 162).

Aside from this study, the elasticities estimated by other studies are broadly similar. The estimates for the United States (Nadiri 1980a) and Australia (Dowrick 1994) are comparable to the non G7 results obtained by Coe & Helpman (1993) and the average result across 53 member countries of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) (Lichtenberg 1992). If the ratios of national income to the stock of R&D in the United States and Australia are similar to that indicated by Coe & Helpman (1993, p. 27), then the rate of return to domestic R&D in Australia is approximately six times that in the United States. Dowrick’s estimated elasticity of +0.07 (table QA7) implies a rate of return to domestic R&D in Australia of approximately 170 per cent (table QA6).[68] Even the industry and firm level returns (tables QA1 to QA4) appear to be broadly consistent across countries.

Based on this limited evidence, it is difficult to come to a conclusion as to whether the rate of return to R&D varies between countries. The limited evidence indicates that the elasticities may be more stable across countries than are the rates of return. However, there is insufficient evidence to identify international patterns or to attribute the underlying causes.

[68] Coe & Helpman (1993, p. 18) outline the procedure needed to convert an elasticity into a rate of return. For the domestic stock of R&D, the estimated elasticity was multiplied by the ratio of GDP to the domestic stock of R&D. For foreign R&D, a similar approach was used, except that the import weighted foreign R&D stock was used instead of the domestic stock. The foreign stock of R&D was calculated as the weighted sum of the domestic R&D stocks of the other 21 countries, where the weights reflect each countries’ share of total imports. All of the necessary data needed is contained in Coe & Helpman (1993, pp. 25 & 27).

Does the rate of return to R&D vary between sectors?

There appears to have been little empirical work undertaken anywhere in the world using sectoral level data.[69] The only study the Commission found is Englander et al. (1988) which pools international data to estimate the elasticity of TFP with respect to the stock of R&D. This study, however, deals with the industry benefiting from the R&D and not that actually undertaking it. In this sense, it is not entirely consistent with most of the other studies here. The results do, however, give a measure of the total, as opposed to private, returns from R&D. Two additional disadvantages with this study are that it does not provide sufficient additional information to enable rates of return to be calculated and that it disaggregates the manufacturing sector down to individual industries. Their results are presented in table QA5.

Englander et al. also estimate an alternative formulation for the manufacturing industries based on the industry actually undertaking the R&D. This measures the private returns to R&D at the industry level. In the Commission's own econometric work, it has extended this approach of looking at the sector undertaking R&D to explore if the private returns to Australian R&D vary between sectors (see appendix QB). In addition, the Commission has attempted to extend its work to cover the benefits from other forms of research (other sector's own R&D, public sector and foreign R&D). The results are presented in table QA5 as both elasticities, to enable comparison with those of Englander et al., and as rates of return.

Before proceeding to discuss these results, some caveats need to be highlighted. Englander et al.'s study includes some sectors for which output is difficult to measure. It is for this reason that the Commission has included only those sectors for which the ABS can independently measure output. Neither study adjusts their measures of TFP to take account of the double counting of the labour and physical capital used in R&D in both deriving TFP and then again in the R&D stock. Thus, the earlier discussion about the effects of double counting is relevant here and, in the case of the Englander et al., so is the discussion relating to output measurement. Schankerman (1981) demonstrates that the failure to adjust for this double counting will lead to an underestimate, possibly even significant underestimate, of both the elasticity and rate of return to R&D.

Based on the findings of these two studies, the returns to R&D do appear to vary between sectors. Both studies indicate that the sign of the statistically significant results may vary. Despite appearing counter intuitive, there may actually be a logical explanation for a negative correlation. It may be that the measured productivity of these industries may be declining because of other factors that

[69] Sectoral level is defined as being equivalent to the ASIC Division level used by the ABS.

have not been taken into account, irrespective of the amount of R&D undertaken (that is a missing variable problem). Both sets of results show significant variation between sectors. Given the small number of studies, not too much significance should be placed on the results for any one sector. By not reporting the R&D stock or their intensities, the reader of these studies is not given an indication of how large these sectors are and how important R&D is for each sector. Such factors are important in assessing the policy relevance of their conclusions. For example, if the results indicate the return to R&D is higher for a relatively small sector that undertakes little R&D than for a much larger sector that undertakes considerably more R&D then the effect on the economy, as well as the budget, would be considerably different.

As discussed earlier, it is not possible to directly compare the rates of return estimated by the agricultural studies with those of the industrial studies due to differences in the way the returns are measured. If the associated marginal products are indeed higher than the MIRRs, as appears to be indicated by the limited number of studies that estimate both (eg. Huffman & Evenson 1993, p. 245), then the returns to agricultural R&D appear substantial (table QA13). It is not, however, possible to say whether they exceed those from industrial R&D or not.

Nevertheless, these studies indicate that the returns do differ between sectors.[70] This would appear to be a logical extension of the industry results discussed below.

Does the rate of return to R&D vary between industries?

All of the industry level studies that the Commission has come across deal with manufacturing industries and are all North American and employ broadly similar methodology. Tables QA10 through to QA12, respectively, present the private and total returns to R&D at the industry level, as well as the ratio of total to direct (in most cases private) benefits from R&D.

The first thing that should be noted is the limited coverage of certain industries, for example *Communication equipment* and *Other machinery*. Aggregation differences may account for some of this limited coverage, especially amongst

70 Earlier econometric studies for the United Kingdom, for example Wise (1986) and Harvey (1987, 1988), found that the return to agricultural R&D was low or, in some cases, even negative. Thirtle & Bottomly (1988, 1989), however, challenge the methodology used in these studies and raise numerous conceptual difficulties with the approaches taken. Using the same methodology as the other international studies, they find that the rate of return to agricultural R&D in the United Kingdom is significantly higher than the earlier studies indicated, in the order of 90 per cent, and is broadly comparable with those of other countries. This estimate is considerably higher than the 20 per cent obtained by Doyle & Ridout (1985).

the Canadian studies.[71] Unfortunately, many of the industries indicating above average rates of return receive only very limited coverage. It is not clear from this whether the higher rates of return are actually higher than other industries or whether they are because of data irregularities.

Nevertheless, the studies presented in tables QA10 and QA11 indicate that the private and total rates of return appear to vary between manufacturing industries. The ratio of total to private returns for individual industries appears to be subject to less variability than that which occurs between studies. For most industries, the ratio of total to private benefits appears to be in the range of 1 and 2 as to 1. The industry receiving the widest coverage is non electrical machinery with an average ratio of total to private benefits across all studies of 5 as to 2. However, even estimates for this industry are subject to considerable variation. In only two of the six studies does the ratio significantly exceed 2 as to 1.

Some firm level cross sectional studies do, however, find some differences in the rate of return to R&D undertaken by the ‘scientific’ sector as opposed to the rest of manufacturing.[72] Griliches & Mairesse (1984) find that the elasticity is over three times higher for the scientific sector (0.18) than for other manufacturing industries (0.05). However, this finding is not supported by the time series studies (Mairesse & Sassenou 1991, p. 11).

There are only a limited number of studies that look at the flow of spillovers between industries. Bernstein (1989) identifies the flow of spillovers between manufacturing industries. He found that the largest spillovers were from the chemical to petroleum products (spillover of 74 per cent), from the primary metals to metal fabricating (59 per cent) and from the primary metals and non electrical machinery to electrical products (55 and 54 per cent respectively). Bernstein & Nadiri (1991) extended this approach by decomposing the intra-industry spillovers into two components: the effects of changes in output price flowing from changes in demand and those that bring about lower production costs. They found that these two effects are often, but not always, offsetting. For many industries, the positive effect of lower production costs and higher sales volumes occur at the expense of lower product prices. In all cases, spillovers from lower production costs are larger than those because of the product price effects, whose direction varies considerably between receiving industries. While the intra-industry flows of spillovers are not as clear cut as that of Bernstein

[71] The United States studies tend to focus on specific groups of industries that may be more susceptible to spillovers. For example, Bernstein & Nadiri (1988) focus exclusively on five high technology industries instead of all United States manufacturing.

[72] The scientific sector comprises a subgroup of manufacturing that generally includes chemicals, drugs, electrical equipment, electronic equipment and scientific instruments.

(1989), their results do support his finding that spillovers tend to be larger between related industries and that R&D undertaken in one industry may benefit more than one industry. However, it is not clear from these studies whether the spillovers are because of the production relationship or the fact that these industries employ similar technology.

Individual agricultural studies indicate that the returns may vary between industries, but not in any discernible pattern across studies (see table QA13). In isolated cases, the estimates may actually be negative.[73]

Nevertheless, the bottom line from all this appears to be that the rate of return to R&D does appear to vary between industries. However, there does not appear to be sufficient agreement between studies as to those industries generating the higher rates of return and by how much they exceed those of other industries. The limited evidence indicates that spillovers may be greater between similar industries.

Does the rate of return differ with ownership?

As only one Canadian study, Bernstein (1989) has attempted to see if the rate of return varies with the nature of ownership (Canadian owned versus foreign owned), the Commission is unable to corroborate his finding that, in some industries, the nature of firm ownership significantly influences the reaction of firms to intra-industry spillovers.

How important is foreign R&D?

The Commission has been able to find only one study (Coe & Helpman 1993), other than its own modelling work, that attempts to directly assess the importance of foreign R&D or international flows of knowledge.[74] They conclude that:

> Not only does a country's total factor productivity depend on its own R&D capital stock, but as suggested by theory, it is also depends on the R&D capital stocks of its trade partners … Foreign R&D has a stronger effect on domestic productivity the more open an economy is to international trade (Coe & Helpman 1993, p. 19).

73 For example, Huffman & Evenson (1993, p. 245) found that the MIRR, as well as the marginal product, of public R&D undertaken for the livestock industry in the United States over the period 1950 to 1982 was negative.

74 In their analysis of the determinants of the growth in total factor productivity in France, Coe & Moghadam (1993) include not only the stock of French R&D capital, but also a measure of the openness of the economy to trade. They do not, however, include a measure of foreign stocks of R&D.

They found that, in ‘large’ countries, the stock of domestic R&D capital was more important than foreign R&D in contributing to TFP growth.[75] For most, but not all, ‘small’ countries, they found the converse to be true – that foreign R&D was more important than domestic R&D.[76] Australia, however, was a notable exception. They do not, however, elaborate as to why Australia or the other exceptions (which also include New Zealand) should be more reliant on domestic R&D than similar countries. What they fail to point out is that according to their own import shares, these countries are the most ‘closed’ of the ‘open’ economies. According to Coe & Helpman’s data, Australia had the third lowest share of imports to GDP in 1990 of any OECD country (plus Israel), lower than all of the ‘closed’ economies except Japan and the United States. This fact seems to further strengthen their conclusions that the more open an economy is to trade, then the more able it is to benefit from R&D undertaken elsewhere. Recent trade liberalisation in Australia over the last decade is likely to increase the importance of foreign R&D to the Australian economy in the future.

As the Commission has not found any other international studies to corroborate the findings of Coe & Helpman, the Commission has sought another way to test their findings. In the absence of studies dealing with international R&D, the Commission has adopted Dempster's rather crude convention of separating those studies dealing with ‘closed’ from those dealing with ‘open’ economies to see if the rate of return to R&D differs with the degree of openness of an economy. This approach is merely capable of identifying if the return to domestic R&D varies and is incapable of identifying the extent to which countries benefit from foreign R&D. The Commission has used a wider definition of ‘closed’ economies than Dempster (1994), by including Japan as well as the United States.[77] All of the remaining countries covered by the empirical studies reviewed here are included in the tables representing the more ‘open’ economies. Whilst these ‘open’ economies import significantly more as a proportion of GDP than do either Japan or the United States, they share little else in common. There is significant variation in their relative importance in

75 As well as Japan and the United States, Coe & Helpman also classify Canada, France, Italy, the United Kingdom and West Germany as ‘large’ countries (all are members of the G7 group of countries).

76 The remaining 14 OECD countries, including both Australia and New Zealand, as well as Israel, were classified as ‘small’ countries (non G7 countries).

77 In terms of the ratio of imports to Gross Domestic Product (GDP) in 1990, Japan is very similar to the United States with 9 and 11 per cent shares respectively. By defining ‘openness’ on the basis of imports, this approach does not take into account any knowledge gain that may occur through the export process. This is a logical extension of the findings of many studies that input suppliers (in this case, exporters) play a valuable role in the R&D process (see, for example, BIE 1994b, p. 17 and Suzuki 1993).

terms of international R&D and the structure of their economies. In terms of their importance to international R&D, the United Kingdom (UK), West Germany (FRG) and France are more like Japan and the United States, than are Australia, Belgium, Canada or Italy (Coe & Helpman 1993, table 12, p. 27).

Given the considerable range and limited number of studies undertaken for small 'open' economies (table QA2 and QA4), it is not possible to draw anything conclusive from this approach. For the 'closed' economies (tables QA1 and QA3), there appears to be less variation, but nonetheless substantial in its own right, than for the small 'open' economies. Even amongst the Canadian studies, Mohnen & Lepine (1988, 1991) produce considerably more variation than does Bernstein (1989) and considerably more than Sterlacchini (1989) does for the United Kingdom.

In terms of the returns to R&D at the manufacturing industry level (tables QA10, QA11 and QA12), the Canadian studies indicate both higher private returns and spillovers to R&D than do the United States studies for a comparable level of aggregation. Despite using broadly similar approaches, this may reflect the more extensive industry coverage of the Canadian studies and specificational differences as to the way R&D influences production costs, rather than the fact that the returns to R&D vary with the openness of an economy to trade.

Despite some sound theoretical justification, the empirical studies do not conclusively demonstrate that the returns to R&D are higher the more open an economy is to trade. The only study that the Commission has found to directly test this hypothesis validates it, but the indirect evidence remains strongly inconclusive.

How does the return to R&D compare to that on physical capital?

The survey work of Mairesse & Sassenou (1991) indicates that the elasticity with respect to physical capital tends to be higher, or lower where negative elasticities are estimated, than those for R&D. This difference does not, however, appear to be sufficiently large between the elasticities given the probable differences in the sizes of the respective capital stocks. The implication of this is that the rate of return to R&D may well exceed that on physical capital.

A limited number of studies, mostly cost functions, also estimate the rate of return to physical capital. Bernstein (1989) estimates that the mean rates of return to R&D at the industry level lie in the range of 24 to 47 per cent, while that on physical capital lies in the range of 9 to 12 per cent. Bernstein & Nadiri (1988) find that the returns to R&D and physical capital lie in the respective ranges of 9 to 27 and 7 to 14 per cent. Bernstein & Nadiri (1991) find the respective returns to be 15 to 28 and 18 to 36 per cent. Collectively they indicate that the returns to R&D are in all cases higher, and subject to greater variability, than to physical capital. These studies indicate that the returns to R&D are between 1.2 and 4 times that of physical capital. In addition, those industries earning higher returns to physical capital also earn higher returns to R&D. It is not clear from these findings whether R&D earns a higher rate of return than physical capital after taking into account the additional risks involved.

Do the returns to R&D vary with the amount of R&D undertaken?

Surprisingly, the literature appears to contain little discussion as to whether the return to R&D varies in proportion to the amount of R&D undertaken. The Commission has used data contained in Bernstein (1988, 1989) and Mohnen & Lepine (1991) to explore the correlation between the stock of R&D, R&D expenditure and R&D intensity and various rates of return to R&D (private, spillovers, total). The degree of correlation varies considerably between studies. In most, but not all, cases the correlation is positive. The total returns and spillovers appear to be more closely correlated to the stock of R&D than the other measures of R&D. However, this analysis only covers a limited number of studies. More research is required to support or refute these findings.

Do the returns to R&D vary by regions?

There is also some empirical evidence (Jaffe 1989, Jaffe et al. 1993) that spillovers may be confined to a given geographic area. Jaffe (1989) finds this for firms benefiting from academic research, while Jaffe et al. (1993) find the existence of geographic spillovers for manufacturing R&D.

However, it is not clear whether the existence of geographic spillovers is a transitory phenomenon or continues over time. Although geographic spillovers may occur initially, over time it is likely that this knowledge will disseminate more widely throughout the rest of the economy and overseas. The continued existence of geographic spillovers in a given area may reflect other factors, such as the fact that similar firms often tend to locate in the same area. For example, many United States computer firms are located in ‘Silicon Valley’ in California.

The complementary nature of R&D

Most studies do not explicitly test for the complementary nature of R&D. Jaffe (1986) is a notable exception. He finds some evidence that firms need to undertake their own R&D to take advantage of spillovers from other firms’ R&D. While this result does not hold in all of his models, where it does, it is statistically significant. Similarly, Mohnen (1990b) finds a complementarity between own and foreign imported R&D. If this is true, this would imply that a country like Australia would need to undertake its own R&D to be capable of benefiting from R&D conducted overseas. In terms of the production process itself, Bernstein & Nadiri (1989b) find that R&D and physical capital are generally complementary, while both R&D and physical capital are both substitutes for labour.

QA.4 Summary

None of the above studies are capable of dealing with the considerable real world complexities associated with R&D. Whilst the degree to which these studies address these complexities is constrained by the quality and quantity of data available, collectively they shed light on some of these issues. Despite numerous limitations, the methodology used is best suited to identifying the importance of R&D undertaken by the private sector. R&D undertaken by the public sector often produces social benefits that are difficult to model within the framework used.

The rates of return to R&D found by the empirical studies are subject to considerable variation. In part, this reflects the wide variety of techniques employed, as well as, differences in the nature of the data used. Where models have been misspecified, or where the data has been inadequately prepared, their results are subject to a range of countervailing biases that may lead to their findings being under or over estimations of the true return. Unfortunately, these biases afflict most studies. Given that the magnitude and direction of these biases vary between studies depending on the idiosyncrasies of each study, the net effect is unclear. Often an individual study is subject to a variety of countervailing biases whose magnitude is not known. Due to these biases and the underlying data limitations, the findings of these studies are best regarded as no more than indicative of the possible magnitudes.

It is difficult to draw definitive conclusions from such a diverse range of studies. The studies clearly indicate that R&D and productivity growth are related. Most of the studies indicate that the private returns to industrial R&D tend to lie in the range of 10 to 55 per cent and often exceed that on physical capital. The studies also indicate that R&D may lead to spillover benefits accruing to other firms. To whom the benefits accrue, and by how much, varies considerably between studies and between industries. Most estimates of the benefits lie in the range of zero to 130 per cent. If anything, the evidence is that spillovers between industries may be more important than those within industries, but the relevant studies have significant limitations. Although many studies indicate that the estimates of the spillovers may be large, they do not in themselves justify the need for government intervention. Rather, they should be interpreted more cautiously in light of the discussion at the beginning of this appendix.

On the question of whether the rates of return vary between industries, sectors or countries, the evidence is fairly inconclusive. The studies indicate that the rate of return often varies between industries, sometimes significantly, but there is little consensus in the literature as to those industries generating the higher social rates of return and by how much they exceed those of other industries. Based on limited evidence, it appears that the use of R&D intensity may be justified as a rule of thumb in indicating those industries earning higher social returns from their R&D.

At the sectoral level, most of the empirical work has been undertaken for the two sectors that constitute the bulk of Australian R&D — agriculture and manufacturing. It is difficult to gauge the social importance of R&D in other sectors given their limited coverage in the literature. In manufacturing and agriculture, R&D is often found to play a significant role. At the level of individual projects, the rate of return can vary significantly, with returns ranging from negative to large and positive. Nevertheless, methodological differences prevent the Commission from assessing whether the rate of return to R&D differs between the agricultural and manufacturing sectors.

Similarly, there is insufficient evidence to indicate to what extent the rate of return varies among countries. However, it does appear that returns vary more between industries than they do between countries. The limited evidence suggests that international flows of R&D spillovers may be important, especially the more open an economy is to trade.

The returns to business R&D appear to be extremely variable. Not only do they appear to vary considerably between individual projects, they also appear to vary depending on the type of R&D and the source of funding. Some studies indicate the returns to basic R&D are higher than that for applied and that the returns to company financed R&D are higher than for publicly funded R&D that is undertaken by the private sector. However, in many cases the distinctions between these classifications are not clear cut. Although a number of studies have concluded that the returns to R&D have declined over time, the evidence is divided on the issue and far from compelling.

Due to the insufficient number of studies, little can be said about the effects of foreign ownership on R&D and the returns to public R&D. Given that agriculture R&D generates significant social returns and that most of this research is undertaken by public sector agencies, elements of public sector R&D are also likely to generate substantial social benefits as well.

Without sufficient data of the appropriate quality, the empirical work is constrained in the questions that it is capable of answering. More detailed data is needed at all levels of aggregation, especially for agriculture and those industries below the ASIC division level, to identify the direction of R&D flows and the source of funding. Such information is particularly relevant for R&D conducted or funded by the public sector, as well as private sector R&D conducted on behalf of other industries. The ABS frequently revises its original estimates, but does not publish these revisions below the aggregate totals. Thus, the revised totals do not equal the sum of the published constituent parts that were published in earlier versions. In addition, it is difficult to obtain a long enough time series based on existing data collections to enable some of the more complex issues to be addressed, without recourse to extrapolation. It should also be recognised that even if these and other problems associated with the data were resolved, the modelling would still be unable to deal adequately with many of the complexities involved in the real world.

Given the lack of unanimity between studies and the fact that, in some areas, little empirical work has been undertaken to test the various theoretical issues, considerably more research needs to be undertaken, and better data needs to be generated. For example, a better understanding of the dynamic aspects of R&D is required to improve the sophistication of the models used. Similarly, research needs to be undertaken to identify those industries actually generating the spillovers, as opposed to those benefiting from them. A more detailed understanding of the impacts of Australian R&D is needed. Virtually no empirical work on Australian spillovers has been undertaken, especially on the magnitude of intra and intra-industry spillovers, identification of those industries generating them and ascertainment of the importance of public R&D. The major constraining factor for Australia is the inadequacy of available data, particularly at the firm level. The inability to adequately resolve many of the measurement and conceptual issues, together with a lack of sufficient data, are likely to remain the major factor constraining the empirical work world wide for years to come.

Table QA1: **Firm level econometric estimates of the gross rate of return to industrial R&D in Japan and the United States** (per cent) [a]

				Rate of return to:				
Study	*Year*	*Country*	*Time period covered*	*The firm undertaking the R&D*	*Other firms within the same industry*	*Industry* [b]	*Firms in other industries*	*National* [c]
Bernstein & Nadiri [d]	1989a	USA	1965 to 1978	17	2 to 9 (6)	19 to 26 (13)		
Bernstein & Nadiri [dh]	1989b	USA	1959 to 1966	19 to 30 (24)				
Clark & Griliches	1984	USA	1970 to 1980	18 to 20 (19)				
Griliches [g]	1980a	USA	1963	27				
Griliches	1986	USA	1967, 1972 & 1977	33 to 62 (46)				
Griliches & Mairesse	1983	USA	1964 to 1973		41		19	
Griliches & Mairesse [g]	1984	USA	1966 to 1977	30				
Griliches & Mairesse [g]	1986	USA	1973 to 1980	25 to 41				
Griliches & Mairesse [g]	1986	Japan	1973 to 1980	20 to 56				
Jaffe [de]	1986	USA	1973 & 1979	32 to 36 (34)			–5	32
Lichtenberg & Siegel [g]	1989	USA	1972 to 1985	13				
Lichtenberg & Siegel	1991	USA	1972 to 1985	13				
Link [fg]	1981b	USA	1971 to 1976	nss				
Link [g]	1983	USA	1975 to 1979	5				
Mansfield	1980	USA	1960 to 1976	28				
Minasian [f]	1962	USA	1947 to 1957	25				
Minasian [g]	1969	USA	1948 to 1957	54				

Table QA1: **Firm level econometric estimates of the gross rate of return to industrial R&D in Japan and the United States** (per cent) (cont…) [a]

				Rate of return to:				
Study	*Year*	*Country*	*Time period covered*	*The firm undertaking the R&D*	*Other firms within the same industry*	*Industry* [b]	*Firms in other industries*	*National*[c]
Odagiri [g]	1983	Japan	1969 to 1981	26				
Odagiri & Iwata [f]	1986	Japan	1966 to 1973	20				
Odagiri & Iwata [f]	1986	Japan	1974 to 1982	11 to 17 (14)				
Sassenou [f]	1988	Japan	1973 to 1981	22 to 69 (46)				
Schankerman	1981	USA	1963	24 to 73 (51)				
Schankerman & Nadiri [h]	1986	USA	1959 to 1969	10 to 15				
Suzuki [d]	1993	Japan	1981 to 1989	30	4	34		
Unweighted mean				27	17	24	7	32
Standard deviation				13	21	15	17	0

nss Not statistically significant at a 90 per cent level of confidence. Numbers in parentheses represent the unweighted arithmetic means.

a Statistically significant at a 90 per cent level of confidence. Those studies sourced from other publications are assumed to represent the return to R&D before depreciation (that is the gross return), unless otherwise stated.

b *Industry* return includes both *The firm undertaking the R&D* and *Other firms within the same industry* returns.

c *National* returns includes both the *Industry* and *Other firms in other industries* returns. As those industries with the lowest (highest) rate of return to the *industry* may not be those with the lowest (highest) rate of return to *Firms in other industries*, the *National* total may not represent the sum of the ranges.

d Net rate of return converted to a gross rate of return assuming a depreciation rate of 10 per cent.

e The return to *Firms in other industries* includes the return to *Other firms within the same industry*.

Sources: Commission calculations based on the above studies; and

(f) Mairesse & Sassenou 1991;

(g) Mohnen 1990b; and

(h) Nadiri 1993.

Table QA2: **Firm level econometric estimates of the gross rate of return to industrial R&D in Belgium, Canada, France and Germany** (per cent) [a]

				Rate of return to:				
Study	*Year*	*Country*	*Time period covered*	*The firm undertaking the R&D*	*Other firms with the same industry*	*Industry* [b]	*Firms in other industries*	*National* [c]
Bardy [g]	1974	FRG	1951 to 1971	92 to 97 (95)				
Bernstein [d]	1988	Canada	1978 to 1981	22	6 to 13	27 to 34	2	29 to 36
Cuneo & Mairesse [g]	1984	France	1972 to 1977	55				
Fecher [g]	1989	Belgium	1981 to 1983	nss				
Griliches & Mairesse[f]	1983	France	1964 to 1973		27 to 45 (36)		31	
Longo [g]	1984	Canada	1980	24				
Unweighted mean				49	23	31	17	33
Standard deviation				34	19	0	21	0

nss Not statistically significant at a 90 per cent level of confidence. Numbers in parentheses represent the unweighted arithmetic means.

a Statistically significant at a 90 per cent level of confidence. Those studies sourced from other publications are assumed to represent the return to R&D before depreciation (that is the gross return), unless otherwise stated.

b *Industry* return includes both *The firm undertaking the R&D* and *Other firms within the same industry* returns.

c *National* returns includes both the *Industry* and *Other firms in other industries* returns. As those industries with the lowest (highest) rate of return to the *Industry* may not be those with the lowest (highest) rate of return to *Firms in other industries*, the *National* total may not represent the sum of the ranges.

d Net rate of return converted to a gross rate of return assuming a depreciation rate of 10 per cent.

Sources: Commission calculations based on the above studies; and

(f) Mairesse & Sassenou 1991; and

(g) Mohnen 1990a.

Table QA3: **Industry level econometric estimates of the gross rate of return to industrial R&D in Japan and the United States** (per cent) [a]

				Rate of return to:		
Study	*Year*	*Country*	*Time period covered*	*Industry*	*Firms in other industries*	*National*[b]
Bernstein & Nadiri [c]	1988	USA	1958 to 1981	19 to 37	2 to 145	21 to 172
Bernstein & Nadiri [c]	1991	USA	1957 to 1986	25 to 39 (32)	0 to 113 (24)	28 to 142 (55)
Goto & Suzuki	1989	Japan	1978 to 1983	26	80	106
Griliches [h]	1980b	USA	1959 to 1968	42		
Griliches [h]	1980b	USA	1969 to 1977	nss		
Griliches	1994	USA	1958 to 1989	13 to 35 (27)		
Griliches & Lichtenberg	1984a	USA	1959 to 1976	3 to 50 (27)		
Griliches & Lichtenberg	1984b	USA	1959 to 1978	11 to 31 (24)	69 to 90 (80)	41 to 62 (55)
Link	1978	USA	Not stated	19		
Mansfield	1988	Japan	1960 to 1979	33 to 42 (38)		
Mohnen et al. [c]	1986	Japan	1966 to 1978	25		
Mohnen et al. [c]	1986	USA	1966 to 1978	21		
Odagiri [g]	1985	Japan	1960 to 1977	–66 to 24		
Schankerman	1981	USA	1963	24 to 73 (51)		
Scherer	1982	USA	1948 to 1978	19 to 43	64 to 147	103
Scherer	1983	USA	1973 to 1978	20 to 28 (24)		
Scherer	1984	USA	1973 to 1978	29	74 to 104	103

Table QA3: **Industry level econometric estimates of the gross rate of return to industrial R&D in Japan and the United States** (per cent) (cont…) [a]

				Rate of return to:		
Study	*Year*	*Country*	*Time period covered*	*Industry*	*Firms in other industries*	*National*[b]
Scherer	1993	USA	1973 to 1988	18 to 30 (24)		
Sveikauskas [h]	1981	USA	1959 to 1969	7 to 25	50	57 to 75
Sveikauskas	1990	USA	1971–72 to 1979–80	28 to 40 (34)		
Terleckyj	1974	USA	1948 to 1966	12 to 37 (26)	45 to 187 (92)	73 to 107 (90)
Terleckyj	1980	USA	1948 to 1966	25 to 27 (26)	82 to 183 (108)	107 to 110 (108)
Wolff & Nadiri [g]	1987	USA	1947 to 1972	11 to 19 (15)	10 to 90 (50)	21 to 109 (65)
Unweighted mean				26	75	85
Standard deviation				13	27	22

Numbers in parentheses represent the unweighted arithmetic means.

a Statistically significant at a 90 per cent level of confidence. Those studies sourced from other publications are assumed to represent the return to R&D before depreciation (that is the gross return), unless otherwise stated.

b *National* returns includes both the *Industry* and *Other firms in other industries* returns. As those industries with the lowest (highest) rate of return to the *Industry* may not be those with the lowest (highest) rate of return to *Firms in other industries*, the national total may not represent the sum of the ranges.

c Net rate of return converted to a gross rate of return assuming a depreciation rate of 10 per cent.

Sources: Commission calculations based on the above studies; and

(g) Mohnen 1990a; and

(h) Nadiri 1993.

Table QA4: **Industry level econometric estimates of the gross rate of return to industrial R&D in Belgium, Canada, France, Germany and the United Kingdom** (per cent) [a]

				Rate of return to:		
Study	*Year*	*Country*	*Time period covered*	*Industry* [b]	*Firms in other industries*	*National* [c]
Bernstein [d]	1989	Canada	1963 to 1983	34 to 57 (42)	0 to 70 (26)	39 to 104 (68)
Globerman	1972	Canada	1960 to 1968	23 to 36 (30)		
Hanel [g]	1988	Canada	1971 to 1982	50	100	150
Mohnen & Lepine [dg]	1988	Canada	1975 to 1983	15 to 284	2 to 90	21 to 324
Mohnen & Lepine [d]	1991	Canada	1975 to 1983	15 to 285 (67)	2 to 90 (29)	21 to 329 (85)
Mohnen et al. [d]	1986	FRG	1966 to 1978	23		
Sterlacchini	1989	UK	1954 to 1984	2 to 33 (16)	7 to 32 (15)	18 to 56 (45)
Unweighted mean				54	43	104
Standard deviation				46	34	55

Numbers in parentheses represent the unweighted arithmetic means.

a Statistically significant at a 90 per cent level of confidence. Those studies sourced from other publications are assumed to represent the return to R&D before depreciation (that is the gross return), unless otherwise stated.

b Industry return includes both *The firm undertaking the R&D* and *Other firms within the same industry* returns.

c National returns includes both the *Industry* and *Other firms in other industries* returns. As those industries with the lowest (highest) rate of return to the *Industry* may not be those with the lowest (highest) rate of return to *Firms in other industries*, the national total may not represent the sum of the ranges.

d Net rate of return converted to a gross rate of return assuming a depreciation rate of 10 per cent.

Sources: Commission calculations based on the above studies; and

(g) Mohnen 1990a.

Table QA5: **Econometric estimates of the elasticity of TFP to R&D at the sectoral level** (per cent) [a]

	Englander et al. *(1988)* [bc]		*Industry Commission (1994)* [de]
Sector/manufacturing industry	*Industry of use R&D*	*Industry of origin*	*Sector of origin*
Country:	Average of 6 countries	Average of 6 countries	Australia
Time period covered:	1970 to 1983	1970 to 1983	1976 to 1991
Sectors:			
Agriculture	–	–	na
Manufacturing	–	–	0.014
Mining	–0.05	–	0.024
Construction	–0.07	–	–
Transportation	nss	–	–
Wholesale & retailing	0.17	–	–0.028
Financial institutions	0.16	–	–
Business real estate	nss	–	–
Social & personal services	–0.16	–	–
Government services	nss	–	–
Other services	–	–	0.068
Manufacturing industries:			
Food	nss	nss	–
Textiles	0.50	0.54	–
Paper	0.09	nss	–
Chemicals & rubber	0.26	0.25	–
Machinery, instruments & equipment	0.30	0.25	–
Primary metals	nss	nss	–
Stone, clay & glass	nss	nss	–
Miscellaneous manufacturing	–0.11	–0.14	–

na Unable to be estimated. nss Not statistically significant at a 90 per cent level of confidence.

a Statistically significant at a 90 per cent level of confidence.

b France, Japan, Italy, United States, United Kingdom, West Germany and Canada (non manufacturing sectors only).

c Insufficient data is provided to convert the elasticities into rates of return.

d Total elasticity with respect to own stock of R&D taking account of direct and interaction effects.

Sources: Englander et al. 1988, table 11, p. 28; and

(e) Commission estimates (see appendix QB).

Table QA6: **Econometric estimates of the gross rate of return to industrial R&D at the economy-wide level** (per cent) [a]

Study	*Year*	*Country*	*Time period covered*		*Own R&D*		*Foreign R&D*		*Total*
Dowrick [bcf]	1994	Australia	1971 to 1990		171		24		195
Industry Commission [degh]	1994	Australia	1976 to 1991		159		32		191
Average across countries:									
Coe & Helpman [f]	1993	OECD + Israel	1976 to 1991	(G7)	128	(G7)	37	(G7)	165
		(22 countries)		(non G7)	90				
Unweighted mean					137		31		184
Standard deviation					36		7		16

a Statistically significant at a 90 per cent level of confidence. All returns have been converted from a net to a gross rate of return by adding the rate of depreciation of the knowledge stocks to the net rate of return (see Mairesse and Sassenou 1991, p.18).
b Using data from Coe & Helpman (1993).
c Converted from elasticity to rate of return using data from Coe & Helpman (1993).
d Financial year ending 30 June.
e Own R&D includes both public and private R&D.
f Converted from a net to a gross rate of return using the 5 per cent rate of depreciation used in the studies.
g The own stock of R&D was converted from a net to a gross rate of return using the 10 per cent depreciation rate used in constructing the stock figures. The gross rate of return to foreign R&D was calculated using the 5 per cent depreciation rate used in Coe & Helpman (1993).
Sources: Commission calculations based on the above studies; and
(h) Commission estimates (see appendix QB). Appendix QB offers a reason why the estimated return to own R&D may be biased upward.

Table QA7: **Econometric estimates of elasticities with respect to R&D at the economy level** (per cent) [a]

Study	*Year*	*Country*	*Time period covered*	*Elasticity of:*	*Measure of R&D*	*Own R&D*	*Foreign R&D*
Dowrick [b]	1994	Australia	1971 to 1990	TFP (level)	Stock	0.07	0.07
Industry Commission [cdf]	1994	Australia	1976 to 1991	Output (level)	Stock	0.14	0.09
Nadiri [e]	1980a	USA	1949 to 1978	Labour productivity (level)	Stock	0.06 to 0.10	
Patel & Soete	1988	USA	1967 to 1985	TFP (level)	Stock	0.61	
Patel & Soete	1988	Japan	1967 to 1985	TFP (level)	Stock	0.41	
Patel & Soete	1988	Canada	1967 to 1985	TFP (level)	Stock	0.26	
Patel & Soete	1988	France	1967 to 1985	TFP (level)	Stock	0.43	
Patel & Soete	1988	FRG	1967 to 1985	TFP (level)	Stock	0.38	
Patel & Soete	1988	Italy	1967 to 1985	TFP (level)	Stock	0.56	
Patel & Soete	1988	Sweden	1967 to 1985	TFP (level)	Stock	0.40	
Patel & Soete	1988	UK	1967 to 1985	TFP (level)	Stock	0.82	
Average across countries:							
Coe & Helpman	1993	OECD + Israel (22 countries)	1971 to 1990	TFP (level)	Stock	(G7) 0.23 (non G7) 0.08	(G7) 0.29
Lichtenberg	1992	UNESCO (53 countries)	1985	Real GDP per capita	Flow	0.09	

a Statistically significant at a 90 per cent level of confidence.
b Using data from Coe & Helpman (1993).
c Financial year ending 30 June.
d Includes both private and public R&D. The elasticities cited are total elasticities, taking account of direct and interactive effects.
Sources: Commission calculations based on the above studies; and
(e) Nadiri 1993; and
(f) Commission estimates (see appendix QB).

Table QA8: **Econometric estimates of the private rate of return to industrial R&D by type of R&D** (per cent) [a]

Study	*Year*	*Country*	*Time period covered*	*Applied*	*Basic*	*Development*	*Total*
Griliches [b]	1986	USA	1967 to 1972		5		39
Lichtenberg & Siegel	1991	USA	1972 to 1985	nss	134	nss	13
Mansfield	1980	USA	1948 to 1966	7 to 8 (8)	67 to 146 (118)		
Mansfield	1980	USA	1960 to 1976	nss	178		28
Mansfield	1988	Japan	1960 to 1969	60	nss		33 to 42 (38)
Mansfield	1988	USA	1948 to 1966	7	149		
Unweighted mean				25	117	nss	30
Standard deviation				30	66		12

nss Not statistically significant at a 90 per cent level of confidence. Numbers in parentheses represent the unweighted arithmetic means.
a Statistically significant at a 90 per cent level of confidence.
b As insufficient information is provided to convert the production function elasticity into a rate of return, the figure reported here is from the R&D intensity equation. The production function approach indicates that basic R&D is statistically significant and, is likely, to yield significantly higher rate of return than that reported here.
Sources: Commission calculations based on the above studies.

Table QA9: **Econometric estimates of the private rate of return to industrial R&D by source of funding** (per cent) [a]

Study	*Year*	*Country*	*Time period covered*	*Level of aggregation*	*Privately funded*	*Publicly funded*	*Total R&D*
Griliches [b]	1980a	USA	1957 to 1965	Firm	37		27
Griliches [b]	1986	USA	1966 to 1977	Firm	24		33 to 62 (46)
Griliches & Lichtenberg	1984a	USA	1959 to 1976	Industry	9 to 50 (28)	nss	3 to 45 (18)
Griliches & Mairesse [b]	1984	USA	1966 to 1977	Firm	42 to 62 (51)		
Lichtenberg & Siegel	1991	USA	1972 to 1985	Industry	35	nss	13
Link [b]	1981a	USA	1971 to 1976	Firm	nss		
Mansfield	1980	USA	1960 to 1976	Industry	nss	12	28
Terleckyj	1974	USA	1948 to 1966	Industry	24 to 37 (32)	nss	12
Terleckyj	1980	USA	1948 to 1966	Industry	25 to 27 (26)	nss	
Unweighted mean					33	12	24
Standard deviation					9	0	13

nss Not statistically significant at a 90 per cent level of confidence. Numbers in parentheses represent the unweighted arithmetic means.
a Statistically significant at a 90 per cent level of confidence.
Sources: Commission calculations based on the above studies; and
(b) Lichtenberg & Siegel 1991, table iv, pp. 215–216.

Table QA10: **Econometric estimates of the direct rate of return to industrial R&D at the industry level** (per cent) [a]

	Canada				*USA*				
Source industry	*Bernstein (1988)* [c]	*Bernstein (1989)*	*Mohnen & Lepine (1988)* [b]	*Mohnen & Lepine (1991)*	*Bernstein & Nadiri (1988)*	*Bernstein & Nadiri (1989a)* [c]	*Bernstein & Nadiri (1989b)*	*Cross country mean*	*Standard deviation*
Number of industries:	7	9	12	12	5	4	4		
Time period covered:	1978 to 1981	1963 to 1983	1975 to 1983	1975 to 1983	1958 to 1981	1965 to 1978	1959 to 1966		
Aircraft & parts	12		8	8				9	2
Business machines				6				6	0
Chemical products	12	25	15 & 51		13	7	20	18	10
Communication equipment				5				5	0
Drugs and medicines				15				15	0
Electrical products	12	38	5 & 33		15			21	12
Food & beverage industry	12						9	11	2
Gas & oil wells		37						37	0
Metal fabricating	12	29	274	275				148	147
Non electrical machinery	12	24	6 & 27		27	7	16	17	7
Other chemical products				51				51	0
Other electrical products				33				33	0
Other machinery				27				27	0
Petroleum products		40	48	48		7		36	20
Primary metals		26	17	17			10	18	7
Pulp & paper industry	12							12	0
Rubber and plastic products		47	143	144				111	56
Scientific instruments			49	49	17	7		31	22
Transport equipment		28			10			19	13
Unweighted mean	12	33	68	57	16	7	14	33	16
Standard deviation	0	8	88	79	6	0	5	37	

a The direct rate of return measures the private rate of return plus intra-industry spillovers for industry level studies and the private rate of return for firm level studies.
b For some industries, the rate of return differs depending on subaggregates within the industry.
c Estimated using firm level data.
Sources: Mohnen 1990a; and Mohnen & Lepine 1991.

Table QA11: **Econometric estimates of the total rate of return to industrial R&D at the industry level** (per cent) [a]

	Canada				*USA*				
Source industry	*Bernstein (1988)* [c]	*Bernstein (1989)*	*Mohnen & Lepine (1988)* [b]	*Mohnen & Lepine (1991)*	*Bernstein & Nadiri (1988)*	*Bernstein & Nadiri (1989a)* [c]	*Bernstein & Nadiri (1989b)*	*Cross country mean*	*Standard deviation*
Number of industries:	7	9	12	12	5	4	4		
Time period covered:	1978 to 1981	1963 to 1983	1975 to 1983	1975 to 1983	1958 to 1981	1965 to 1978	1959 to 1966		
Aircraft & parts	23		11	3				12	10
Business machines				6				6	0
Chemical products	26	81	17 & 132		21	12	–	43	32
Communication equipment				20				20	0
Drugs and medicines				2				2	0
Electrical products	26	38	24 & 47		18			29	9
Food & beverage industry	20						–	20	0
Gas & oil wells		37						37	0
Metal fabricating	20	29	314	44				102	142
Non electrical machinery	19	94	12 & 117		58	9	–	49	35
Other chemical products				83				83	0
Other electrical products				17				17	0
Other machinery				90				90	0
Petroleum products		87	52	4		16		40	38
Primary metals		42	51	33			–	42	9
Pulp & paper industry	20							20	0
Rubber and plastic products		89	157	18				88	70
Scientific instruments			75	27		14		39	32
Transport equipment		29			11			20	13
Unweighted mean	22	58	93	29	27	13		40	39
Standard deviation	3	28	92	30	21	3		30	

a The direct rate of return measures the private rate of return plus intra-industry spillovers for industry level studies and the private rate of return for firm level studies.
b For some industries, the rate of return differs depending on subaggregates within the industry.
c Estimated using firm level data.
Sources: Mohnen 1990a; and Mohnen & Lepine 1991.

Table QA12: **Ratio of total to direct benefits from industrial R&D at the manufacturing industry level** (per cent) [a]

	Canada				USA				
Source industry	*Bernstein (1988)* [c]	*Bernstein (1989)*	*Mohnen & Lepine (1988)* [b]	*Mohnen & Lepine (1991)*	*Bernstein & Nadiri (1988)*	*Bernstein & Nadiri (1989a)* [c]	*Bernstein & Nadiri (1989b)*	*Cross country mean*	*Standard deviation*
Number of industries:	7	9	12	12	5	4	4		
Time period covered:	1978 to 1981	1963 to 1983	1975 to 1983	1975 to 1983	1958 to 1981	1965 to 1978	1959 to 1966		
Aircraft & parts	1.9		1.4	0.4				1.2	0.8
Business machines				1.0				1.0	0
Chemical products	2.2	3.2	1.1 & 2.6		1.6	1.7	–	2.1	0.8
Communication equipment				4.0				4.0	0
Drugs and medicines				0.1				0.1	0
Electrical products	2.2	1.0	4.8 & 1.4		1.2			2.1	1.6
Food & beverage industry	1.7						–	1.7	0
Gas & oil wells		1.0						1.0	0
Metal fabricating	1.7	1.0	1.1	0.2				1.0	0.6
Non electrical machinery	1.6	3.9	2.0 & 4.3		2.1	1.3	–	2.5	1.3
Other chemical products				1.6				1.6	0
Other electrical products				0.5				0.5	0
Other machinery				3.3				3.3	0
Petroleum products		2.2	1.1	0.1		2.3		1.4	1.0
Primary metals		1.6	3.0	1.9			–	2.2	0.7
Pulp & paper industry	1.7							1.7	0
Rubber and plastic products		1.0	1.1	0.1				0.7	0.5
Scientific instruments			1.5	0.6		2.0		1.4	0.7
Transport equipment		1.0			1.1			1.1	0
Unweighted mean	1.9	1.8	1.9	1.2	1.5	1.8		1.6	0.7
Standard deviation	0.3	1.1	0.9	1.3	0.5	0.4		0.9	

a The direct rate of return measures the private rate of return plus intra-industry spillovers for industry level studies and the private rate of return for firm level studies.
b For some industries, the rate of return differs depending on subaggregates within the industry.
c Estimated using firm level data.
Sources: Mohnen 1990a; and Mohnen & Lepine 1991.

Table QA13: **Econometric estimates of the marginal internal rate of return to agricultural R&D** (per cent) [a]

Study	*Year*	*Country*	*Survey coverage*	*Nature of research*	*Returns to farmers*	*Returns to society*
Bredahl & Peterson [h]	1976	USA	1969	Cash grains		36
Bredahl & Peterson [h]	1976	USA	1969	Poultry		37
Bredahl & Peterson [h]	1976	USA	1969	Dairy		43
Bredahl & Peterson [h]	1976	USA	1969	Livestock		47
Chavas & Cox [ig]	1992	USA	Not stated	Private research		17
Chavas & Cox [i]	1992	USA	Not stated	Aggregate		28
Cline [h]	1975	USA	1939 to 1948	Aggregate		41 to 50
Davis [h]	1979	USA	1949 to 1959	Aggregate		66 to 100
Davis [h]	1979	USA	1964 to 1974	Aggregate		37
Davis [d]	1981	USA	1954	Aggregate		60 to 137 (113)
Davis [d]	1981	USA	1964	Aggregate		30 to 52 (40)
Evenson [h]	1967	USA	1949 to 1959	Aggregate		47
Evenson [h]	1980	USA	1868 to 1926	Aggregate		65
Evenson [h]	1980	USA	1927 to 1950	Aggregate		95
Evenson [h]	1980	USA	1948 to 1971	Aggregate		45
Evenson [h]	1992	USA	1950 to 1982	Crops		45
Evenson [h]	1992	USA	1950 to 1982	Livestock		11
Evenson & Welch [h]	1979	USA	1964	Crops		55
Evenson & Welch [h]	1979	USA	1964	Livestock		55 to 60
Griliches [e]	1964	USA	1949 to 1959	Aggregate		10 to 16 (13)

Table QA13: **Econometric estimates of the marginal internal rate of return to agricultural R&D** (per cent) (cont…)[a]

Study	*Year*	*Country*	*Survey coverage*	*Nature of research*	*Returns to farmers*	*Returns to society*
Huffman & Evenson [h]	1989	USA	1950 to 1982	Aggregate		43
Huffman & Evenson [h]	1989	USA	1949 to 1978	Crops		62
Huffman & Evenson [h]	1993	USA	1950 to 1982	Crops		47
Huffman & Evenson [h]	1993	USA	1950 to 1982	Livestock		<0
Huffman & Evenson [hg]	1993	USA	1950 to 1982	Private research		41
Huffman & Evenson [h]	1993	USA	1950 to 1982	Crops		42
Huffman & Evenson [h]	1993	USA	1950 to 1982	Livestock		87
Huffman & Evenson [hg]	1993	USA	1950 to 1982	Private research		46
Knutson & Tweeten [h]	1979	USA	1949 to 1958	Aggregate		39 to 47
Knutson & Tweeten [h]	1979	USA	1959 to 1968	Aggregate		32 to 39
Knutson & Tweeten [h]	1979	USA	1969 to 1972	Aggregate		28 to 35
Latimer [h]	1964	USA	1949 to 1959	Aggregate		nss
Mullen & Cox [b]	1994a	Australia	1953 to 1988	Broadacre		50 to 328 (166)
Mullen & Cox [c]	1994a	Australia	1953 to 1988	Broadacre		85 to 562 (292)
Peterson [h]	1967	USA	1915 to 1960	Poultry		21
Peterson & Fitzharris [h]	1977	USA	1937 to 1942	Aggregate		50
Peterson & Fitzharris [h]	1977	USA	1947 to 1952	Aggregate		51
Peterson & Fitzharris [h]	1977	USA	1957 to 1962	Aggregate		49
Peterson & Fitzharris [h]	1977	USA	1957 to 1972	Aggregate		34

Table QA13: **Econometric estimates of the marginal internal rate of return to agricultural R&D** (per cent) (cont…)[a]

Study	*Year*	*Country*	*Survey coverage*	*Nature of research*	*Returns to farmers*	*Returns to society*
Scobie & Everleens [i]	1986	New Zealand	1927 to 1984	Aggregate		30
Thirtle & Bottomly	1988	UK	1951 to 1981	Aggregate		54 to 84
Thirtle & Bottomly	1989	UK	1965 to 1980	Aggregate		74 to 100 (91)
White & Havlicek [h]	1982	USA	1943 to 1977	Aggregate		36
Unweighted mean						55
Standard deviation						47

nss Not statistically significant at a 90 per cent level of confidence. Numbers in parentheses represent the unweighted arithmetic means.
a All R&D relates to public R&D unless otherwise stated.
b Evaluated at 1988 values.
c Evaluated at geometric mean.
d Current dollar research and output.
e Marginal product.
g Private sector specific R&D.
Sources: Commission calculations based on the above studies; and
(h) Huffman & Evenson 1993, tables 9.1 & 9.2, pp 245–246; and
(i) Mullen & Cox 1994a, pp. 1–2.

Table QA14: **Case study estimates of the rate of return to agricultural R&D** (per cent)

Study	*Year*	*Country*	*Product field*	*No. of projects*	*Discount rate*	*Return to the firm: Range*	*Return to the firm: Mean*	*Return to the society: Range*	*Return to the society: Mean*
ACIAR [bd]	1991	Various	Agriculture	12	10			15 to 2 213	308
ACIAR [be]	1991	Various	Agriculture	186	10				27
CSIRO [b]	1992d	Australia	Plant production and processing	10	5			18 to 421	74
CSIRO [c]	1993f	Australia	Natural resources and environment	6	5			2 to 67	29
Gross et al. [b]	1990	Australia	Pasture & onion sectors	2	10			17 to 260	251
Grains RDC [c]	1992	Australia	Grains sector	21	10			30 to 2 970	190
Griliches [b]	1958	USA	Hybrid Corn	1	5			37	37
Griliches [b]	1958	USA	Hybrid Corn	1	10			69	69
Griliches [b]	1958	USA	Hybrid Sorghum	1	5			396	396
Griliches [b]	1958	USA	Hybrid Sorghum	1	10			358	358
IAC [a]	1975	Australia	Animal health	1	10			50	50
IAC [a]	1985	Australia	Biological control of euchium species	1	5			43	43
IAC–CSIRO [b]	1980	Australia	Entomology	13	5			22	22
IAC–CSIRO [b]	1980	Australia	Entomology	13	10			23	23
IAC–CSIRO [b]	1980	Australia	Entomology	13	20			19	19
MRC [b]	1991	Australia	Meat & livestock sector	6	10			56 to 767	138
Page et al. [a]	1991	Australia	Legumes	17	9			6 to 1 248	112

Table QA14: **Case study estimates of the rate of return to agricultural R&D** (per cent) (cont…)

Study	*Year*	*Country*	*Product field*	*No. of projects*	*Discount rate*	*Return to the firm: Range*	*Return to the firm: Mean*	*Return to the society: Range*	*Return to the society: Mean*
Parham & Stoeckel [a]	1988	Australia	Control of sheep blowfly	1	2			2	2
Parham & Stoeckel [a]	1988	Australia	Control of sheep blowfly	1	5			4	4
Parham & Stoeckel [a]	1988	Australia	Control of sheep blowfly	1	10			6	6
Unweighted mean									118
Standard deviation									133

a Ex-ante project evaluation.
b Ex-post project evaluation.
c A combination of ex-post and ex-ante project evaluation.
d Only the 12 successful projects.
e Includes the costs of all 186 projects and only the benefits of the 12 successful projects.
Source: Commission calculations based on the above studies.

Table QA15: **Case study estimates of the rate of return to industrial R&D** (per cent)

Study	*Year*	*Country*	*Product field*	*No. of products*	*Discount rate*	*Return to firm: Range*	*Return to firm: Mean*	*Return to society: Range*	*Return to society: Mean*
BIE [a]	1992	Australia	Industrial & communication technologies	3	5			10 to 14	12
BIE [a]	1992	Australia	Industrial & communication technologies	3	10			16 to 22	20
McLennan et al. [b]	1988	Australia	Minerals & process engineering technologies	8	10			2 to 125	27
Trajtenberg [bc]	1990	World wide	CT Scanners	1	5			187 to 346	267
Unweighted mean									82
Standard deviation									124

a Ex-ante project evaluation.

b Ex-post project evaluation.

c Range represents the return to the USA & the rest of the world respectively.

Source: Commission calculations based on the above studies.

APPENDIX QB: PRODUCTIVITY GROWTH AND THE RETURNS TO R&D IN AUSTRALIA

Successful research and development (R&D) can raise the level of feasible output for a given level of labour, capital and natural resource inputs. In order to provide a net benefit to society, the benefits from improved productivity must outweigh the cost of R&D.

This appendix first examines Australia's productivity record over the past two decades. It then uses the productivity improvements attributable to R&D to estimate social rates of return to Australia's R&D effort. The work controls for some of the sources of bias found in overseas studies. The estimates range from 25 to 90 per cent, with one estimate as high as 150 per cent. The latter estimate is likely to be biased upward for technical reasons, and all remain sensitive to a number of assumptions and measurement problems.

The appendix also looks at productivity performance and R&D expenditure by sector to assess whether the rates of return to R&D vary significantly across sectors. The sectoral analysis also provides some explicit evidence of spillover benefits from R&D, in the sense that R&D undertaken in one sector may improve the productivity of other sectors.

QB.1 Productivity performance in Australia

Changes in output over the last two decades can be decomposed into the changes due to the growth of labour and capital inputs, plus the growth due to other factors, normally referred to as multi-factor productivity (MFP). Thus productivity growth can be estimated by subtracting from output growth the contributions due to labour and capital growth.

It is not possible to analyse productivity growth for the economy as a whole. Because of data limitations, the analysis must be restricted to the 'market sector' which is detailed in table QB1. The market sector accounts for about two-thirds of national output and employment. The 'non-market' sector is excluded from the analysis because its output cannot be measured directly — the ABS estimates its output on the basis of movements in labour inputs. The inability to obtain an independent measure of output makes it impracticable to disaggregate output growth into its capital, labour and productivity components.

Within the market sector, productivity can also be examined by industry to give an assessment of the importance of productivity changes in individual industries to economy-wide growth.

Table QB1: **Industries in the market sector**[a]

Market sector
Agriculture, forestry, fishing and hunting
Mining
Manufacturing
Electricity, gas and water
Construction
Wholesale and retail trade
Transport, storage and communication
Recreation, personal and other services
Other activities
Finance, property and business services
Public administration and defence
Community services
Ownership of dwellings
Plus
Import duties
Imputed bank service charges

a This definition of the market sector is adopted in ABS, Cat. No. 5234.0.

Gross domestic product (GDP) is the output concept used throughout this appendix, although strictly speaking GDP measures output only for the economy as a whole. The comparable concept at the industry/sectoral level is Gross product (GP). Thus the output of the market sector is measured as the sum of the GP contributions of individual industries included in that sector. Data for the gross product of each industry at average 1989–90 prices were obtained from ABS (1994a).

Although gross product is a standard measure of output, it is not comprehensive. For example, it excludes most of the activity that takes place in households or is otherwise not registered in market transactions. Similarly it does not take into account externalities such as environmental degradation, nor environmental improvements. As conventionally measured, it may not accurately reflect improvements in the quality of output. It nevertheless is widely used to measure the social returns to various activities, including those to R&D.

In the current analysis, the Commission has estimated aggregate indexes of labour and capital inputs from estimates for the individual industries.[1] Industry shares in the aggregate value of labour and capital, respectively, have been used as weights in the aggregation of industry labour and capital indexes. Under this procedure the resulting growth contributions of capital and labour inputs partially embody the effects of quality improvements in capital and labour. To the extent that these quality improvements are themselves the result of technological change, the multi-factor productivity residual does not reflect the full impact of technological change (box QB1).

The output data show that the market sector has grown on average by around 2 per cent a year between 1975–76 and 1992–93. In parallel to the growth in output, there has been a small net growth of around 0.5 per cent a year in labour inputs, as measured by an index of hours worked. Available estimates suggest that capital inputs to production, as measured by the value of capital capacity, have grown at an average annual rate of over 2 per cent, slightly ahead of output growth.

In the absence of change affecting the productivity of labour and capital, the growth in output should be fully explained by growth in labour and capital inputs. In order to isolate the implied growth in output arising only from the growth in a particular input, the growth rate for that input should be multiplied by its output elasticity, the latter measuring the percentage increase in output generated by a one per cent increase in the input, holding all other things constant. Under the assumption of constant returns to scale and perfect competition, output elasticities are equal to the respective income shares of labour and capital in production. Under these circumstances, the contributions

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1 The quantities of labour inputs, ie hours worked, are indexes obtained from ABS (1994a) and are derived by the ABS by multiplying average hours worked from the labour force survey by industry employment. The quantities of capital inputs are indexes of published aggregate fixed capital stocks at average 1989–90 prices (ABS 1994a). To allow for the fact that the service life of assets does not decline in proportion to the depreciated value of the asset, the index of capital inputs adopted in this appendix gives equal weight to the gross value and the written down value of fixed assets. The value of agricultural land, a third input recognised in agriculture, forestry, fishing and hunting, is set equal to a constant $122 billion (ABS 1994a).

Labour and capital input shares are estimated by the share of wages, salaries and supplements, and gross operating surplus in gross product at factor cost by industry. An estimate of imputed wages of owner operators is deducted from the gross operating surplus of industries showing a concentration of unincorporated businesses (ie agriculture, wholesale and retail trade, and construction) and added to wages, salaries and supplements for the same industries. Information on the importance of imputed wages is taken from the Commission's ORANI model database (Kenderes and Strzelecki 1991).

of labour or capital to output growth therefore depend on the extent to which each input grows, and on how important each is as an input to production. As measured, the contribution of each input would also partially reflect changes arising from technological and quality improvements embodied in new capital and better educated labour.

Box QB1: **Treatment of quality changes in indexes of labour and capital**

Conceptually, growth in labour and capital inputs refers to changes in the effective flow of their services as inputs in production. Growth coming from technical and quality change embodied in capital, and improved quality of labour (eg through education and on the job training) should be attributed to an increased service flow by those factors. Within this framework, measured multi-factor productivity would exclude the impact of improvements in the quality of labour and capital.

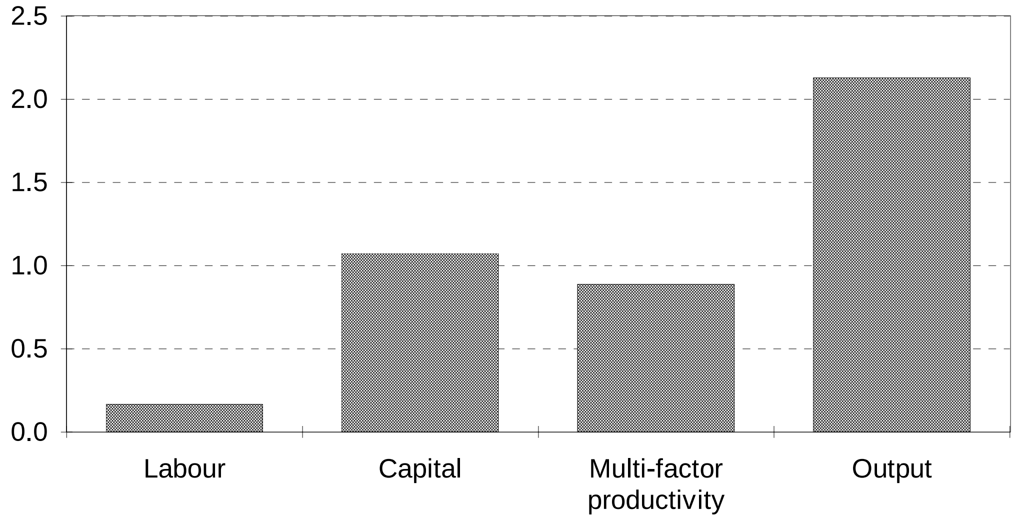
However, in the estimation of multi-factor productivity, capital inputs are based on changes in capital stocks as a surrogate for capital services and labour inputs are based on hours worked as a surrogate for labour services. The ABS uses a diversity of methods to derive its constant price estimates of capital expenditure and capital stocks, and the final estimates available may not truly reflect the user cost value of the service flow (ABS 1990b, p. 274). By using hours worked as a measure of labour input, changes in the service flow of labour arising from changes in the skill level of the labour force are not fully reflected in the indexes of labour inputs (ABS 1994a, p. 7).

Aggregate (market sector) indexes of labour and capital inputs are estimated by aggregating the estimates for individual industries. Because the labour and capital employed in each industry is not necessarily homogeneous, the value share of each industry’s labour and capital in aggregate market sector labour and capital has been used to aggregate the industry indexes. Through this aggregation process, technology and quality changes in the labour and capital used by individual industries are partially included in the estimated indexes of labour and capital for the market sector. The multi-factor productivity estimates therefore only partially exclude the impact of technological change and quality improvements in labour and capital.

However, within any one year productivity can also be improved. When this occurs, growth in output cannot be fully explained by growth in labour and capital inputs — any difference provides a measure of multi-factor productivity growth.

Figure QB1 takes this feature of economic growth into account and shows that over the period 1975–76 to 1992–93, growth in capital inputs contributed (after weighting the underlying input growth by the relevant income share) about 1 per cent per annum to the market sector’s output growth. Productivity growth was nearly as important as capital as a contributor to growth, while labour inputs made a negligible contribution in line with the low growth in the volume of labour inputs and a slight decline over time in the labour income share (from about 65 to 60 per cent between 1975–76 and 1992–93).

Figure QB1: **Average annual contribution of labour, capital, and multi-factor productivity to market sector output growth, 1975–76 to 1992–93** (per cent)



Source: Commission estimates based on ABS data.

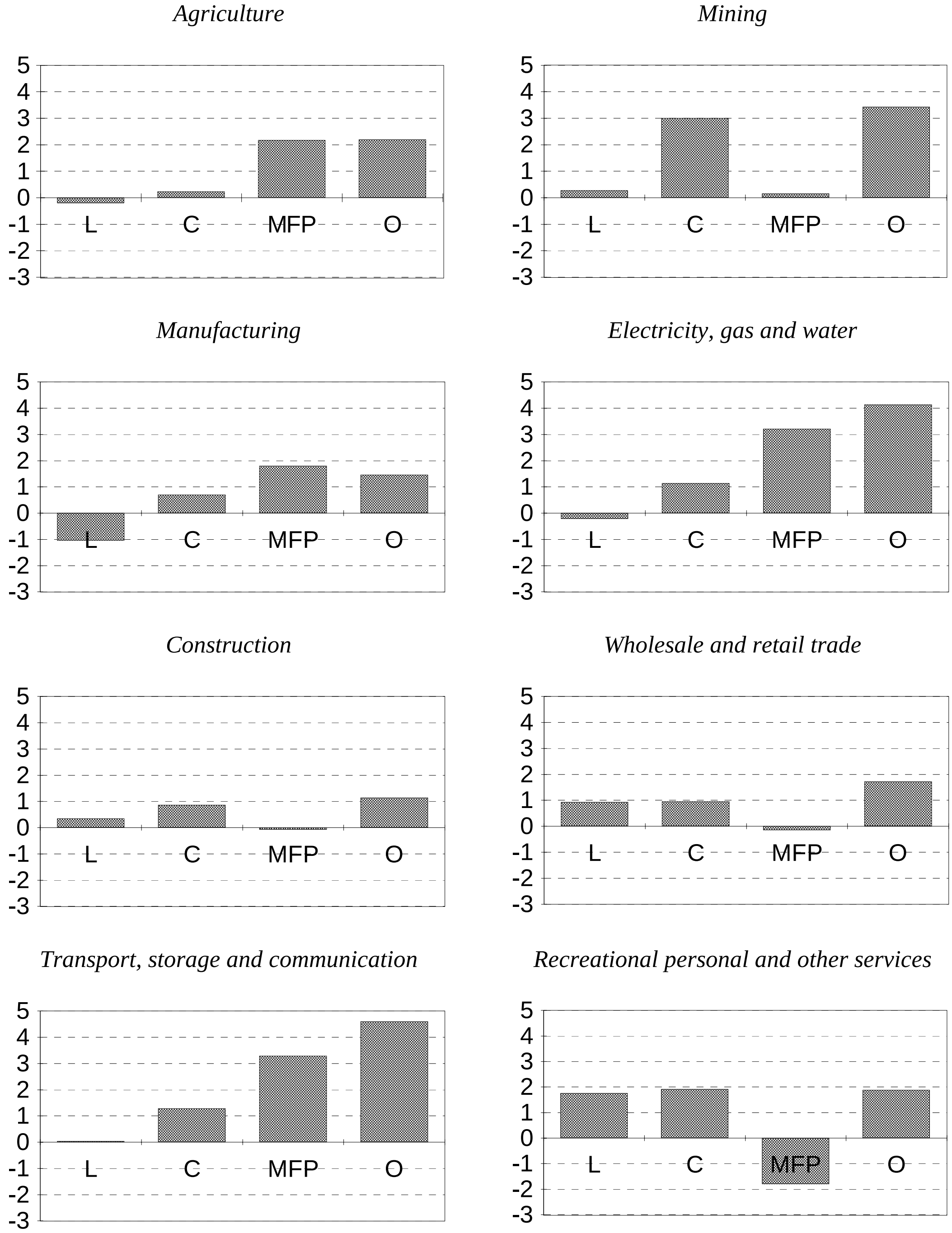
In dollar terms, GDP (in average 1989–90 dollars) grew from $229 billion in 1974–75 to $377 billion in 1992–93. The market sector contributed $76 billion, or fractionally more than half of the total change in output. Multi-factor productivity improvements in the market sector in turn contributed around 40 per cent of market sector growth, or around $34 billion over the period.

Growth contributions by industry

The contributions to growth reported for the market sector as a whole can be further examined at the individual industry level. Such analysis shows there are marked differences in the contributions to output growth for the industry divisions of the market sector (figure QB2).

Growth in the service industries Wholesale and retail trade, and Recreational, personal and other services has been supported by almost uniform growth in labour and capital inputs. The growth in their use of inputs has moved ahead of growth in output resulting in a decline in measured multi-factor productivity.

Figure QB2: **Average annual contribution of labour (L), capital (C) and multi-factor productivity (MFP) to output (O) growth by industry, 1975–76 to 1992–93** (per cent)



Source: Commission estimates based on ABS data.

Growth in output of Wholesale and retail trade is estimated on the basis of the volume of goods traded (ie the series is quantity revalued, ABS 1990b, p. 31). The decline in measured multi-factor productivity indicates that the labour and capital requirement per unit of throughput of goods and services has increased. The higher labour and capital input could be absorbed by the provision of more elaborate warehousing/shopping environments or extended services (eg air conditioned shopping, higher staffing levels associated with extended shopping hours). Growth in output of Recreational, personal and other services is also based on quantity indicators. Changes in the nature of those services requiring additional factor inputs would also be reflected in the negative contribution of multi-factor productivity to growth.

Growth in the Agriculture, Manufacturing, Electricity, gas and water, and Transport, storage and communication industries has been strongly supported by growth in multi-factor productivity. In each industry, labour inputs have made only a small positive or (possibly) negative contribution to growth. Substantial labour shedding technological development is evident in Manufacturing.

These estimates should be interpreted against the backdrop of the methodology used to estimate industry gross product at constant prices. Growth in the output of this group of industries is estimated by the gross output method (ABS 1990b, pp. 115, 119, 124–7). The gross output method takes a direct measure of the gross product of an industry only in a single year (in this case 1989–90), and makes estimates for gross product in other years by assuming that gross product (unobserved for those years) grows at the same rate as gross output (broadly equivalent to sales plus increase in stocks, observed for those years). The method therefore makes the Leontief assumption that the ratio of intermediate inputs to gross output, both valued at constant prices, is stable (ABS 1990b, p. 30). Estimates of the ratio of intermediate inputs to output at constant prices are not available directly. However, if the ratio were to rise due to labour shedding and contracting out, gross output would rise relative to labour and capital inputs, even though gross product may not have. Misestimation of gross product in this way could lead to an estimated multi-factor productivity that was positive. The industry restructuring over the period which had a significant labour shedding component is likely to have placed some upward pressure on the multi-factor productivity estimates reported.[2]

By contrast, the growth in the Mining and Construction industries mainly reflects the employment of additional capital.

2 Because the productivity estimates are affected by possible movements in the ratio of intermediate inputs to output, they have been called multi-factor productivity estimates in this appendix, rather than total factor productivity estimates.

The largest MFP contribution to market sector growth in percentage terms was made by the Manufacturing industry over the last two decades (figure QB2). However, when assessed against the size of the industry, Electricity, gas and water, and Transport, storage and communications afforded proportionately larger social returns in dollar terms from MFP sourced growth.

QB.2 The social returns to R&D in Australia

R&D can be instrumental in productivity growth by providing new technologies and applications. By comparing productivity growth at the national level directly with R&D effort, it is possible to derive a simple measure of the social rate of return to R&D. However, if the social return is to be truly national, there is no choice but to make an assumption about the rate of productivity growth in the non-market sector.

The social return to R&D is defined as the permanent increase in national output generated by a unit increase in the stock of knowledge (see also appendix QA). If the main impact of R&D were felt in productivity growth in the market sector, and if Australia's domestic R&D were the only factor contributing to that productivity growth, then the productivity growth measured above can provide a measure of the permanent increases in income generated by domestic R&D activity.

The contribution of productivity growth to market sector output over the past two decades has averaged 0.89 per cent a year (figure QB1). After taking into account the importance of the market sector in the total economy (about two-thirds), the contribution of market sector productivity growth to national GDP growth is estimated to be around 0.6 per cent a year. Over a similar period, R&D expenditure in Australia has averaged around 1.2 per cent of GDP. The social rate of return to Australia's R&D spending can therefore be estimated as[3]

$$\frac{0.6*100}{1.2} = 50\ per\ cent.$$

Similar methods could be used to derive measures of the rates of return to R&D in the various industries comprising the market sector.

However, R&D is clearly not the only factor contributing to productivity growth. If the main impact of R&D is felt in productivity growth, but if

[3] The social return to R&D is defined as $\partial Y/\partial R$, the increase in national GDP (Y) resulting from a unit increase in the stock of knowledge (R), measured in percentage terms. Ignoring knowledge obsolescence, ∂R can be measured by S, the annual expenditure on R&D. Then dividing the numerator and denominator by Y gives the required formula for the social return to R&D as $[\partial Y/Y]/[S/Y]$.

Australia's domestic R&D is not the only factor contributing to that productivity growth, then some method needs to be found to control for the influence of other factors influencing productivity.

As noted in the previous section, the standard method of measuring multi-factor productivity makes an implicit assumption of constant returns to scale and perfect competition. Since recent theoretical discussion of the sources of growth has stressed the importance of non-constant returns to scale, it would be desirable to measure the influence of R&D and other factors on multi-factor productivity in a framework that allowed the assumption of constant returns to scale to be relaxed.

Finally, it would be desirable to test the sensitivity of the derived measures of the social return to R&D to the so-called double-counting problem (see also appendix QA). Multi-factor productivity growth is normally measured as the excess of GDP growth over the combined growth of capital and labour inputs. In the previous section, the measures of labour and capital used were inclusive of the capital and labour used to undertake R&D. Thus some of the direct impact of R&D on output growth has already been netted out of measured multi-factor productivity. Schankerman (1981) argues that in these circumstances, any final measure of the social return to R&D expenditure will tend to be biased downwards.

Methodology

One way of estimating the contribution of R&D to economic growth is by first calculating multi-factor productivity in a growth accounting framework, and then econometrically estimating how much of the multi-factor productivity can be explained by knowledge stocks, while controlling for the other possible influences on measured productivity. Another way is by econometrically estimating a production function directly, in which output is a function of labour, capital, the stock of knowledge capital and some additional variables likely to affect productivity.

The two approaches are related. Both can be derived from a production function of the form:

$$Y = A\,K^{\alpha}\,L^{\beta}, \qquad (QB1)$$

where Y is output;
A is productivity;
K is the stock of physical capital; and
L is labour.

If productivity can be explained by the stock of knowledge capital and other factors, then equation *(QB1)* can be rewritten as:

$$Y = K^{\alpha} L^{\beta} R^{\gamma} Z^{\delta}, \qquad (QB2)$$

where R is the stock of knowledge capital; and
Z is other factors affecting measured productivity.

In the production function approach, a log linear version of equation *(QB2)* would be estimated directly:

$$\ln Y = \alpha \ln K + \beta \ln L + \gamma \ln R + \delta \ln Z, \qquad (QB3)$$

with no further restrictions placed upon the parameters. The estimate of γ would provide a direct estimate of the percentage increase in output obtainable from a one per cent increase in knowledge stocks, holding all other factors constant.

In the two-step productivity approach, equation *(QB3)* would be rewritten as:

$$\ln Y - \alpha \ln K - \beta \ln L = \gamma \ln R + \delta \ln Z. \qquad (QB4)$$

Under the additional assumptions that $\alpha + \beta = 1$ and that α and β equal capital and labour income shares, the left hand side of equation *(QB4)* simply equals multi-factor productivity (in level, not growth form) as conventionally measured in a growth accounting framework. Observations on multi-factor productivity would first be obtained, then these would be regressed on the variables shown on the right hand side.

In either case, estimates of the parameter, γ, can easily be converted from an elasticity to a rate of return $\partial Y/\partial R$:

$$\partial Y/\partial R = \gamma\,(Y/R). \qquad (QB5)$$

Because the two-step method involves fewer explanatory variables on the right hand side of the estimating equation, it may be preferred for the purely technical reason that it conserves degrees of freedom. Since long time-series data sets on R&D are scarce, the two-step productivity method is by far the most common method used to measure returns to R&D.[4] However, the production function approach has the advantage of imposing fewer a priori restrictions on the parameters.

Partly to conserve degrees of freedom, and partly because of data constraints at the industry level, the two-step productivity method is the method used in the next section to investigate returns to R&D at the industry level for Australia.

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4 See also appendix QA. Furthermore, most two-step productivity methods regress multi-factor productivity growth on annual R&D expenditures and other flow variables, rather than regressing productivity levels on R&D knowledge stocks and other stock variables.

The industry-level analysis tends to require more degrees of freedom than economy-wide analysis because when an equation such as *(QB3)* or *(QB4)* is estimated for a single industry, the relevant knowledge stock variables are not just the knowledge stocks acquired from R&D undertaken in that industry, but also the knowledge stocks acquired from R&D in other industries. In the economy-wide analysis, a single domestic knowledge stock variable can be used to capture the knowledge acquired from R&D for the economy as a whole. Thus conserving degrees of freedom is more critical for the industry-level analysis. In both cases, however, foreign knowledge stocks are also included in order to recognise that Australia's productivity may be enhanced by R&D undertaken overseas.

The functional forms of equations *(QB3)* and *(QB4)* imply that when several different knowledge stocks are entered in simple log linear form, there is a maintained assumption that the knowledge stocks are substitutes for each other. However, many commentators and participants in this inquiry have noted the complementary nature of different types of R&D. In order to allow for complementarity, an interaction term can also be included as a separate explanatory variable, with the interaction term defined as the log of one knowledge stock multiplied by the log of the other.[5] If the estimated coefficient on this interaction term is positive, it means that an increase in one type of knowledge stock increases the returns to the other type of knowledge stock, and vice versa. A positive coefficient on the interaction term is therefore an indication of complementarity. Because of data limitations, however, not all feasible pairwise interaction terms can be included. At the economy-wide level, the analysis investigates the interaction between domestic and foreign knowledge stocks. At the industry level, the analysis investigates the interaction between an industry's own R&D and that undertaken in other domestic industries.

Commentators and participants have also stressed that the benefits from R&D may take time to accrue. In order to conserve degrees of freedom, the current analysis does not include lagged knowledge stocks as explanatory variables in equation *(QB3)* or *(QB4)*. But note that the analysis examines the impact of current knowledge stocks on current productivity or output levels, rather than the impact of current R&D expenditures on current productivity or output growth. Since knowledge stocks are themselves assumed to be the outcome of current and past R&D expenditures, the lagged effects of R&D on output and productivity are implicitly taken into account.

5 The resulting functional form is a restricted translog form.

The two-step productivity method is used for the industry-level analysis, but its assumption of constant returns to scale can nevertheless be relaxed in an indirect way (see, for example, OECD 1993h). This can be done by including labour and capital variables in log form on the right hand side of equation *(QB4)*. If the original maintained assumptions about the values of α and β are correct, then the estimated coefficients of the additional labour and capital explanatory variables should not be significantly different from zero. This procedure is used for the industry level analysis, although it reimposes a cost in terms of degrees of freedom.

While the two-step productivity method is used for the industry-level analysis, a comparison of this with the production function method is made at the economy-wide level to test the sensitivity of the resulting measures of social returns to R&D to the method of estimation used. This comparison also indicates the effectiveness of the indirect method of relaxing the constant returns to scale assumption in the productivity framework. The economy-wide analysis in this section also examines the sensitivity of the estimates to the problem of double counting.

Data

This section uses annual data from 1975–76 to 1990–91. The ABS is the principal data sources for the Australian R&D expenditure data. The cumulative stock of Australian business and non-business (general government, higher education and non-profit private) R&D was calculated using the perpetual inventory method (Griliches 1980b), assuming an obsolescence rate of 10 per cent. The foreign R&D stock is taken from Coe and Helpman (1993). Their data are slightly inconsistent because they derive the foreign R&D stocks from underlying expenditure data using a depreciation rate of 5 per cent. However, the resulting elasticity estimates are not sensitive to small changes (eg from 5 to 10 per cent) in the depreciation rates (Coe and Helpman 1993; Bernstein 1989). Both Australian and foreign R&D measures are beginning-of-year stocks.

The two-step productivity approach uses the same estimates of multi-factor productivity as in the beginning of this appendix. The production function approach uses economy-wide measures of real GDP and net capital stocks from ABS (1994b), and labour hours from ABS (1993d, 1994b). To remove the effects of double counting in the production function framework, data on the labour and capital used in R&D were separated from traditional labour and capital stocks.

Other factors affecting productivity

Finally, in order to estimate an equation such as *(QB3)* or *(QB4)*, the variables captured in the vector, *Z*, need to be defined and measured. The new growth theories have stressed the importance of several factors apart from R&D that are likely to affect productivity growth. In addition, particularly when examining the productivity performance of an individual industry, there are a number of industry-specific or idiosyncratic factors that need to be taken into account — an obvious example is the influence of the weather on productivity in the agricultural sector.

Human capital

Many researchers have argued a link between productivity and human capital (Welch 1970; Schultz 1975; Lucas 1988; Boskin and Lau 1991; Benhabib and Spiegal 1992). Education is seen as improving the adaptability of the labour force to new ideas and technology, thus allowing productivity to rise more rapidly (Romer 1986, 1989, 1990b).

To the extent that these contributions to output growth are not captured via the conventional measures of labour input growth, or to the extent that they imply a labour contribution to output growth in excess of labour's factor income share, then some measure of education or human capital should be included as a separate variable explaining measured productivity.

Empirical studies find some support for the impact of education on productivity. Levine and Renelt (1992) find that education consistently influences productivity in various specifications of their model. Similarly, Boskin and Lau (1991) find that education significantly affects GDP growth in the G5 countries[6]. Education also appears to be a significant variable in an OECD (1993h) study, although the authors note that this result is not robust as the coefficient of their education variable changes with the inclusion of other variables. Similarly, Barro (1991) finds school enrolment rates to be weakly correlated with output growth.

School enrolment rates are a standard proxy for human capital in cross-country studies, because the data are readily available on a comparable basis from sources such as the World Bank. In the time-series formulation above, the preferred measure is the educational attainment of the labour force, as measured by the proportion of the labour force with post-secondary eduction. Data for Australia are available from the ABS.

6 France, Germany, Japan, UK and USA.

Investment in physical capital and public infrastructure

De Long and Summers (1991, 1992) find that the ratio of machinery investment to GDP positively affects productivity growth, but find no evidence of a significant effect from the proportion of GDP invested in structures and transport. They suggest this provides evidence of externalities associated with machinery investment.

The OECD (1993h) suggests that any link between capital intensity and productivity has weakened since 1973. Similarly, Heston (1993) finds that higher ratios of investment in machinery and equipment to GDP do not appear to raise productivity growth rates significantly in OECD countries. In a bigger sample (24 OECD countries plus 13 rapidly developing countries), he finds that the price of equipment, rather than the quantity purchased, significantly affects productivity growth. Countries with lower equipment prices, at a given level of equipment, grow faster. His explanation is that equipment prices seem to capture the effect of overall government policies toward growth, with pro-growth governments implementing policies that keep equipment prices low.

Both Aschauer (1989) for the United States, and Otto and Voss (1994) for Australia, find that private sector productivity is influenced by public infrastructure. OECD (1993h) suggests that because output expansion also increases the demand for infrastructure, the relationship is not one way and the estimates of Aschauer (and so of Otto and Voss) are likely to be biased. OECD (1993h) did not find any stable relationship between infrastructure capital and productivity in the OECD countries.

If either machinery and equipment or public infrastructure are a source of externalities leading to non-constant returns to scale, then at the economy-wide level, so long as the measure of capital stock is comprehensive, then estimation of equation *(QB4)* should allow these effects to be picked up without having to include any additional explanatory variables. The same is not true at the sectoral level. Largely because of the findings of Otto and Voss, the sectoral estimation of equation *(QB4)* includes as a separate variable a measure of public sector capital, obtained from ABS.

International trade

International trade is likely to produce a more rapid diffusion of new research output between national economies. Grossman and Helpman (1991) emphasise the importance of international trade as a carrier of knowledge spillovers — international trade in tangible commodities facilitates the exchange of intangible ideas.

Coe and Moghadam (1993) find that a variable measuring the extent of EC integration positively affects French GDP. However, Levine and Renelt (1992) find their international trade variable is not robust in explaining productivity growth. In OECD (1993h), the trade variable is found to have a negative coefficient, which the authors note does not have a plausible economic interpretation.

If Grossman and Helpman are correct, then the importance of trade to a country should be highly correlated with the amount of research done overseas. However, inclusion of foreign R&D is perhaps a better way to account for the effect of international research on productivity, since knowledge can transfer across international boundaries through many channels, not just by being embodied in traded goods. As noted above, foreign knowledge stocks are included as a separate explanatory variable in both the economy-wide and sectoral level analysis.

Government spending

Barro (1991) investigates whether the size of government affects productivity, either in terms of the average share of government spending in total GDP or the investment to GDP ratio. In the OECD (1993h) study, neither of these variables appeared significant at conventional testing levels. Largely for this reason, variables representing the size of government are excluded from the present study at both the economy-wide and sectoral level.

Inflation

A number of studies have included inflation, generally specified as the average rate of change of the GDP deflator, among various factors affecting productivity performance (Jarrett and Selody 1982; Fischer 1992; Corbo and Rojas 1992; Cozier and Selody 1992; and OECD 1993h). The OECD study notes that the impact of inflation on productivity is complex, although the general presumption is that the effect will be negative. The OECD found that a one per cent increase in inflation lowered productivity growth by 0.06 per cent, a stronger effect than found by Fischer or Corbo and Rojas, but the t-ratios of the OECD estimates were at less than the conventional levels of significance. Inflation is included in the current study at the economy-wide level, but not pursued separately at the sectoral level. Data on Australia's annual rate of inflation of the GDP deflator is obtained from ABS.

Energy prices

Since the period of estimation covers the oil crises, an energy price index is included as a separate variable affecting productivity at both the economy-wide and sectoral level. The general presumption is that the disruptive effects of the oil price shocks would have a negative effect on productivity, although the direction of impact is less clear for the energy producing sectors themselves. The OECD (1993h) used the ratio of real energy consumption to real business sector GDP as its measure of the impact of energy prices, and found that a one percentage point fall in this variable reduced productivity by about 0.08 per cent, although once again the t-ratios of the estimates were at less than conventional levels of significance. In this appendix, petroleum import prices are used, taken from ABARE (1993a).

Other factors

There are additional factors that clearly affect the productivity of individual sectors in the economy, although it is less clear that their effects would translate to the economy as a whole. As previously mentioned, the weather clearly affects measured agricultural productivity. In the sectoral analysis, an unpublished pasture growth index obtained from ABARE has been used. In Australia’s primary sectors, declines in world commodity prices can spur producers to find better production methods in order to survive. In both the economy-wide and sectoral analysis, Australia’s terms of trade are used as an additional variable explaining productivity growth.

Finally, a time trend is included, the coefficient of which is sometimes interpreted in studies such as these as denoting disembodied technical change (see also appendix QA).

Economy-wide results

In order to estimate equation *(QB4)* at the economy-wide level, an economy-wide productivity measure is required. As noted in the first section, however, productivity is only measured directly for the market sector. An economy-wide productivity measure can only be obtained by making an assumption about the rate of productivity growth in the non-market sector.

One assumption is that productivity growth in the non-market sector is zero. This is consistent with the assumption made at the beginning of this section. The econometric results from estimating equation *(QB4)* using economy-wide productivity data embodying this assumption are shown in the first two columns of table QB2. Some econometric problems encountered in estimating these equations are discussed in box QB2.

Box QB2: **Some econometric problems**

There are two main problems in estimating the contribution of R&D to productivity or output. Firstly, there tends to be a high correlation among different types of R&D variables, as well as between R&D and some other potential explanatory variables. In both the economy-wide and sectoral analysis presented in this appendix, this problem is controlled by using principal component analysis within the ordinary least squares (OLS) framework. The estimates obtained by this method are more precise (statistically efficient) than standard OLS estimates (Greene 1991, p. 285).

The second problem of possible non-stationarity of the variables is dealt with in the present analysis by checking for the presence of cointegrating relationships. The Augmented Dickey Fuller (ADF) tests gave mixed results on whether the variables were nonstationary. Therefore, each equation is tested for cointegration. This is done by testing the residuals of the estimated equations for stationarity. Estimates obtained from cointegrating relationships are super consistent (Stock 1987), ie the proof of consistency does not require the assumption that the regressors be uncorrelated with the error term. Moreover, the existence of cointegrating relationships also generally avoids the problem of autocorrelation. However, standard statistical tests are performed to test the presence of autocorrelation in the estimated equations.

In equation *(ia)* of table QB2, Australia's productivity is estimated as a function of Australian and foreign knowledge stocks only. Equation *(ib)* extends this equation by including education and time trend variables. Australia's terms of trade, weather, energy prices and a domestic/foreign interaction term were also tried in these specifications at the economy-wide level, but produced highly insignificant estimates.

The estimated coefficients represent elasticities of multi-factor productivity with respect to the included variables. Both of the R&D variables are significant in equation *(ia)*. This equation gives an elasticity of economy-wide multi-factor productivity with respect to both total Australian and foreign knowledge stocks of 0.055, meaning that if either the domestic or the foreign knowledge stock were to increase by one per cent, Australia's productivity would rise by 0.055 per cent. However, the domestic knowledge stock is smaller than the foreign stock to start with, so that the same elasticity translates into a larger rate of return. Using equation *(QB5)* above, the implied rate of return to Australian R&D can be calculated as 58 per cent and the implied rate of return to foreign R&D as 16 per cent.

Table QB2: **Impact of domestic and foreign R&D on Australian productivity, 1975–76 to 1990–91**

Explanatory variables	*Dependent variable is multi-factor productivity, derived assuming non-market sector productivity growth is zero*		*Dependent variable is multi-factor productivity, derived assuming market and non-market sector productivity growth rates are equal*	
	Equation (ia)	*Equation (ib)*	*Equation (iia)*	*Equation (iib)*
stock of R&D	0.055	0.024	0.081	0.040
	(7.02)	(0.89)	(6.85)	(0.94)
stock of foreign R&D	0.055	0.028	0.080	0.041
	(7.12)	(2.01)	(6.84)	(1.89)
education		0.056		0.072
		(0.81)		(1.11)
time		0.001		0.002
		(1.81)		(1.81)
Summary statistics				
R square adjusted	0.78	0.76	0.77	0.76
Serial corr. coeff	0.03	0.12	0.04	0.12
Autocorrelation				
LM χ^2	1.68	2.23	1.92	2.37
result	no autocorr.	no autocorr.	no autocorr.	no autocorr.
Heteroskedasticity				
Glejser χ^2	2.63	8.95	2.68	9.21
result	no heterosk.	no heterosk.	no heterosk.	no heterosk.
Cointegration test				
ADF statistics	5.87	7.09	6.06	7.08
10% critical value	3.78	3.78	3.78	3.78
result	cointegrated	cointegrated	cointegrated	cointegrated

Figures in parentheses represent t-values.
Source: Commission estimates.

In equation *(ib)*, the time trend is significant. Education is insignificant at conventional testing levels, but is included in the equation for the sake of uniformity with equations to follow, some of which include education as a significant explanator. The rates of return of both domestic and foreign R&D

are about half their value in equation *(ia)*, at 25 and 8 per cent respectively. This result suggests that failure to account for other variables explaining productivity may bias upwards the estimated returns to R&D.

An effort was also made to relax the assumption of constant returns to scale implicit in the two-step productivity method, by including capital and labour variables in log form as separate regressors. When these variables were added, the coefficients on all variables reverted to insignificance. In the industry-level analysis of the next section, the method is also used to correct for the assumption of constant returns to scale, with the results suggesting that the returns to labour and capital may be increasing in some sectors but decreasing in others. This lack of uniformity in the pattern of returns may explain why the same correction method performed relatively poorly at the economy-wide level.

The second two columns of table QB2 show the results of a similar estimation process using an economy-wide productivity measure that assumes that productivity growth in the non-market sector is the same as in the market sector. In general, these equations give a higher elasticity of Australian productivity with respect to domestic and foreign R&D stocks. When only domestic and foreign R&D are included, the implied rates of return rise to 87 and 23 per cent, respectively. Thus economy-wide estimates of the rate of return to R&D are sensitive to the assumption made about the rate of productivity growth in the non-market sector. When additional explanatory variables are added, the estimated rates of return to domestic and foreign R&D fall to 43 and 12 per cent, respectively.

Before leaving the two-step productivity method at the economy-wide level, it is useful to compare the results obtained so far with those obtained in other studies for Australia. Coe and Helpman (1993) do not report separate results for Australia, but Dowrick (1994), in a report prepared for the Industry Commission, uses Coe and Helpman's data and methods to derive a return to domestic business R&D and foreign R&D for Australia. His resulting return to domestic business R&D is very much higher than that obtained here so far, at 166 per cent, while his resulting return to foreign R&D is 19 per cent.

Further investigation suggests that the differences are attributable to the different productivity data for Australia used by Coe and Helpman, rather than to any differences in R&D data or underlying methodology. When Coe and Helpman's productivity data are used as the dependent variable in equation *(iia)* of table QB2 (ie taking their data on productivity in the business sector and assuming an equal rate of productivity growth in the non-business sector), the implied rates of return to domestic and foreign R&D are 131 and 17 per cent, respectively. When other explanatory variables are added, the results change in a similar way to those in table QB2. When plotted, Coe and Helpman's productivity data show a noticeably different pattern over time from the Commission's productivity data, which in turn move very closely in line with the ABS's own productivity series. However, insufficient is known about Coe and Helpman's productivity data to be able to assess its quality or to explain the source of the difference.

An alternative way of relaxing the assumption of constant returns to scale and perfect competition is by estimating an unrestricted production function along the lines of equation *(QB3)*. The results of such an estimation, still using capital and labour data that include the capital and labour used in R&D and therefore incorporate the double-counting problem, are shown in table QB3.

The results use as the dependent variable the ABS's measure of real GDP, a measure derived by the ABS making their own assumptions about output in the non-market sector. Since the measured economy-wide returns to R&D have been shown to be sensitive to such assumptions, it is important to understand how the ABS derives its output data for the non-market sector. This is done by assuming that output in this sector moves in line with labour inputs. The approach therefore ignores the contribution of both capital and productivity. Were the capital contribution taken into account, it is not clear what the implied residual contribution from productivity growth would be. However, the implied productivity contribution is unlikely to be zero.

In table QB3, equation *(iiia)* includes domestic and foreign R&D variables, capital and labour as variables explaining Australia's output over time. In equation *(iiib)*, education and a time trend are added. Equation *(iiic)* also includes an interaction term between domestic and foreign R&D. In contrast to earlier productivity-based specifications, all variables in this third specification, with the exception of education, have coefficients that are significant at a 95 per cent testing level.

The direct elasticity with respect to domestic R&D relates to GDP and is noticeably larger than those reported above which relate to productivity, a component of output growth. The total impact also needs to take into account the interaction term, which in the production function specification of equation *(iiic)* is significant. The total elasticity with respect to domestic R&D is given by the direct elasticity plus the product of the interaction elasticity and the log of the foreign R&D stock (evaluated at its sample mean). Similarly, the total elasticity with respect to foreign R&D is given by the direct elasticity plus the product of the interaction elasticity and the log of the domestic R&D stock (evaluated at its sample mean). Thus the total elasticities with respect to domestic and foreign R&D are 0.136 and 0.08 per cent, respectively. These translate into rates of return on domestic and foreign R&D of 149 and 27 per cent, respectively.

Table QB3: **Impact of domestic and foreign R&D on Australian GDP, 1975–76 to 1990–91**

Explanatory variables[a]	*Equation (iiia)*	*Equation (iiib)*	*Equation (iiic)*
stock of R&D	0.166	0.133	0.120
	(21.35)	(30.68)	(25.08)
stock of foreign R&D	0.093	0.053	0.035
	(2.99)	(3.31)	(2.26)
stock of capital	0.168	0.126	0.118
	(8.87)	(14.63)	(14.00)
stock of labour	0.756	0.719	0.712
	(6.23)	(6.86)	(6.45)
education		0.073	0.042
		(2.11)	(1.26)
time		0.004	0.003
		(14.28)	(13.61)
interaction term[b]			0.004
			(13.70)
Summary statistics			
R square adjusted	0.98	0.99	0.98
Serial corr. coeff	0.32	0.17	0.18
Autocorrelation			
LM χ^2	1.34	0.49	0.53
result	no autocorrelation	no autocorrelation	no autocorrelation
Heteroskedasticity			
Glejser χ^2	5.39	7.56	6.94
result	no heteroskedasticity	no heteroskedasticity	no heteroskedasticity
Cointegration test			
ADF statistics	2.65	2.70	2.71
10% critical value	2.57	2.57	2.57
result	cointegrated	cointegrated	cointegrated

Figures in parentheses represent t-values.

a The dependent variable is real GDP.

b Interaction term is defined as the product of logarithms of domestic and foreign R&D.

Source: Commission estimates.

At the economy-wide level, the estimated returns to R&D appear to be sensitive to the estimation method used, with the production function approach producing larger estimates. This may be a result of the different underlying assumption about the rate of productivity growth in the non-market sector, rather than a feature of the estimation method per se. However, the estimated elasticities of labour, capital and R&D stocks obtained from direct production function estimation seem plausible as compared to other studies (Coe and Moghadam 1993; Coe and Kruger 1990; Boskin and Lau 1988). For example, in their study of the French economy, Coe and Moghadam found the estimated output elasticity of R&D equal to 0.17. They acknowledge that in aggregate studies the R&D elasticity is generally larger than in the micro studies:

> Recent studies at the aggregate level for the United States, Japan, and Germany find an elasticity of about 0.13.....Griliches (1988) reports that estimated elasticities from firm and industry-level data tend to lie between 0.06 and 0.1. ....the estimation of an aggregate production function is better able to capture spillovers that increase the social, and hence the aggregate, return to research and development (Coe and Moghadam 1993, p. 552).

The results for Australia may suggest that the production function approach is an adequate method, and the adjusted two-step production function approach an inadequate method, of allowing for non-constant returns to scale at the economy-wide level. In a series of results Boskin and Lau (1988, 1990, 1991), Kim and Lau (1992, 1993) and Lau (1992) tested directly the sensitivity of measured productivity to the assumptions of constant returns to scale and perfect competition, as well as to profit maximisation, in their empirical analysis of France, Germany, Japan, the United Kingdom, the United States, and some South East Asian countries. Both assumptions were rejected. Using their unrestricted production function estimates they found that the contribution of productivity to output was much higher than the estimates obtained from the conventional growth accounting framework (more than one and a half times, in most cases), partially reflecting their finding of a lower capital elasticity. If unrestricted production function estimation finds a higher productivity contribution, it will find a higher return to R&D.

But since the Commission’s draft report was released, a paper by Hall and Mairesse (1995) has been published suggesting that either method of correcting for non-constant returns to scale may inadvertently introduce an additional *upward* bias in the estimated returns to R&D. Ideally, explanatory variables appearing on the right hand side of an estimating equation should be predetermined, meaning that it is impossible for them to be altered during the course of a year so as to affect the observed outcome for the left hand side variable (output or measured productivity) in that year. This is likely to be true for capital, R&D and other stock variables (and true for R&D stocks by definition since they are measured as beginning-of-period stocks), but is less likely to be true for labour. If labour is not predetermined, then including it as an additional explanatory variable raises the possibility of simultaneity bias.[7]

Hall and Mairesse (1995) note that the upward direction of the bias they find is not what they expected a priori. In other contexts, simultaneity bias more often than not biases coefficient estimates downwards. But Hall and Mairesse offer the following explanation for the upward bias:

> ... in firms and industries where 'true' productivity is higher than the norm, possibly because of previous investments in technological innovation, labour input is permanently lower. Such an explanation accounts ... for the upward bias on the R&D coefficient when labour is (incorrectly) treated as predetermined (Hall and Mairesse 1995, p. 288).

In one formulation, for example, their estimated R&D elasticity falls from 0.18 to 0.13 when the simultaneity of labour and output is recognised.

They find that correcting properly for simultaneity bias also reduces the discrepancy between cross-section and time-series estimates. Further, they find that taking account of the heterogeneity of firms, in terms of their underlying production technologies, also reduces the measured rate of return to R&D. This finding is relevant when considering the sectoral results in the next section of this appendix. The method proposed by Hall and Mairesse (1995) to correct for simultaneity bias is similar to the two-step method of equation *(QB4)*. This is also relevant when considering the sectoral results in the next section.

In a final set of sensitivity testing, table QB4 shows the results from unrestricted production function estimation using labour and capital data that have been corrected for the double-counting problem. Contrary to the suggestion of Schankerman (1981), double counting appears to make little difference to the estimated returns to R&D at the economy-wide level in Australia.

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[7] This possibility is certainly known to arise when all variables are stationary. If they are not (as noted, the results of tests for stationarity were mixed), but if the estimated relationship is a true cointegrating relationship, the coefficient estimates will be super consistent, as noted in box QB2. This means that the estimates will converge to the true value in large samples (ie be unbiased in large samples), even when not all explanatory variables are predetermined. The small sample properties of such estimators, however, are much less well understood.

Table QB4: **Impact of domestic and foreign R&D on Australian GDP, correcting for double counting, 1975–76 to 1990–91**

Explanatory variables[a]	*Equation (iva)*	*Equation (ivb)*	*Equation (ivc)*
stock of R&D	0.166	0.133	0.119
	(21.35)	(31.04)	(25.40)
stock of foreign R&D	0.095	0.055	0.036
	(2.99)	(3.41)	(2.32)
stock of capital	0.169	0.147	0.130
	(8.87)	(14.59)	(14.70)
stock of labour	0.758	0.722	0.726
	(6.23)	(6.88)	(6.44)
education		0.074	0.043
		(2.18)	(1.31)
time		0.004	0.004
		(14.36)	(14.17)
interaction term[b]			0.005
			(9.76)
Summary statistics			
R square adjusted	0.98	0.99	0.99
Serial corr. coeff	0.22	0.18	0.19
Autocorrelation			
LM χ^2	1.33	0.50	0.65
result	no autocorrelation	no autocorrelation	no autocorrelation
Heteroskedasticity			
Glejser χ^2	5.46	7.56	6.65
result	no heteroskedasticity	no heteroskedasticity	no heteroskedasticity
Cointegration test			
ADF statistics	2.65	2.68	2.68
10% critical value	2.57	2.57	2.57
result	cointegrated	cointegrated	cointegrated

Figures in parentheses represent t-values.

a The dependent variable is real GDP.

b Interaction term is defined as the product of logarithms of domestic and foreign R&D.

Source: Commission estimates.

Schankerman (1981) discusses the issue of double counting of R&D expenditure, once in the available measures of traditional labour and capital and again in the research expenditure input. He notes, however, that if the share of R&D inputs in labour and capital is constant over time, no bias in the estimated return to R&D would occur. In his empirical work, he finds

> In postwar US manufacturing the measured residual is biased downward by as much as 30 per cent. The net effect of double counting and expensing is a downward bias of about 10 per cent (Schankerman 1981, p. 455).

The finding for Australia in this appendix is consistent with shares of labour and capital used in R&D being very small. Indeed, when the net and gross capital and labour data are plotted against each other, the net and gross graphs are virtually indistinguishable. This appears to explain why the correction for double counting makes little difference for Australian estimates in practice.

Overall, the results suggest that of the direct production function specifications investigated, equation *(ivc)* is the preferred equation to estimate a social rate of return to R&D in Australia within the production function framework. Its direct elasticity of output with respect to Australian R&D is 0.119, and its direct elasticity of output with respect to foreign R&D is 0.036. When the interaction term is taken into account, the total elasticity with respect to domestic R&D is 0.140 and the total elasticity with respect to foreign R&D is 0.086. These translate into economy-wide rates of return on domestic R&D of 149 per cent, and on foreign R&D of 27 per cent.

These estimated rates of return do not embody an assumption of constant returns to scale, nor are they subject to double counting or some kinds of omitted variable bias. However, they are still subject to the assumptions made about productivity in the non-market sector and to a range of other data and methodological problems canvassed in appendix QA. They are also potentially affected by simultaneity bias. Many of the measurement problems, such as the need to interpolate the R&D data and the problems of measuring input and output quality changes, are such that it is difficult to determine the direction of the resulting bias. In the case of simultaneity bias, however, Hall and Mairesse (1995) have suggested that the bias may be upward.

The two-step productivity method gives estimated returns of between 25 and 87 per cent to domestic R&D and between 8 and 23 per cent to foreign R&D. These estimates are also subject to the assumptions made about productivity in the non-market sector and to the range of other data and methodological problems. They have the virtue of being unaffected by simultaneity bias, but do not correct for double counting and also embody an assumption of constant returns to capital and labour. However, the double-counting problem has been shown to be minor in Australia. The impact of relaxing the assumption of constant returns at the economy-wide level has been difficult to assess.

QB.3 Sectoral returns to R&D

The economy-wide analysis gave an insight into the magnitude of the aggregate benefits from domestic and foreign stocks of R&D. At the sectoral level, the objective is to quantify not only the sectoral benefits, but also to identify inter-industry spillovers.

The sectoral analysis is conducted using the two-step productivity framework rather than the direct production function approach considered in the economy-wide analysis. Within this framework, relaxing the implicit assumption of constant returns to scale proves easier than at the economy-wide level. The sectoral estimates presented below do not suffer to the same extent from the econometric problems evident when capital and labour were added to the specifications in table QB2, and the varying evidence on returns to scale at the sectoral level appears to be plausible.

The method of relaxing the implicit assumption of constant returns to scale reintroduces the possibility of upward simultaneity bias, since it reintroduces a variable that may not be strictly predetermined into the right hand side of the estimating equation. However, the bias is likely to be significantly less than in a direct production function framework, since these variables now do most of their ‘work’ on the left hand side.

The estimates obtained in this section also suffer from a double-counting problem. However, the results of the previous section suggest this may not be an important source of bias.

To capture the inter-industry spillovers, the sectoral analysis examines the impact of four distinct stocks of R&D, two of which are sector-specific. First, each sector undertakes its own R&D and hence generates an internal stock of knowledge.[8] Second, there is a pool of knowledge generated by businesses in other sectors that may benefit any one individual sector.

The remaining stocks are not sector-specific. R&D undertaken by the ‘public sector’ is another potential source of spillovers and is identified separately. The public stock of knowledge incorporates all R&D undertaken by government departments, organisations, authorities, higher education institutions and private non-profit organisations. It has not been tailored to each sector in any way,

8 All sectors undertake significant R&D with the exception of agriculture, forestry, fishing and hunting. This point is elaborated when the results for agriculture are discussed.

even though each sector will undoubtedly be dependent upon different components of the aggregate stock of public research. Nevertheless, to generate an industry-specific stock of public R&D would require a considerable amount of information about technical proximity, as well as a degree of subjectivity.

The final source of a potential spillover benefit is the stock of foreign R&D. The measure used is the same as that in the economy-wide analysis.

There are many types of spillover benefits, yet not all arise from market failure. The spillovers that are relevant to policy decisions are those benefits that are uncompensated. As highlighted in appendix QA, studies that estimate spillover benefits are generally incapable of distinguishing between those benefits that result from market transactions and those that are uncompensated. In addition, while econometric studies measure the benefits to industries receiving the spillover benefits, they are not generally capable of distinguishing additional welfare gains or losses to consumers.

To estimate knowledge spillovers to receiving industries, the data must be classified appropriately. An industry's own R&D activity should be defined to include all R&D expenditure made by that industry, regardless of whether the R&D was undertaken 'in-house'. The ABS does not publish R&D expenditure data in this form. Instead they give what they call intramural and extramural data. Intramural R&D is R&D undertaken by an organisation on its behalf or on behalf of other organisations, institutions or individuals, whereas extramural R&D refers to R&D activity funded by an organisation but carried out by other enterprises, organisations, institutions or individuals (ABS various d). Theoretically, it should be possible to construct the appropriate series to estimate knowledge spillovers from the published data. However, the published data do not contain enough detail to construct a long enough time series for all business and public sectors separately. Therefore, the sectoral results presented in this section are based on intramural data, measuring the R&D undertaken by a sector rather than the R&D funded by that sector.

An approximate measure of 'own-funded' R&D for some business sectors can nevertheless be constructed, but only for the period 1984–85 to 1990–91. To determine the direction and magnitude of the bias from using intramural R&D, a comparison was made of the results of a simple regression of sectoral productivity on (i) sectoral intramural R&D, and (iii) the proxy for sectoral own-funded R&D, over this time period. This restricted comparison suggested that the estimated elasticities from intramural data may be marginally biased upwards. When interpreting the effects of R&D on sectoral productivity it should be noted that this is one source of potential upward bias.

The functional form used is of the type shown in equation *(QB4)* of the previous section. More specifically, for each sector an equation of the following form is estimated:

$$\ln MFP = \phi_1 \ln rdo + \phi_2 \ln rde + \phi_3 \ln rdo * \ln rde + \phi_4 \ln rdp + \phi_5 \ln rdf + \gamma_i \ln x_i \qquad (QB6)$$

where *MFP* is measured multi-factor productivity for the sector;
rdo is its stock of internally generated R&D;
rde is its stock of external R&D;
rdp is the stock of R&D undertaken by public organisations;
rdf is the stock of foreign R&D; and
x_i are additional variables explaining the level of MFP.

The functional form in equation *(QB6)* makes allowance for complementarity between a sector's own R&D stock and that generated by businesses in other sectors. It only allows for the interaction between these business stocks of R&D and not other factor inputs for two reasons. The first is to conserve degrees of freedom. Secondly, given this constraint, the interaction between own and external business R&D stocks was chosen as being the most policy relevant interaction to investigate. If business knowledge stocks are substitutes, there is a possible incentive for sectors to reduce the amount of R&D they undertake and to free ride on the R&D of others. If R&D stocks are complementary, the incentive to free ride is reduced.

There is an element of complementarity between own and external knowledge stocks when the estimated coefficient on the interaction term is positive. This indicates that the value of undertaking additional 'own' R&D is increased because it also provides a greater understanding of the existing spillover pool of knowledge available. Conversely, the spillover benefit a sector receives from additional R&D in other business sectors is enhanced by the industries existing 'own' stock of knowledge.

In addition to the various stocks of R&D, other factors influence the level of multi-factor productivity. There are general factors that influence the level of productivity in all sectors, such as educational attainment levels. There are also sector-specific factors such as weather in agriculture. The additional explanatory variables were discussed in the previous section, but a list and description of the all explanatory variables considered in the sectoral analysis is reproduced for convenience in table QB5. Note that for the manufacturing sector an additional explanatory variable was tried, namely, the nominal rate of manufacturing assistance, using data from IC (1993). This variable, however, was not used in the final specifications (see below).

Table QB5: **Explanatory variables used in sectoral analysis**

Explanatory variable	*symbol*	*Description*
Stocks of R&D:		
Own	*rdo*	Cumulative R&D expenditure for a sector.
External	*rde*	Unweighted sum of all other sectors' R&D stocks.
Public	*rdp*	Cumulative R&D undertaken by government departments, organisations, authorities, higher education institutions and private non-profit.
Foreign	*rdf*	Stock of knowledge developed by 21 OECD countries and Israel.
Additional variables	x_i	
Labour		Aggregate hours worked.
Capital		Physical capital stock - net of depreciation.
Time		A time trend.
Public infrastructure		General government stock of net public capital (including non-dwelling construction and equipment).
Education		Percentage of the labour force with post-secondary education.
Terms of terms		Ratio of the implicit price deflator for export goods and services to the implicit price deflator of import goods and services.
Energy price index		Petroleum import price index.
Nominal rate of assistance		Nominal rate of assistance for the manufacturing sector.
Weather		Pasture growth index weighted by receipts from AAGIS regions.

Source: See text.

Further data limitations restrict the coverage of the sectoral analysis for two reasons. First, the non-market sector is excluded from the analysis as it lacks an independent measure of output with which to measure its productivity. This restricts the sectoral analysis to the market sector, as defined in table QB1. Second, the disaggregation at which the ABS publishes Business Expenditure on Research and Development (BERD) does not correspond exactly to the market sector disaggregation, with several of the market sectors being classified together in the BERD data. The sectors covered in this analysis are:

- broadacre agriculture;
- mining;
- manufacturing;
- wholesale and retail trade; and
- other services.

The other service sector is defined to include Electricity, gas, and water, Transport, storage and communications, and Recreation, personal and other services.[9]

The regression results are presented in table QB6, estimated over the period 1976–77 to 1990–91. As for the economy-wide analysis, not all explanatory variables are included in every reported equation. The included variables have been chosen on the basis of a general-to-specific search in which all variables were initially included, then the most insignificant variables successively dropped. Given the large number of potential explanatory variables, this search method initially places very great weight on the principal component estimation technique, since this method, in addition to dealing with problems of multicollinearity, also conserves degrees of freedom in a purely technical sense. The results chosen for reporting in table QB6 still tend to be generous in the number of explanatory variables included, but give a reasonable picture of which factors are important in influencing multi-factor productivity in each sector.

Broadacre agriculture

The Commission initially examined the effects of R&D on the full agriculture, forestry, fishing and hunting sector, using its own productivity data for this sector discussed in the first section. The results obtained were not considered reliable. The only significant influence on the level of multi-factor productivity was weather, and the explanatory power was low with an adjusted R^2 of 26 per cent. These poor results were attributed to the sector's highly heterogeneous nature.

The analysis was then restricted to explaining productivity for broadacre agriculture, along similar lines to Mullen and Cox (1994a). There are five industries covered in broadacre agriculture:

[9] The measure of multi-factor productivity for 'other' services is a weighted average of the measures for these three market sector industries. However, the measure of 'own' R&D is slightly broader, also including R&D undertaken by 'services to mining', the finance industry and some community service industries.

Table QB6: **Determinants of multi-factor productivity by sector**

Explanatory variables	*Broadacre agriculture*	*Mining*	*Manufacturing*	*Wholesale & retail trade*[a]	*Other services*
Stocks of R&D					
Own	na		0.014	-0.017	0.052
			(3.057)	(-2.555)	(2.208)
External	0.044	0.109	-0.004	-0.010	0.018
	(5.869)	(4.472)	(-0.293)	(-2.586)	(6.023)
Own*external	na	0.003	0.000	-0.001	0.002
		(3.539)	(0.250)	(-2.566)	(3.494)
Public	0.109	0.094	0.065		0.048
	(5.215)	(3.067)	(18.390)		(4.939)
Foreign	0.066		0.066	0.044	0.030
	(3.969)		(5.236)	(2.072)	(1.758)
Additional Variables					
Time	0.003	0.002	0.002		0.001
	(5.236)	(2.484)	(11.730)		(3.857)
Capital stock		-0.098	0.095	0.044	0.032
		(-5.622)	(25.150)	(1.989)	(6.330)
Labour				-0.214	0.083
				(-2.467)	(3.999)
Public infrastructure	0.284		0.268	0.156	
	(5.695)		(4.238)	(2.071)	
Education	0.132	-0.086	0.128	0.097	0.051
	(5.037)	(-3.754)	(4.558)	(2.129)	(1.487)
Terms of trade		-0.570			
		(-2.051)			
Energy price index		-0.274			
		(-5.545)			
Weather	0.371				
	(2.488)				
Summary statistics					
adjusted R^2	73.95	69.85	97.94	26.22	97.78
DW	1.307	1.271	1.307	1.914	1.627
Serial correlation coefficient	0.318	0.351	0.324	-0.094	0.133
ADF[b]	-2.39	-2.122	-2.41	-3.75	-1.731

na Not available (unable to be estimated).

Figures in parentheses represent t-values.

a This equation displays evidence of misspecification and data problems that are discussed in the text.

b Cointegration critical value at 10% level of significance is -1.62.

Source: Commission estimates.

- wheat and other crops industry;
- mixed livestock-crops industry;
- sheep industry;
- beef industry; and
- sheep-beef industry.

All five industries are covered by ABARE’s Australian Agricultural and Grazing Industries Survey (AAGIS). ABARE has calculated total factor productivity for broadacre agriculture from data collected in the AAGIS. One explanatory variable used in the analysis of this productivity variable is ABARE’s pasture growth index. This is based on the broadacre AAGIS regions and this is consistent with the measure of total factor productivity.

The agricultural sector analysis differs slightly from other sectors in that there is no internally generated stock of R&D. The ABS business enterprise R&D survey excludes enterprises mainly engaged in agriculture, forestry, fishing and hunting. They are excluded partly on the basis of collection difficulties and partly because such enterprises are believed to have very low R&D activity, as R&D activity for this sector is generally carried out by specialised research institutions (ABS various d). As a result it is assumed here that broadacre agriculture does not undertake any significant R&D expenditure and thus does not have a stock of internally generated R&D.

Table QB6 shows that the level of productivity in broadacre agriculture depends on the stock of R&D generated by other business sectors, public research organisations and foreign economies, as well the provision of public infrastructure, education attainment levels and weather conditions.

The overall fit of the equation is good with an adjusted R^2 of 74 per cent. The formal test for a long-run cointegrating relationship is easily accepted at the 10 per cent level of significance.[10] Nevertheless, given the small number of observations, formal testing of cointegration may not be entirely reliable because the small sample properties of these tests are unknown. To complement the formal testing procedure, informal methods are also used.

The presence of a high adjusted R^2 and low Durbin-Watson statistic are informal indicators of spurious regressions, that is, a relationship that is not

[10] Engle and Granger (1987) point out that when using Augmented Dickey-Fuller tests, the probability of accepting the null hypothesis of non-stationarity when it is false is high, especially when the errors are strongly autocorrelated. Given this, the general convention is to used 10 per cent rather than 5 per cent significance levels, in order to increase the chance of detecting cointegration.

genuine and purely an illusory effect resulting from the non-stationary nature of the data. The difficulty of using informal methods is that they require a degree of subjectivity in defining 'high' and 'low'. In the case of broadacre agriculture, this is not a large problem as even though there is evidence of autocorrelation, as indicated by a Durbin-Watson statistic of 1.307, 'low' is usually taken to be less than 1. Thus the informal evidence supports the formal testing methods indicating that the relationship between productivity, R&D and other variables is not spurious.

The broadacre agriculture sector receives significant spillover benefits from three sources. Firstly, the level of broadacre agriculture productivity is positively related to the stock of R&D generated by other business sectors; a one per cent increase in the stock of 'external' R&D raises productivity by 0.044 per cent. Secondly, broadacre agriculture receives large spillovers from public research; a one per cent increase in the stock of R&D generated by public organisations raises productivity by 0.109 per cent. Thirdly, a one per cent increase in 'foreign' R&D leads to a 0.066 per cent increase in broadacre productivity. When converted to rates of return (using an output measure from ABARE 1994), these estimates imply rates of return of 6.3, 7.1 and 1.9 per cent on the stocks of external, public and foreign R&D, respectively.

Public infrastructure is another factor often described as a driving force behind economic growth. A one per cent increase in the stock of public infrastructure is estimated to increase the level of productivity in broadacre agriculture by 0.284 per cent. These findings extend the findings of Otto and Voss (1994) for Australia. Otto and Voss found public capital played an important role in influencing the level of productivity in the aggregate economy. However, when the same model was applied to the sectoral level the results were generally poor. They allude to a possible problem of inadequacies in their sectoral model specification. The analysis undertaken in this appendix allows for a more general specification by including several possible sources of endogenous growth, rather than a single exogenous sector-specific factor.

The general education attainment level of the labour force is positively related to the level of productivity in broadacre agriculture. A general, rather than sector-specific, education measure is used for two reasons. First, because of changes in the ABS labour force survey, a consistent series of the educational attainment of the labour force in each sector was unavailable. Second, educational attainment is a proxy measure for the stock of human capital, which like stock of R&D and public infrastructure capital can have positive externalities that flow into the wider economy. For example, the qualifications of farmers' financial advisers may be equally important in determining productivity in broadacre agriculture. The estimates suggest that a one per cent rise in the percentage of the labour force with post-secondary school attainment levels would lead to a 0.132 per cent increase in productivity in broadacre agriculture.

The final factor affecting the broadacre agriculture sector is the weather. As expected, a one per cent improvement in the weighted pasture growth index, which captures the impact of rainfall, temperature and soil moisture, results in a 0.371 per cent improvement in the productivity of broadacre agriculture.

Mining

The level of multi-factor productivity in mining depends on the various stocks of R&D generated in the domestic economy, in addition to general education attainment levels of the labour force, time, the terms of trade, energy prices and the level of capital stock in mining.

The overall fit of the equation is sound. There is no evidence of a spurious relationship as the adjusted R^2 is moderately high at 70 per cent and the Durbin-Watson is above one at 1.271. In addition, the formal tests for a cointegrating long-run relationship are satisfied.

The R&D undertaken by the mining sector does not significantly explain the level of mining productivity. However, externally generated stocks of R&D influence mining productivity and represent a spillover benefit, though not necessarily an uncompensated benefit. Because of the way the ABS categorises R&D data, the pool of spillover knowledge available to the mining sector includes R&D undertaken by ‘services to mining’, the industry that undertakes mining exploration. Thus a significant portion of the R&D undertaken by mining companies is counted as external to the mining industry. A one per cent increase in the ‘external’ stock of R&D increases the productivity of mining by 0.109 per cent.

In addition to the direct benefits derived from the external stock of R&D there are interaction effects. A positive sign on the interaction term indicates that external R&D complements the R&D undertaken within the sector. Thus, even though the mining sector does not apparently benefit directly from its own R&D, increases in its own R&D improve its ability to make use of external R&D. This indirect benefit means that a one per cent increase in the internally generated stock of R&D leads to a 0.024 per cent indirect increase in mining productivity. The interaction term also increases the spillover benefits derived from additional external R&D above what the sector would have obtained had it undertaken no R&D. The total benefit derived from a one per cent increase in external R&D is a 0.124 per cent increase in mining productivity, as opposed to the 0.109 per cent direct increase.

The mining sector also benefits from the stock of R&D generated by public organisations. The level of mining TFP is estimated to increase by 0.094 per cent as a result of a one per cent increase in the stock of public R&D. There are no significant spillovers from the foreign stock of R&D.

The mining sector earns substantial rates of return from R&D. The internally generated R&D has a rate of return of 81 per cent. The external and public stocks of knowledge generate a return of 21 and 7 per cent, respectively.

The mining industry exhibits evidence of slight decreasing returns to labour and capital, as indicated by the negative coefficient on the capital stock variable. This result is consistent with the idea of diminishing returns to a fixed ore body. As more and more capital and labour are applied to a given ore body, a point is eventually reached at which proportional increases in capital and labour will contribute less than proportionately to output.

There are several factors, both general and sector-specific, in addition to R&D stocks that influence mining productivity. The first additional variable is education. Somewhat counter intuitively, a one per cent increase in education attainment levels is estimated to lead to a reduction in mining productivity. One possible explanation for this result is that the education variable is capturing the effects of an omitted variable and the result is not regarded as reliable.

Another factor influencing mining productivity is the terms of trade. The impact is negative, with a one per cent decline in the terms of trade estimated to increase mining productivity by 0.570 per cent. This result is consistent with Beck et al. (1985), who argue that in high income periods (an increase in the terms of trade), expenditure on inputs will increase but in the short term the relative inelastic supply will be little affected, thus resulting in an apparent short term decline in productivity.

The final factor affecting the productivity of the mining sector is the energy price index. A one per cent increases in the energy price index is estimated to reduce the level of mining productivity by 0.274 per cent. The disruptive effects of oil price shocks were also found to adversely affect productivity in a cross-country study by the OECD (1993h).

Manufacturing

There is a robust relationship between manufacturing productivity and stock of knowledge generated internally, by public institutions and overseas countries, in addition to time, net capital stock and education attainment. These determinants explain 98 per cent of the variation in manufacturing productivity. There is no evidence, neither formal nor informal, of a spurious relationship.

A one per cent increase in the manufacturing sector's 'own' R&D stock is estimated to raise manufacturing productivity by 0.014 per cent. Interestingly, the manufacturing sector does not receive any significant spillover benefit from other business sectors, nor is there evidence that the 'external' stock of R&D complements the own stock of knowledge. Nevertheless, there are significant benefits derived from both foreign and public R&D stocks. A one per cent increase in the stock of public or foreign R&D leads to a 0.065 or 0.066 per cent increase in manufacturing productivity, respectively.

The manufacturing sector earns significant rates of return to internally generated R&D and the stock of knowledge developed by public organisations. The internally generated R&D has a rate of return of 13 per cent, while public stocks of knowledge generate a return of 16 per cent. Although the elasticity on foreign R&D is slightly higher than on public R&D, the foreign R&D stock is bigger than the public stock so that the rate of return to foreign R&D is lower, at 7 per cent.

The assumption of constant returns to labour and capital is not born out empirically. The positive and significant coefficient on the capital stock variable suggests there is evidence of increasing returns to scale — a proportional increase in both capital and labour leads to more than a proportional increase in output. This result is consistent with evidence Hall (1988) presents for the US manufacturing sector. Hall rejects the assumption of constant returns to scale for all seven manufacturing industries analysed, although at varying degrees of significance. The result for Australian manufacturing could also reflect the impact of unmeasured quality improvements in capital and labour inputs.

There are two general economy-wide factors that effect the level of productivity in the manufacturing sector. First, the public provision of infrastructure has a large and significant impact on the level of manufacturing productivity; a one per cent increase in the level of public capital leads to a 0.268 per cent increase in productivity. Second, a one per cent increase in the education attainment levels of the labour force increases the level of manufacturing productivity by 0.128 per cent.

Nominal rates of manufacturing assistance do not appear to have a significant effect on manufacturing productivity. However, the manufacturing sector is a diverse sector in terms of assistance levels and it is conceivable that dynamic productivity gains from reductions in protection could be detected at a more disaggregated level of analysis.

Wholesale and retail trade

The level of productivity in the wholesale and retail trade sector is estimated as a function of various stocks of R&D generated both inside and outside the domestic economy, labour, the net capital stock of the sector, public capital and education. The results are poor with an adjusted R^2 of 26 per cent, yet there is no evidence of autocorrelation (DW=1.914) and the formal cointegration tests are satisfied. These results are disappointing given the general framework performs well for all other sectors. This may imply that there is a general inadequacy in the specification for this particular sector, or alternatively a problem of mismeasurement in this sector's productivity.

One key characteristic of the wholesale and retail trade sector is that its measured multi-factor productivity has been declining over the period of analysis. As outlined in section QB.1, the average growth in inputs has moved ahead of growth in output resulting in a decline in measured productivity. However, this may reflect the inability to take into account changes in the quality of output or inputs when calculating productivity. The wholesale and retail trade sector has undertaken major restructuring since the late 1970s. For example, there has been a progression away from 'street shopping' to homogenous 'chain' store shopping centres. Retail trading hours have been extended with management placing a greater emphasis on customer service. The wholesale sector has implemented improved inventory management techniques such as 'just in time'. Hence, the calculated decline in productivity for the wholesale and retail trade sector could well be an illusory result from the inability to adequately incorporate quality changes in the sector's inputs and outputs.

By contrast, the framework used to analyse productivity in this appendix is able to explain mining productivity, despite a similar decline in measured mining productivity over some parts of the sample period. Thus, the factors causing the decline in measured mining productivity are accounted for in the model specification above, including terms of trade and oil price shocks.

Other services

The total factor productivity of the other services sector is estimated to be a function of R&D stocks, time, labour, capital, and education. The other services sector displays a strong relationship between the various stocks of R&D and productivity. Formal tests indicate that a long-run cointegrating relationship exists. Informal guidance also supports the statistical evidence that the results are not spurious, with a high adjusted R^2 (98 per cent) and minimal evidence of autocorrelation (DW=1.627).

The other services sector receives strong benefits from both internally and externally generated stocks of knowledge. A one per cent increase in the own stock of R&D increases the level of productivity by 0.052 per cent. The interaction of the stock of ‘own’ and ‘external’ R&D shows that the knowledge generated outside the sector complements the stock of own R&D. As a result, the total benefit from increasing the ‘own’ stock R&D by one per cent is a 0.068 per cent increase in productivity, as opposed to the 0.052 per cent increase arising from direct benefits. The total spillover benefit from a one per cent increase in the external stock of R&D, including complementary effects, is a 0.031 per cent increase in productivity in the other services sector.

In addition to the benefits derived from R&D undertaken in the business sector, the other services sector receives spillovers from public and foreign stocks of R&D. A one per cent increase in the R&D undertaken by public organisations leads to a 0.048 per cent increase in productivity. A one per cent increase in the R&D undertaken overseas leads to a 0.030 per cent increase in productivity.

The results translate into exceptionally large rates of return to domestically generated R&D. Internally generated R&D has a rate of return of 263 per cent. The external, public and foreign stocks of knowledge generate rates of return of 18, 11 and 3 per cent, respectively.

The presence of significant and positive coefficients on the labour and capital variables indicates a violation of the assumption of constant returns to capital and labour used in calculating the multi-factor productivity index for the other services sector. Nevertheless, the finding of increasing returns to capital and labour would not necessarily apply to all portions of this sector. The other services sector is a conglomerate of industries, covering Electricity, gas and water, Transport, storage and communications, and Recreational and personal services. The result of increasing returns to labour and capital is plausible for electricity and rail, for example. However, the existence of increasing returns to capital and labour is not as likely in recreational and personal services.

A final variable, educational attainment, has a positive effect on the productivity of the other services sector. A one per cent increase in the percentage of the labour force with post secondary school education increases productivity by 0.051 per cent.

Summing up

The objective of this section was to quantify the inter-industry spillovers for five market sectors: broadacre agriculture, mining, manufacturing, wholesale and retail trade and other services. Using a two-step productivity framework, the sectoral analysis estimated the inter-industry spillover using four distinct R&D

stocks. Not all stocks were found to be significant sources of spillover benefit. To ensure the estimated R&D elasticities were robust, other sources of endogenous growth and additional influences on productivity were taken into account.

The other services sector was the main sector that generated a significant ‘own’ benefit from the internally generated stock of knowledge. However, the magnitude of the benefit may be affected by the fact that the ‘own’ stock of R&D for the other services sector includes R&D from a wider range of industries than covered in the measure of productivity. The mining and manufacturing sectors are the remaining two sectors to receive a positive benefit from the stock of internally generated R&D, although the mining sector return is indirect, through the complementarity of its own with ‘external’ R&D. The average of the direct rates of return to own R&D in manufacturing and other services is approximately 90 per cent.

The mining sector received a substantial inter-industry spillover benefit from other business sectors. However, the benefit is not necessarily an uncompensated benefit as ‘services to mining’ is included in the ‘external’ stock of knowledge. Furthermore, it is noteworthy that the manufacturing sector is the only sector that does not receive a significant benefit from other business.

The interaction between the own and external stocks of R&D indicates that business R&D has complementary effects in two sectors. That is, the stock of R&D generated by other businesses is used as a complement to the internally generated stock of knowledge, so that the value of undertaking additional ‘own’ R&D is increased through a greater understanding of the spillover pool of knowledge available.

Broadacre agriculture productivity is very responsive to changes in the stock of public knowledge. The spillover benefit broadacre agriculture receives from the stock of R&D developed by public organisations is not surprising given the performance of R&D in some government agencies is directed primarily at agricultural activities. To the extent that broadacre agriculture directly or indirectly funds the public research done on its behalf, the spillover benefit need not be an uncompensated one.

The stock of foreign R&D is an important source of spillover benefit for all sectors except mining.

The additional sources of endogenous growth are large and significant factors influencing the level of productivity in most sectors. Broadacre agriculture and manufacturing productivity are highly responsive to changes in the stock of public infrastructure. Furthermore, the educational attainment level of the labour force is an important influence on the level of productivity in four sectors.

The manufacturing and other services sectors exhibit evidence of increasing returns to labour and capital. The manufacturing result is consistent with evidence for US manufacturing and the other services result with characteristics of the electricity and rail industries. The regression results also indicate decreasing returns to labour and capital in the mining sector.

QB.4 Conclusion

This appendix has used the productivity improvements attributable to R&D to estimate a social rate of return to Australia's R&D effort. The measured economy-wide returns to R&D have been shown to be sensitive to a number of biases, assumptions and measurement problems. The estimation methods in this appendix have attempted to control for some of the sources of bias.

Any attempt to measure an economy-wide return to R&D needs to make some assumption about the rate of productivity growth in the non-market sector, a sector in which output is not measured directly, but which is estimated by the ABS to account for about one-third of the economy.

On the assumption that the rate of productivity growth in the non-market sector has been zero, an economy-wide rate of return to Australia's R&D effort can be calculated at between 50 and 60 per cent. On the assumption that productivity growth in the non-market sector has equalled that in the market sector, the measured economy-wide rate of return to R&D rises to around 90 per cent.

Failing to control for factors (such as education) that have also contributed to productivity growth tends to bias upwards the measured social returns to R&D. When some of these factors are controlled for at the economy-wide level, the measured social return to R&D falls, sometimes by as much as a half.

Attempting to correct for mismeasurement of productivity can increase the measured return to R&D. One of the assumptions made in conventional measures of multi-factor productivity is that of constant returns to scale. When this assumption is relaxed (by estimating an unrestricted production function), the capital contribution to output growth falls while the productivity contribution rises. To the extent that R&D explains this larger productivity contribution, the social return to R&D increases to as much as 150 per cent.

However, it remains unclear how much of this apparent increase in the measured return to R&D is also accounted for by the implicit assumption the ABS makes about productivity growth in the non-market sector when deriving its measure of national output. Another study has also shown that the process of estimating an unrestricted production function can introduce an upward simultaneity bias. Correcting for this in the current context could reduce the economy-wide measured returns to R&D back towards the 25 to 90 per cent range.

The rates of return to R&D appear to vary among the sectors for which output measures are available, with direct returns to own R&D averaging around 90 per cent in manufacturing and an ‘other services’ conglomerate. The ‘other services’ sector, along with agriculture and mining, also appear to receive spillover benefits from the R&D undertaken in other business sectors, although in the case of mining in particular the spillover benefits are likely to paid for. Most sectors are also estimated to receive spillover benefits from R&D undertaken in public institutions and from foreign R&D.

Although attempts have been made to control for several sources of bias, the estimated returns to R&D reported in this appendix are still subject to a number of assumptions and measurement problems. Among the data problems likely to affect the estimates in unknown ways are the need to interpolate R&D data for the years not covered by ABS surveys, the shortness of the time series obtained even with interpolation, and the problems in accurately capturing changes in input and output quality. Also to the extent that not all expenditure on R&D is included in the data, the return to the identified R&D will be over estimated.

APPENDIX QC: ECONOMY-WIDE EFFECTS OF THE TAX CONCESSION

The 150 per cent tax concession is one of several forms of assistance to R&D. Tax arrangements normally allow firms to deduct 100 per cent of current business expenses immediately from their taxable income, or to deduct depreciation on an acquired asset over time until 100 per cent of its value is written off. The 150 per cent R&D concession allows firms immediately to deduct 150 per cent of eligible expenses on R&D. One rationale for assistance is that R&D produces spillover benefits to other firms and industries (see part A of this report).

This appendix uses information on the incidence of the 150 per cent tax concession from appendix QD, and information on the strength of spillovers from R&D in appendix QB, to estimate the long-term economy-wide impact were the assistance component of the tax concession eliminated, that is, were R&D expenses deductible at a rate of 100 per cent rather than 150 per cent. Since R&D expenditure can be regarded as investment expenditure producing an asset such as a patent or a body of knowledge, rather than current expenditure producing current output, non-concessionary tax treatment would also require R&D expenditure to be deductible over time rather than immediately. However, this appendix examines only the final long-term impact once 100 per cent rather than 150 per cent of R&D expenditure is written off. It does not examine the pattern of effects over time. By taking a long-term snapshot view, this appendix abstracts from the distinction between immediate deductibility and deductibility over time.

The appendix uses a special-purpose economy-wide model capturing salient features of R&D. The model results suggest that deductibility of R&D expenditures at 150 per cent rather than 100 per cent can boost Australia’s R&D activity and add to economic growth. But a BIE survey (1993c) suggests that under the current scheme, the bulk of eligible R&D would have been undertaken anyway. Consistent with such a relatively low estimated 'inducement rate', the model’s projected impact of reducing the rate of deductibility to 100 per cent is also relatively small. The impact of the concession would be considerably greater if it could induce more R&D than would have been undertaken otherwise.

A number of participants have noted that the value of the 150 per cent tax concession has fallen over time with reductions in the company tax rate. They have argued that the rate of tax concession should be increased above 150 per cent in order to restore its initial value. Against this is the argument that the reductions in the company tax rate over time are likely to have improved the capacity of companies to carry out all types of activity, including R&D. The model results in this appendix suggest that reductions in the company tax rate would indeed stimulate R&D activity in an absolute sense, although the erosion of the subsidy-equivalent value of the concession is projected to reduce the R&D intensity of the economy.

Currently, the tax concession is available for all eligible R&D expenditure, irrespective of whether that R&D is ultimately successful in a commercial sense and irrespective of whether it produces spillover benefits to other firms or industries. There are strong arguments on political economy grounds for making such assistance uniform (or as uniform as possible given variations in company dividend and other policies that may affect the level of assistance afforded by a tax concession). These arguments are discussed in part D of this report.

However, the empirical evidence here and overseas suggests that the strength of spillovers may vary from industry to industry, and possibly also over time. The arguments for government support of R&D also suggest that on economic efficiency grounds, the level of support to R&D should vary with the value of spillovers being induced by that support.

Finally, this appendix attempts to quantify the likely economic efficiency losses arising from giving a uniform tax concession rather than one that varies with the extent of spillovers being generated. The available evidence on the strength of spillovers identifies industries that are receiving spillover benefits, but not those particular industries generating them. It is therefore difficult to devise with any accuracy a set of concession rates that vary with the strength of spillovers being generated. To the extent that guesses can be made based on evidence of which industries are receiving spillover benefits, the results suggest that the potential economic efficiency losses from not fine tuning the tax concession are likely to be relatively small compared with the benefits already provided by the current uniform scheme.

QC.1 An economy-wide model of R&D

The economy-wide effects of the tax concession are examined using a computable general equilibrium model based on ORANI (Dixon *et al.* 1982; McDougall and Skene 1992), but capturing salient features of R&D as outlined in Grossman and Helpman (1991).

Firms in each industry use material inputs and primary factors to produce goods and services. As in ORANI, these inputs are combined according to a constant returns to scale technology. The various categories of demand for the goods and services are also the same as in ORANI. Demands are therefore sensitive to incomes or activity levels and to relative prices.

In those industries undertaking private R&D, additional material inputs and primary factors are also devoted to R&D. Thus the model recognises that R&D initiatives use real resources, so that the benefits of higher productivity accruing to the firm, or spilling over to other firms and industries, are not obtained as a free lunch. Any particular level of R&D activity can be achieved by combining the resources devoted to R&D according to a constant returns to scale technology.

The R&D activity of firms constitutes a fixed cost that needs to be born in addition to the cost of inputs used to produce goods and services. The cost of R&D is fixed in the sense that there is no reason for it to vary systematically with the quantity of goods and services being produced. The firm's *average* production plus R&D costs decline as output expands, because the fixed R&D component can be spread over a greater sales volume. The model therefore incorporates declining average (production plus R&D) costs and increasing returns to scale.[1]

Each firm would only incur the fixed costs of undertaking R&D if this gave it a competitive edge over its rivals, providing a degree of monopoly power in the market for its output. The firm could then exploit this monopoly power by pricing its output above marginal production costs, thereby having some mechanism for recovering its fixed R&D costs. The extent of monopoly power depends on the nature of the innovative process.

Grossman and Helpman (1991) outline two types of innovative process, both of which bestow monopoly power best exploited by charging a price that is a fixed multiple of marginal production costs.

In the first process consumers value variety, and firms use R&D to develop new varieties differentiated from those of their rivals. The monopoly power of a single firm comes from the differentiated nature of its product, and the price/cost multiple that maximises the firm's profit depends on consumers'

1 There is no reason for the fixed cost of R&D to be immutably fixed on a per firm basis — each firm has the option of choosing the level of R&D activity it undertakes in conjunction with its productive activity. Thus the current treatment of fixed costs and increasing returns to scale differs slightly from Harris (1984) and Horridge (1987), for example, who assume fixed costs to be fixed on a per firm basis.

elasticity of substitution between varieties of the same product — the higher the elasticity, the lower the markup each firm can charge.

In the second process, each firm uses R&D to develop a higher quality product that completely, though temporarily, supplants rival products in the market place. The monopoly power of the single successful firm comes from the higher quality of its product, and the price/cost multiple that maximises the firm's profit is greater, the better its product is relative to those of its rivals. Rivals nevertheless remain in the industry undertaking R&D so as to have a chance of inventing the next state-of-the-art product.

Either approach suggests firms will charge a price that is a fixed multiple of marginal production costs, fixed in the sense that it does not vary with sales volume nor with the scale of R&D. For firms undertaking private R&D, the model incorporates this assumption.

The fixed-multiple pricing rule, and the monopoly power lying behind it, explains why firms may be willing to incur the fixed costs of R&D in the first place, but does not explain how much R&D each firm would undertake. In the long run, the fixed cost of R&D must be *fully* recovered through the selling price of the output the firm produces, otherwise firms would eventually go bankrupt. In the longer term, free entry and exit will ensure that the sales revenue of each firm just covers production and R&D costs (including a normal return to the capital used in production and R&D), with no firm earning an excess return above this level. Given the output pricing rule, the scale of R&D can be adjusted to ensure this comes about.[2]

The above framework offers an insight into why R&D expenditures appear to be a relatively small proportion of total costs in most industries, both here and overseas, despite empirical evidence that R&D can be highly productive from both a private and social perspective. Within that framework, recovery of R&D costs relies on exploiting monopoly power in the market for goods and services, so if the degree of monopoly power is limited, so too will be the scale of R&D activity. The relatively small scale of private R&D, averaging about 2 per cent of the domestic product of industry in the OECD countries, is consistent with consumers having a relatively high elasticity of substitution between different

2 In the oligopoly framework of Harris (1984) or Horridge (1987), fixed costs per firm are given and their models determine the equilibrium number of firms in the industry. In the monopolistic competition framework of Grossman and Helpman (1991), a large number of firms may operate in an industry (although in the product quality version only one firm sells its state-of-the-art product at any one point in time), and the model determines the average level of R&D per firm.

varieties of the same product, and/or with new state-of-the-art products being only a little higher in quality than the rival products they replace.[3]

Finally, the model used in this appendix spells out the way in which R&D expenditures are productive. It incorporates the same relationships between the productivity of an industry and the stocks of knowledge accumulated in that and other industries as were used for estimation purposes in appendix QB. The data issues in that appendix that lead to a distinction between multi-factor and total factor productivity are ignored — R&D is modelled as affecting total factor productivity. The formulation parallels Grossman and Helpman, but goes further by allowing for inter-industry as well as intra-industry spillovers.[4] The model also incorporates the necessary accumulation relations showing how current R&D activity adds to future knowledge stocks, using techniques outlined in McDougall (1993).[5]

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3 The model used in this appendix retains ORANI's assumption that domestic goods are also differentiated from imported goods. The model can be thought of as implicitly incorporating a double-nested choice framework, with users first choosing domestic varieties (or the current domestic state-of-the-art), then choosing between domestic goods and imports. As noted, the small share of R&D expenditures in total costs suggests the elasticity of substitution between domestic varieties is large, much larger than the econometrically-based elasticities of substitution used in ORANI for the next choice between domestic goods and imports. An alternative, and possibly more realistic formulation would allow choice between all domestic and imported varieties in a single nest.

4 Grossman and Helpman show that under either of their conceptions of the innovative process, the productivity (measured in the conventional sense) of the goods and services in which R&D is incorporated improves as the stock of knowledge (the cumulative outcome of current and past R&D activity) grows. Intra-industry spillovers are incorporated in their framework because the productivity of the good produced by any individual firm depends on the stock of knowledge accumulated via the R&D done by all firms in the industry.

5 The model's knowledge accumulation relations are based on the same perpetual inventory equations used to derive data on knowledge stocks (shown in appendix QA), along with the assumption that the rate of growth of real R&D expenditures is constant over the simulation horizon (with policy changes affecting this constant rate of growth). Under these assumptions, it can be shown that at the end of a solution horizon of length T, the percentage deviation from control in knowledge stocks in an industry will be proportional to the percentage deviation from control in final-year real R&D expenditures, with the constant of proportionality being equal to $[(g+d)T - 1]/[(g+d)T]$, where g is the rate of growth of real R&D expenditures in an industry and d the rate of knowledge obsolescence. Values for g are calculated from ABS data on R&D expenditures by industry, d is set to 0.1 (equivalent to a depreciation rate of 10 per cent) and the solution horizon, T, used is 10 years.

Data requirements

The model has the same data requirements as ORANI, but also requires data on the cost structures of private R&D. The required database was therefore constructed by starting with an 18-sector version of the standard ORANI database for 1986-87 (Kenderes and Strzelecki 1991), then for each of those industries known to carry out private R&D, subtracting out the 1986–87 labour, capital and other gross costs associated with that R&D (obtained from ABS 1988a), along with estimates of assistance to R&D taken from appendix QD, to form the required vector of R&D fixed costs born by firms.[6]

The 18-sector aggregation corresponded closely to the level at which the R&D data were available, although in a few instances sectors were retained separately despite a lack of corresponding R&D data because of the importance of those sectors in the economy. Thus the model distinguishes separately a transport and insurance service industry, important for transporting other goods and services around the country (see table QC1), and imputes its corresponding R&D expenditure from that available for a much larger 'other' service industry on a pro rata basis. The model also identifies separately a public research industry, which differs from private research activities by being treated as a separate industry with its own output (public research), which it explicitly sells to government. Data on the cost structure of this public research industry were obtained from ABS (1987, 1988b).

The model also requires econometric estimates of the elasticities of total factor productivity in each industry with respect to the private knowledge stock in that industry, the total of private knowledge stocks in all other industries, the stock of knowledge generated by public R&D and the stock of foreign knowledge. The econometric estimates are discussed in detail in appendix QB, but those incorporated into the model are reproduced for convenience in table QC1. For most industries, the elasticities used in the model are exactly those that were estimated to be significant. For wholesale and retail trade, all model elasticities are set to zero because of doubts that the productivity data used in the econometric estimation adequately captured quality changes in this sector.

The econometric estimates were obtained for a broader sectoral classification than is incorporated in the model. Here it is assumed that each of the narrower

6 The ABS data used were based on intramural R&D by business enterprise, ie data measuring the gross cost of R&D carried out by business enterprises, whether or not it was on behalf of (and possibly formally paid for by) some other industry. Thus the data do not strictly correspond to the costs of R&D born by firms. Nevertheless, ABS data on the sources of funds for intramural R&D show that for the industry groupings in table QC1, between 86 and 99 per cent is internally funded within the manufacturing sector and between 82 and 85 per cent is internally funded in mining and services.

model industries has the same elasticities as the sector within which it resides. This creates two problems.

Table QC1: **Elasticities of total factor productivity with respect to knowledge stocks, by industry** (per cent)

Sector from which elasticities drawn (app. QB)	*Industry*	*Elasticity with respect to:* Own stock	External stock	Own/ external interaction	Public stock	Foreign stock
Agriculture	1. Agriculture[b]	0.000	0.044	0.000	0.109	0.066
Mining	2. Mining	0.000	0.109	0.003	0.094	0.000
Manufacturing	3. Food, beverages, tobacco	0.014	0.000	0.000	0.065	0.066
	4. Textiles, clothing, footwear	0.014	0.000	0.000	0.065	0.066
	5. Wood, paper products	0.014	0.000	0.000	0.065	0.066
	6. Chemicals, petroleum, coal	0.014	0.000	0.000	0.065	0.066
	7. Basic metals, minerals	0.014	0.000	0.000	0.065	0.066
	8. Fabricated metal products	0.014	0.000	0.000	0.065	0.066
	9. Transport equipment	0.014	0.000	0.000	0.065	0.066
	10. Other machinery, equipment	0.014	0.000	0.000	0.065	0.066
	11. Miscellaneous manufacturing	0.014	0.000	0.000	0.065	0.066
na[a]	12. Construction	0.000	0.000	0.000	0.000	0.000
Wholesale, retail	13. Wholesale, retail trade	0.000	0.000	0.000	0.000	0.000
Other services	14. Transport, insurance services	0.052	0.018	0.002	0.048	0.030
na[a]	15. Business services nec	0.000	0.000	0.000	0.000	0.000
Other services	16. All other services nec	0.052	0.018	0.002	0.048	0.030
na[a]	17. Public research[b]	0.000	0.000	0.000	0.000	0.000
na[a]	18. Ownership of dwellings[b]	0.000	0.000	0.000	0.000	0.000

a Sectoral estimate not available. Appendix QB examines the productivity performance of the other services sector, defined to include Electricity, water and gas, Transport and communications, and Recreational and personal services. It does not provide sectoral estimates for these industries.
b Industries not undertaking private R&D. The available data on private R&D for the ASIC category 63, Property and business services, a category corresponding to the input-output industries Business services nec (industry 15 above), and Ownership of dwellings (industry 18 above), was attributed solely to Business services nec.
Source: appendix QB.

The first is that while econometric evidence may suggest that the manufacturing sector as a whole receives no significant spillover benefits from R&D undertaken outside the manufacturing sector, it is less plausible that individual industries within manufacturing receive no significant spillover benefits from other industries, including other industries within manufacturing. However, there is no econometric evidence below the manufacturing sector level on which to base a more plausible set of estimates.

The second problem is that strictly speaking, even the non-zero elasticities relating to 'own' and 'external' knowledge stocks for the narrower model industries, although assumed to be uniform, should be corrected for the fact that what is 'external' to an individual industry is a larger scale of R&D activity than what was 'external' to the sector for which the elasticities were estimated. This point is relevant to the non-zero elasticities assumed for industries in the manufacturing and other services sectors. Although such a correction could have been made, it would have made little difference to the elasticities assumed for the 'own', 'external' and interaction terms because the raw non-zero elasticities with respect to 'external' stocks and the interaction term are relatively small for those sectors. For simplicity, therefore, simple 'parent values' are assumed throughout.

Note that in the model applications reported in the next section, only the elasticities in the first three columns are in effect relevant. The reason is that in those applications, neither the scale of public nor foreign R&D varies. The scale of public R&D is determined in the model by the amount that government spends on it, and that is held constant by assumption in these experiments. Similarly, the scale of foreign R&D does not vary because foreign R&D is treated as an exogenous variable, beyond the control of private or government action in Australia. Thus the elasticities in the last two columns apply to variables that do not change in model simulations.

Nature of model projections

The last point highlights that the model, like ORANI, is comparative static. This has implications for the way the model results should be interpreted. The model does not trace out the growth path of the economy over time as physical capital and knowledge stocks accumulate at current rates. Instead it examines the impact that policy changes would have on the rates of accumulation of physical capital, knowledge stocks and other variables, and gives results for the percentage difference this would make in the *levels* of economic variables after a certain length of time, chosen in this appendix to be a period of 10 years. Thus a model result of *x* per cent for real GDP means that real GDP is projected, 10 years hence, to be *x* per cent higher than it otherwise would have been, as a result of the policy change in question.

In the model applications that follow, certain assumptions are made about the extent to which resources can adjust in the economy in response to policy changes. The first main assumption is that capital in each productive or R&D activity accumulates or decumulates so as to eliminate abnormal returns after 10 years — capital used in all activities adjusts fully so that it earns the going, globally determined real rate of return.

Real wages in each occupation are assumed to adjust so as to maintain constant occupational employment rates. The ABS data show that R&D activity tends to be more intensive in the use of professional and paraprofessional occupations (scientists and technicians, respectively) than productive activity. This feature is reproduced in the model's database. Policy action that encourages R&D can be expected to put upward pressure on wages in these occupations, with consequent spillover effects on productive activity. This result is highlighted by Grossman and Helpman. However, in the current model the pressure is somewhat alleviated by a limited amount of occupation-switching on the supply side in response to relative occupational wage changes (Dee 1989).

Finally, unless otherwise stated, personal and corporate income tax rates are assumed to vary so as to hold constant the real public sector borrowing requirement. Thus changes in assistance to R&D are assumed to be fully funded, although the method of funding will have its own corresponding efficiency implications (see also BIE 1993c).

QC.2 The impact of eliminating the 150 per cent tax concession

As noted in the introduction, assistance is afforded to R&D by being able to deduct eligible R&D expenditures from taxable income at a rate of 150 per cent rather than 100 per cent. In 1990–91, total tax expenditures on the concession were $290 million, or 12.7 per cent of the gross cost of private R&D undertaken in that year (appendix QD).

The impact of removing the tax concession could potentially be modelled by reducing the assistance afforded private R&D activity by $290 million in 1990–91 dollars. This would assume that the elimination of every dollar of tax expenditures could potentially affect the level of private R&D activity. However, the BIE (1993c) has estimated that between 83 and 90 per cent of eligible R&D would have taken place without the concession. It is therefore assumed in this appendix that only 15 per cent of the eliminated tax expenditures could potentially affect the level of private R&D activity.

Eliminating the tax concession is therefore modelled by reducing the assistance afforded private R&D activity by $43.5 million, or 15 per cent of current tax expenditures, while reducing net subsidies on current production (or increasing net taxes on current production) by the remaining $246.5 million. This treatment recognises that every dollar of the current tax concession improves cash flow, even if it does not induce additional R&D.[7]

The modelled reductions in tax expenditures have been spread across individual industries in proportion to the gross cost of the R&D they currently undertake. DIST provides alternative, direct estimates of the distribution of current tax expenditures by industry. Because these direct estimates seem to imply anomalous rates of current assistance (see also appendix QD), they have not been used to apportion the direct impact of eliminating the tax concession.

The projected industry impacts of eliminating the tax concession are shown in table QC2. The results are reported to two decimal places. This conveys a very false sense of precision, but it is sometimes necessary to distinguish between the effects of different simulations, or the effects on different economic agents. For practical purposes, the results should be rounded. The results differ from those in the draft report because a 15 per cent inducement rate has been assumed here, as opposed to the 10 per cent rate assumed in the draft report.

When assistance affecting private R&D is reduced, firms have to bear a greater proportion of the total costs of R&D activity themselves. Since their ability to price their output over marginal production costs (net of production subsidies) is unaffected, because this depends on consumer tastes, firms react by cutting back the scale of their private R&D activity. This effect is shown in the third column of table QC2.

With the lower level of R&D activity being sustained over time, knowledge stocks are accumulated in industries at a slower rate than otherwise. The impact on the level of own knowledge stocks after a ten-year period is shown in the fourth column of table QC2. Since all industries are projected to cut back on private R&D activity, external knowledge stocks are also lower than otherwise after a ten-year period. This is shown in the fifth column of table QC2.

The level of total factor productivity in most industries depends on the stocks of internal and external knowledge at any point in time, with the impacts being governed by the elasticities shown in table QC1. If internal and external knowledge stocks are lower than otherwise after a ten-year period, so too will be the level of total factor productivity in those industries. This effect is shown in the second column of table QC2.

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7 The current treatment also allows the remaining 85 per cent of tax concession expenditures to be retained within an industry and to affect current production decisions. An alternative assumption could have been that the remaining 85 per cent of tax concession expenditures were immediately paid out to shareholders. The latter assumption would have been more neutral, in that the remaining 85 per cent would have had income effects but no direct resource allocation effects. The current treatment is more conservative, in that it allows resource allocation effects to be taken into account in the event that they occur.

Table QC2: **Projected industry impacts of removing the tax concession** (percentage deviations from control)

	Productive activity		*Private research activity*		
	Output	*Total factor productivity*	*Current R&D activity*	*Own knowledge stock*	*External knowledge stock*
1. Agriculture	0.03	-0.04	na	na	-1.01
2. Mining	-0.66	-0.17	-2.91	-1.66	-0.99
3. Food, beverages, tobacco	..	-0.01	-2.34	-1.05	-1.01
4. Textiles, clothing, footwear	..	-0.01	-2.36	-0.98	-1.01
5. Wood, paper products	-0.06	-0.02	-2.40	-1.26	-1.01
6. Chemical, petroleum products	-0.10	-0.01	-2.40	-0.91	-1.03
7. Basic metals, minerals	-0.23	-0.01	-2.50	-0.94	-1.02
8. Fabricated metal products	-0.10	-0.01	-2.63	-0.99	-1.01
9. Transport equipment	-0.32	-0.02	-2.53	-1.21	-0.99
10. Other machinery, equipment	-0.23	-0.02	-2.38	-1.20	-0.97
11. Miscellaneous manufacturing	-0.09	-0.02	-2.26	-1.13	-1.01
12. Construction	-0.07	0.00	-2.47	-0.57	-1.02
13. Wholesale, retail trade	-0.06	0.00	-2.47	-1.40	-0.99
14. Transport, insurance services	-0.10	-0.07	-2.46	-0.57	-1.04
15. Business services nec	-0.09	0.00	-2.22	-1.30	-0.98
16. All other services nec	-0.04	-0.07	-2.41	-0.56	-1.11
17. Public research	0.00	0.00	na	na	-1.01
18. Ownership of dwellings	-0.02	0.00	na	na	-1.01

.. Between +0.005 and -0.005.
na not applicable.
Source: Model projections.

With total factor productivity being lower in most industries, all other things being equal, demand would fall and output contract (strictly speaking, both would be lower than otherwise). With industries also losing that component of the tax concession that affects current production costs without inducing further R&D, there would be a further impetus for demand to fall and output to contract. The output projections for each industry are shown in the first column of table QC2.

Output in mining is projected to be the most adversely affected because of its relatively large decline in total factor productivity. This comes about because of its relatively high dependence on the knowledge stocks accumulated in other industries, and because of the complementarity between its own R&D and that of other industries.[8]

Output is also projected to decline throughout the manufacturing and services sectors, with the exception of public research. Government spending on public research is assumed to be held constant in real terms.

Finally, output is projected to expand slightly in agriculture. The competitiveness of agriculture is cushioned somewhat, particularly by the induced decline in wages, and agriculture is projected to gain more from this source than it loses from its own small decline in total factor productivity.

The macroeconomic impact of reducing the R&D tax concession to 100 per cent is shown in table QC3. The decline in overall activity is projected to reduce real GDP by 0.08 per cent below what it would otherwise have been after a ten-year period, equivalent to $360 million a year in current dollar terms or $320 million a year in 1990–91 dollar terms. This contraction is slightly more that the initial $290 million reduction in tax expenditures (in 1990–91 dollars) on the R&D tax concession. The contraction in real GDP takes into account the offsetting benefits to economic efficiency of not having to fund the R&D tax concession. Without this offsetting benefit, the cost to the economy of eliminating the tax concession would have been greater.

Table QC3: **Projected macroeconomic effects of eliminating the tax concession** (percentage deviations from control)

Real GDP	-0.08	Real GNP	-0.07
Real household consumption	-0.03		
Real investment	-0.12	Capital stock	-0.10
Real government spending	0.00	Real pre-tax wage	-0.14
Export volume	-0.31	Real post-tax wage	-0.02
Import volume	-0.05	GDP deflator	-0.01

Source: Model projections.

Real GNP, a better measure of welfare than real GDP, is projected to be 0.07 per cent lower than otherwise after a ten-year period. The reduction in real GNP is projected to be slightly lower than the reduction in real GDP because with a capital stock lower than otherwise, foreign investment is lower than

8 Recall, however, that the R&D related to mining exploration and done by the ‘services to mining’ industry is counted as external to the mining industry in this industry classification (see also appendix QB).

otherwise and Australians incur less debt service payments to foreigners.[9] However, the difference between the real GDP and real GNP results is smaller than in some other contexts (eg IC 1991a). This is because the change in overall activity projected here is accompanied by a smaller change in capital than in some other contexts. While the capital used in current production is projected to be smaller than otherwise following elimination of the tax concession, the largest proportional reductions in capital are projected to occur in research activity, and research tends to be less capital intensive than current production.

The results suggest that while some of the R&D tax concession may currently benefit foreigners, this should not be a major concern if foreigners in return are willing to fund Australian-based R&D that would not have been undertaken otherwise. The model implicitly assumes that the current tax concession is equally effective at inducing additional foreign-funded R&D in any industry as it is at inducing domestically-funded R&D. With this assumption, the results suggest that at current inducement rates, the tax concession yields a small net gain to the economy. However, if the R&D tax concession is even less effective at inducing new foreign-funded R&D than it is at inducing new domestically-funded R&D, or if it simply shifts the location in which the foreign-funded R&D is undertaken (since Australian industry would also benefit to some extent from R&D undertaken overseas), the welfare cost of funding the concession could dominate the benefits from the additional R&D.

If the tax concession were more effective than currently at inducing additional R&D, the net cost to the economy of eliminating the concession would be greater, but less than proportionately so.[10] In an alternative simulation, the R&D tax concession was eliminated on the assumption that 40 rather than 15 per cent of it could potentially affect the level of private R&D activity. A 40 per cent inducement rate would be a major improvement on current performance, although it is less than the estimated upper limits achieved by the Discretionary Grants Scheme (55 per cent), the Generic Technology Grants Scheme (67 per cent) or the National Procurement Development Program (46 per cent) (see part D). However, it is in line with what has been achieved by the National Teaching Company Scheme (25 to 55 per cent).

With a 40 per cent inducement rate, eliminating the tax concession is projected to reduce real GDP by 0.16 per cent, or around $700 million in current dollar terms, and real GNP by 0.14 per cent. Thus an increase in the inducement rate by a factor of 2.7 (=40/15) is projected to increase the cost of eliminating the tax

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9 For example, the largest contraction in capital used for current production is projected to occur in mining, where foreign ownership is initially relatively high.

10 All model results reported in this appendix are corrected for linearisation error (ie by the use of linear approximations to the underlying non-linear behavioural relations).

concession by a factor of only 1.9. The contraction in R&D activity is projected to be greater than with a 15 per cent inducement rate, as are the corresponding reductions in total factor productivity. However, more resources are released from R&D activity that can be used to help maintain production levels. In other respects, the results are similar to those in tables QC2 and QC3.

The results suggest that there might be significant gains from better targeting the tax concession to R&D that would not have been undertaken otherwise. The projected benefits from improved targeting are likely to be somewhat overstated, however, since they assume that R&D induced by a tax concession is just as productive as R&D that would have been undertaken anyway.

The projected impacts of eliminating the tax concession are also sensitive to the estimates of the extent of intra-industry spillovers (if present at all, then implicit in the 'own' knowledge stock elasticities of table QC1) and the extent of inter-industry spillovers (explicit in the 'external' knowledge stock elasticities of table QC1). To test this sensitivity, the impact of eliminating the tax concession (assuming a 15 per cent inducement rate) was examined, firstly with the external and interaction knowledge stock elasticities set to zero, then with the internal, external and interaction elasticities set to zero.[11] In both cases, eliminating the tax concession was projected to yield a smaller economic loss — with reductions in real GDP of 0.03 and 0.01 per cent, respectively (reductions in real GNP also of 0.03 and 0.01 per cent).[12]

QC.3 The impact of company tax rate reductions in eroding the value of the tax concession

A number of participants have argued that the tax concession should be raised above 150 per cent to offset the reductions in company tax rates that have occurred, from 46 per cent at the inception of the scheme to 36 per cent in 1995–96. As argued in part D, the increase in concession that would preserve the subsidy per pre-tax dollar cost of R&D in the face of this tax reduction is an increase from 150 to 164 per cent. In the absence of such an increase, the

[11] As discussed in appendix QB, a positive interaction elasticity has the effect of increasing the effective or total elasticities with respect to both own and external knowledge stocks above the direct elasticities reported in table QC1.

[12] When an inducement rate of 100 per cent rather than 15 per cent was assumed, eliminating the tax concession with all elasticities set to zero is projected to yield an economic gain of 0.11 per cent in real GDP. Under these circumstances, all of the tax concession merely subsidises an unproductive fixed cost associated with production activity, and the efficiency cost imposed by having to raise income tax rates to fund the subsidy dominates.

subsidy per dollar of eligible R&D expenditure will have been eroded from 23 cents in the dollar to 18 cents.

However, the reduction in company tax rates is likely to have had its own independent effect on R&D. It would have improved the capacity of companies to carry out all types of activity, including R&D. An increase in the concession rate from 150 to 164 per cent could therefore overcompensate companies for the effect of the fall in the company tax rate.

To evaluate these arguments, the economy-wide model of R&D has been used to examine the impact on both overall activity, and R&D intensity, of a reduction in the company tax rate, with its consequent erosion in the subsidy equivalent value of the 150 per cent tax concession. It has therefore been used to examine the impact of

- a 22 per cent reduction in the company tax rate (equivalent to the reduction from 46 to 36 per cent); and
- a 22 per cent reduction in the subsidy per pre-tax dollar cost of R&D (equivalent to the reduction from 23 to 18 cents in the dollar).

Because the model includes an explanation of how firms choose their level of R&D in an economy-wide framework, it can capture the independent impact that a reduction in the company tax rate would have on the level of R&D activity. The reduction in the company tax rate and the associated reduction in the value of the tax concession are examined under the assumption that only 15 per cent of the tax concession has a potential impact in inducing R&D that would not have taken place otherwise. However, the projected impacts are likely to be overstated because the role of dividend imputation in diluting the value of the tax concession has been ignored.

In the absence of other adjustments to the government budget, these changes would increase the public sector borrowing requirement because revenue from income taxes exceeds tax expenditures on the R&D tax concession. In reality, these budgetary changes have been accompanied by a number of other measures to prevent a budget blow-out. The current exercise is designed to examine the impact of just these two changes, in order to isolate the arguments put forward by participants. Therefore, the real public sector borrowing requirement has been allowed to increase, with no offsetting changes to other tax rates or to government spending.[13]

[13] In particular, there is no offsetting reduction in government spending on public research that would release additional research resources to the private sector.

Table QC4: **Projected macroeconomic effects of company tax rate reduction** (percentage deviations from control)

Real GDP	1.19	Real GNP	0.31
Real household consumption	0.92		
Real investment	3.71	Capital stock	3.42
Real government spending	0.00	Real pre-tax wage	1.01
Export volume	0.78	Real post-tax wage[a]	0.86
Import volume	2.02	GDP deflator	0.19

a Differs from real pre-tax wage because of PAYE tax progressivity and compositional effects.
Source: Model projections.

Table QC5: **Projected industry impacts of company tax rate reduction** (percentage deviations from control)

	Productive activity		*Private research activity*		
	Output	*Total factor productivity*	*Current R&D activity*	*Own knowledge stock*	*External knowledge stock*
1. Agriculture	-0.90	0.01	na	na	0.22
2. Mining	3.66	0.05	2.07	1.17	0.19
3. Food, beverages, tobacco	-0.30	-0.01	-1.22	-0.54	0.26
4. Textiles, clothing, footwear	0.31	..	-0.44	-0.18	0.23
5. Wood, paper products	1.28	..	0.26	0.14	0.22
6. Chemical, petroleum products	1.00	..	-0.20	-0.08	0.26
7. Basic metals, minerals	1.82	..	0.70	0.26	0.22
8. Fabricated metal products	2.36	..	0.95	0.36	0.22
9. Transport equipment	1.16	..	0.61	0.29	0.22
10. Other machinery, equipment	2.62	0.01	1.81	0.90	0.07
11. Miscellaneous manufacturing	1.14	..	0.07	0.04	0.23
12. Construction	2.82	0.00	2.43	0.56	0.22
13. Wholesale, retail trade	1.03	0.00	0.34	0.19	0.23
14. Transport, insurance services	1.02	0.01	0.33	0.08	0.23
15. Business services nec	1.31	0.00	-0.11	-0.06	0.26
16. All other services nec	0.73	..	-0.34	-0.08	0.29
17. Public research	0.00	0.00	na	na	0.22
18. Ownership of dwellings	1.57	0.00	na	na	0.22

.. Between +0.005 and -0.005.
na Not applicable
Source: Model projections.

The combined changes are projected to be beneficial to the economy, with real GDP projected to be 1.19 per cent higher than otherwise (real GNP 0.31 per cent higher) after 10 years (table QC4). In many industries, both productive output and R&D activity are also projected to increase (table QC5).

In most industries the output projections are explained primarily by the fall in the company tax rate, rather than by the induced change in R&D activity. The fall in the company tax rate reduces the cost to industries of non-labour inputs, encouraging them to employ more capital. As industries expand, the additional demand for labour, combined with the capital, puts upward pressure on wages. The industries projected to expand most fall into two categories. They are either the capital-intensive industries such as mining, basic metals and fabricated metal products, for which the reduction in the user cost of capital greatly outweighs the impact of the induced increase in wages. Alternatively, they are industries that are important suppliers of capital goods, such as the machinery and construction industries, that benefit from the increased demand for their product. For a few industries, notably agriculture and food processing, the induced increase in wages is projected to more than offset the policy-induced fall in the user cost of capital, and these industries are projected to contract.

For many industries, private R&D activity moves in line with current production, with small induced changes in total factor productivity. In all cases, however, R&D intensity is reduced, since private R&D activity either rises by less than current production, or falls by more. Private R&D activity is adversely affected in a relative sense by the induced reduction in the subsidy-equivalent of the tax concession. As a relatively labour-intensive activity, private R&D is also adversely affected by the induced increase in real wages. Overall, aggregate private R&D activity is projected to rise by 0.50 per cent, compared with a projected increase in output (current production plus R&D) of 1.17 per cent for the economy as a whole.[14]

[14] The model's aggregate output result differs from its real GDP result because, in contrast to appendix QB, the model's output concept is a gross concept, including goods and services produced for intermediate use by other industries. Although each industry in the model is assumed to maintain a constant ratio of each intermediate input to gross output, individual industries are assumed to be able to change the amount of each intermediate input they buy domestically, in response to changes in the relative prices of domestic and imported intermediate goods. Different industries also have different intermediate input intensities initially, so that changes in the relative sizes of industries can change the aggregate intermediate input intensity of the economy as a whole. For both these reasons, the model's aggregate output result differs slightly from its result for real GDP.

QC.4 The impact of redistributing the tax concession towards industries with the greatest private R&D spillovers

The currently relatively uniform assistance provided by the R&D tax concession is projected to yield a small economic benefit when R&D has the intra- and inter-industry spillover effects outlined in table QC1. But economic theory suggests that in the presence of spillovers, the optimal assistance to private R&D should vary in some way with the strength of the spillover effects.

The first difficulty in modelling such an optimal regime is that the theoretical literature gives little guidance as to what it would look like in the presence of both intra- and inter-industry spillovers of possibly differing magnitudes. Even with only intra-industry spillovers, Grossman and Helpman (1991) show that if a subsidy is warranted, the subsidy should indeed increase with the strength of the spillovers, but not in a simple linear or proportional fashion.[15] In the current context, it is not clear how to weight the intra-industry spillovers implicit in the 'own' knowledge stock elasticities together with the inter-industry spillovers indicated by the 'external' knowledge stock elasticities.

The second difficulty in modelling such an optimal regime is that table QC1 shows explicitly which industries are receiving inter-industry spillovers, but not which individual industries are generating them. However, some assumptions can be made as to the source of both intra- and inter-industry spillovers, based on the pattern of 'own' and 'external' effects shown in table QC1.

Table QC1 suggests that the manufacturing and other services sectors are the only sectors to benefit in a direct way from 'own' R&D, although the mining sector also gains indirectly through the complementarity between its own and external R&D. In addition, the manufacturing sector does not benefit from external R&D, although most other sectors do (wholesale and retail trade is the exception). If one is happy to accept the argument that private R&D is unlikely to yield positive inter-industry spillovers to other industries if it does not yield a positive 'own' return (incorporating intra-industry spillovers), the pattern of elasticities suggests that the source of both intra- and inter-industry spillovers may be within the manufacturing and other services sectors.

In the first redistribution, the entire $290 million in tax expenditures in 1990–91 dollars is given to industries in the manufacturing and other services sectors in proportion to their scale of R&D activity. It is assumed that both before and

[15] They do show, however, that the optimal subsidy setting is the same, irrespective of whether the government also corrects the market distortion created by some firms pricing their output above marginal production costs.

after the redistribution, only 15 per cent of the tax expenditures would induce additional R&D that would not have been undertaken otherwise.

This redistribution is in fact projected to lower real GDP and real GNP slightly, with both being 0.001 per cent a year lower than otherwise after ten-years. The redistribution regime does not recognise the indirect productivity of 'own' R&D in the mining sector, and the loss of mining productivity from this source is not offset by the increased productivity accruing from higher levels of external R&D. The projected contraction in mining output in this scenario contributes to the slight decline in overall activity.

The second redistribution recognises that even within the manufacturing and other services sectors, the productivity of R&D is not uniform. In this scenario, the entire $290 million in tax expenditures in 1990–91 dollars is given to industries in the manufacturing and other services sectors, not just in proportion to their scale of R&D activity, but also with a simple proportional correction for the relative sizes of their 'own' knowledge stock elasticities (0.014 for industries in manufacturing, 0.052 for industries in other services). As before, it is assumed that only 15 per cent of the tax expenditures before or after redistribution would induce additional R&D that would not have been undertaken otherwise.

This redistribution is projected to increase real GDP and real GNP slightly, both by 0.02 per cent a year after ten-years. Although mining productivity is still adversely affected by the induced contraction in mining R&D, mining competitiveness is somewhat better insulated because the productivity improvements in the services sector, and the cost reductions they generate, are projected to be greater than under the simple pro rata redistribution.

These results highlight the difficulty of fine-tuning R&D assistance so as to provide greater benefits to industries generating higher private R&D spillovers, given the current lack of information about which industries are generating the spillovers as opposed to which industries are receiving them. To the extent that guesses can be made, the results suggest that the potential gains from fine tuning the tax concession would be small compared with the benefits provided by the current uniform scheme.

APPENDIX QD: ASSISTANCE TO PRIVATE R&D AND BENEFITNG INDUSTRY

QD.1 Introduction

In this appendix, information about the many sources, forms and industry distributions of government support for R&D is arranged in an economic framework in order to provide an estimate of the costs of that support. A model of nominal and effective rates of industry assistance has been used to do this. By definition, industry assistance is provided by any government intervention that selectively alters incentives to engage in production activities. However, the model in itself does not provide judgements about the desirability (or undesirability) of the provision of government support nor the appropriate level of support.

In particular cases, assistance might be provided to compensate for difficulties individual activities face as a result of the nature of production process problems, instability of markets and prices, or inability of individual firms to appropriate the full benefits of expenditures incurred. In the case of R&D, it is argued that individual firms cannot always appropriate the full benefits of expenditures incurred. Without government support there would be an under provision of R&D services.[1]

The industry focus adopted throughout this presentation has required the reclassification of much of the source data used in the study. Government budget information which gives emphasis to departmental program responsibilities and official statistical series which emphasise socio-economic objectives and fields of research have been reclassified to an industry basis.

The industries likely to benefit from public R&D and the level of benefit afforded each industry are determined by a detailed examination of government funding of R&D programs. The analysis of benefiting industries by portfolio administering the funding, is reported in detail in an information paper titled '*Government support to R&D by benefiting industry*' (IC 1995b). Information about the level of R&D activity and industry production is drawn from ABS R&D statistics, Australian National Accounts input–output tables and national

1 Positive assistance is not always found to be justified on economic or social grounds. For example, the Commission has recommended the lowering of tariff assistance on the grounds that the economic returns to assisted activities are outweighed by the costs of protection to other members of the community.

income and expenditure accounts. These broad indicators of the level of industry activity are used in conjunction with estimates of the level of R&D support to estimate assistance to industry.

The reference year for this study is 1990–91. This was the most recent year for which comprehensive information about R&D assistance programs and survey information was generally available when the analysis was actually undertaken.[2] In the study, industries are also grouped into the market sector and other sectors. This distinction has been adopted so the results may be examined in conjunction with the results of other studies of productivity which also adopt that industrial sectoring. (See appendix QB, where the market sector is also defined).

This appendix is set out as follows. Section 2 discusses the concept of effective assistance and its application in this study. Section 3 provides an overview of R&D expenditure by benefiting industry. Section 4 identifies the full scope of business R&D and government schemes that support business R&D. Nominal and effective rates of assistance to business R&D are provided. Section 5 looks at government expenditure programs that support industry through the public provision of R&D. Nominal and effective rates of assistance to industry are provided by benefiting industry. To place the R&D estimates into the context of the Commission’s other analyses of industry policy using the nominal and effective rates framework, assistance provided by other measures is also reported.

QD.2 The concept of assistance

General framework

The model for nominal and effective rates is applied by the Commission to meet its annual reporting and industry inquiry obligations. Broadly, the Commission is required to report on '...assistance and regulations affecting industry ... and the effect of such assistance, regulations and matters on industry and the Australian economy generally'.[3] To meet the first part of this requirement, it is desirable that assistance for individual industries be measured on a common basis so that assistance levels may be compared across industries. The Commission’s nominal and effective rates model enables such comparisons.

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[2] With the completion of the ABS publication program for 1992–93, information to update the results from 1990–91 to 1992–93 has now become available.

[3] IC Act 1989, section 45(2)(b).

The nominal and effective rates model looks at the effects of government regulation and interventions on individual industries from the point of view of price differences between some benchmark price and prevailing industry levels. It also takes into account the effects of any direct grants or subsidies to industry. In this sense, the model looks at the changes in incentives (or initial effects) of industry programs before they are translated into the production and consumption decisions of industries and consumers. (In economic terminology the model can be regarded as coming within a partial equilibrium framework.)

The importance of prices

The changes in incentives work through changes in costs and prices faced by business. Government interventions that change costs and prices can work through:

- assistance to outputs (usually positive), which relates to government measures that increase the producers' returns from the supply of goods and services;
- assistance to inputs (usually negative), which relates to measures that raise the cost of intermediate inputs of goods and services to production; and
- assistance to value adding factors, which relates to measures that increase the entrepreneurial income available to enterprises from the employment of labour, capital, intangible assets and natural resources.

Funding of business R&D by government (eg through a taxation concession, or grant) would lower the producers' price of that R&D and make domestic R&D output more attractive to industrial users of those services. R&D serves to raise the level of accumulated knowledge within the community. Accumulated knowledge enters the economic system as a value adding factor of production. Government R&D and assistance to business R&D would also lower the cost of R&D to users of R&D knowledge and increase the returns to value adding factors employed in industry. Assistance would thereby be provided to value adding factors of industry.

Model assumptions

The concept of effective assistance is applied using a static, partial equilibrium framework. The focus of attention is on the initial impact of interventions on costs and prices. While the effective rate measures indicate the income transfers associated with interventions, they do not indicate changes in supply and demand and more general effects arising from those measures. The major assumptions that are adopted in effective rate calculations are:

- the small country assumption whereby Australia does not affect the world price of either its imports or exports;
- perfect substitution between domestic and foreign goods and services for import competing supplies and export oriented goods and services. This assumption allows domestic production of traded goods to be assessed against a world reference price;
- the direction of trade can be assessed so that import parity prices form the benchmark for import competing goods and services, export parity prices for exports, and domestic prices, without assistance, for non-traded goods and services;
- production relationships (that is between intermediate inputs and primary inputs) are unchanged by the structure of assistance, that is, there is no substitution between nominally different goods. This assumption allows the income transfer effects of assistance to be considered in advance of production and consumption changes that government interventions might induce; and
- there are no price or quantity distortions other than those included in the analysis. This assumption enables the reporting of nominal and effective rates from an 'unassisted' base.

The direction of trade

The choice of the direction of trade of a good or service is not always straightforward, while the choice finally made has some important implications for the evaluation of government support to R&D.

For R&D performed in Australia to be a traded service, it would need to be easily substitutable with foreign R&D either in export markets or in the domestic market. With respect to export markets, there may be some exports of R&D services from Australia. However, these are most likely to be related to niche markets (eg universities selling patents coming out of graduate research programs) rather than a dominating force in Australian R&D. Therefore, at this stage, it would not be appropriate to treat Australian R&D as export oriented.

With respect to imports of R&D and intellectual property, Australia benefits from R&D undertaken in other countries. It also provides a small proportion of international R&D. For these reasons, arguments could favour the treatment of Australian R&D as an import competing service. Under this view, R&D is a generic activity that can be performed anywhere in the world and the knowledge transferred in world markets (including journals and learned reports). R&D knowledge would thereby be channelled to the most appropriate destination for use in the production and distribution of goods and services. According to this view, Australia would be a net importer of R&D services.

On the other hand, if there was little or no substitutability between import and domestic sources of R&D, the performance of R&D activity would afford a predominantly non-traded service. Arguments in favour of this treatment include:

- R&D activity undertaken in Australia is based on the need to maintain a local R&D capability for absorbing R&D from offshore. Under this view, foreign R&D would be complementary to domestic R&D; and
- business R&D in Australia is generally performed and inextricably mixed with the production and distribution of Australian goods and services. Such R&D could well have a fixed relationship to local production.

For the analysis of R&D, it has been assumed that Australian R&D is complementary with foreign R&D. The activity is therefore treated as a non-traded service in the assistance evaluation methodology. Consistent with the general treatment of non-traded goods and services, the price of R&D is determined by domestic costs of material, labour and capital inputs. R&D performers who purchase those inputs for the supply of R&D services would therefore be price takers.

Interpretation of results

The model abstracts from the complex intra-industry and inter-industry linkages in both supply and demand which take into account behavioural responses to the initial effects of nominal and effective rates. For this reason, care should be taken in interpreting the results.

The standard assistance evaluation data concepts used in this appendix are defined in annex 1. The derivation of the assistance measures relating to the performance of business R&D is set out in annex 2. The derivation of assistance to industry provided by government R&D support programs is provided in annex 3.

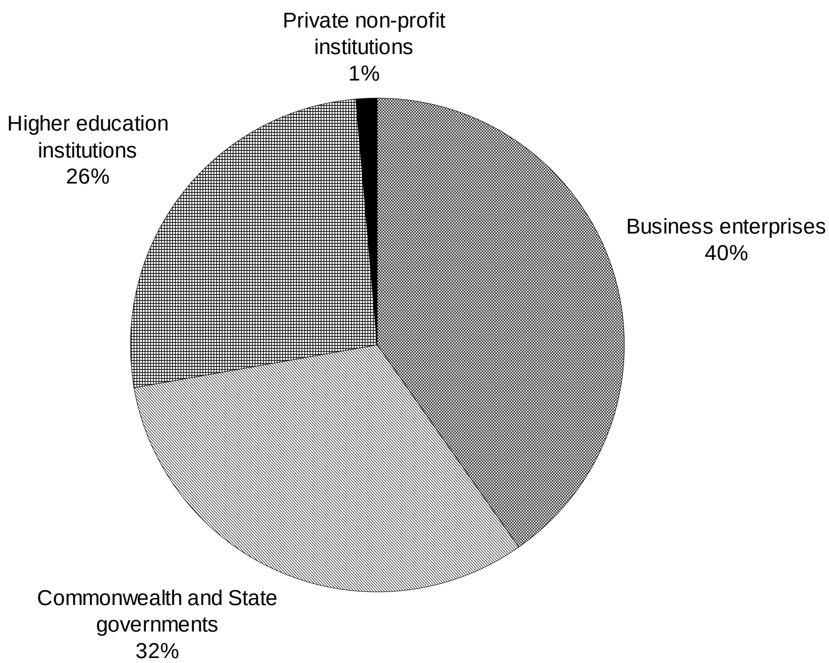
QD.3 Industries benefiting from R&D

The R&D supply and usage chain begins with the performance of R&D by institutions. These institutions may be grouped for convenience, according to whether they are business enterprises, government agencies, educational bodies or private non–profit organisations. Of these groups, business enterprises performed around 40 per cent of R&D in Australia in 1990–91 (figure QD1).

Commonwealth and State government agencies and higher education bodies are the other main performers of R&D (32 per cent and 26 per cent, respectively).

From 1990–91 to 1992–93, some fractional changes have occurred in the contributions of the groups to the national R&D effort. In particular, business R&D as a share of the total has risen from 40 to 44 per cent. The government contribution has declined from 32 to 28 per cent.

Figure QD1: **Performance of R&D by institutional group, 1990–91** (per cent)



Sources: ABS, Cat. Nos 8112.0; and 8104.0.

To be economically meaningful, the R&D performed by institutions needs to be of benefit to some industrial activity. For example, R&D may benefit the manufacture of goods, the provision of advice to government, the provision of health, education or other community services, or the provision of other services to businesses, households, government or export. In order to elaborate the distribution of R&D in a quantitative framework the concept of initial benefiting industry is adopted. This concept is discussed in detail in the information paper '*Government support to R&D by benefiting industry*' and summarised in box QD1.

Box QD1: **Concept of initial benefiting industry**

In making a link between R&D performance and support to a benefiting industry, it is important to nominate an appropriate point in the production and distribution chain for evaluating the point of industry impact of R&D.

A number of options are available:

- the *initial* point of impact. This is the point at which the effects of R&D first enter the production and distribution system;
- the *direct supplier* point of impact. This relates to suppliers of goods, services, labour and capital to the industrial sector designated as the initial point of impact. It looks upstream in the production and distribution chain; and
- the *direct beneficiary*. This relates to the sector of final use of the goods or services produced by the sector of initial impact. The concept looks downstream in the production and distribution chain.

The concepts of direct supplier and direct beneficiary could be extended to relate to the *ultimate supplier* (ie domestic value adding factors plus imports) and the *ultimate beneficiary* (ie final consumption plus exports). This would involve working through the production and distribution chain to find how R&D effects the economic system in its totality.

The initial point of impact of R&D is chosen as the focus of this study.

Source: Industry Commission 1995b.

Looking at R&D performed by business, table QD1 shows that manufacturing is the main beneficiary from R&D and, in particular, machinery and equipment manufacturing. While this R&D effort may enter the production and distribution chain through the machinery industry, other industries stand to benefit through product improvements embodied in manufactured machinery and equipment (product R&D) or through efficiencies achieved in the manufacture of machinery (process R&D). Because the machinery and equipment industry is a major supplier of capital equipment to other industries, product improvements in that industry can have strong downstream benefits on industries purchasing that equipment. There are also concentrations of R&D benefits in manufacturing in the chemical, coal and petroleum, and transport equipment industries. Each of these industries are intermediate and capital good suppliers for which product improvements would have strong downstream effects.

Other than manufacturing, the main focus of business R&D is in the mining industry (including mining and mineral exploration). As this industry produces standard commodity products, it is likely that the main focus of this R&D is on mining and exploration processes which flow into the economy through increases in the availability of minerals, oil and gas from domestic sources. The remainder of the business R&D effort is spread across agricultural and service industries. The small allocation to agriculture ($32 million in 1990–91) is performed entirely by enterprises predominantly engaged in other activities (eg manufacturing, wholesale and retail trade, and business services). This is because individual farmers are not in a position to undertake research programs of any size and rely on the purchase of research from other industries (outsourcing) or R&D commissioned by other sectors (including R&D corporations and councils administered by the Department of Primary Industries and Energy).

A guide to the industries benefiting from the R&D undertaken by government and higher education institutions has been obtained by reclassifying ABS statistics on socio-economic objective (SEO) to industry.

After the reclassification of government R&D, the main benefiting industries are agriculture, public administration and defence, and the community services group. The most prominent benefiting industry for R&D by higher education institutions is the education industry itself. That is, the initial use of R&D is assumed to benefit the provision of educational services, including further R&D within the sector.

R&D benefiting manufacturing is not as prominent with government and educational sector R&D as it is with business R&D. R&D expenditure by private non-profit organisations mainly benefits the health industry.

QD.4 Assistance to business R&D

Level of business R&D

The R&D performed by business enterprises reported in table QD1 (column 1) covers R&D that individual business enterprises perform on their own account. It also includes R&D performed on contract to other business enterprises and other institutional groups. However, the business interest in R&D also extends to R&D performed by other institutional groups for businesses (often termed ’extramural R&D’). Such R&D would be part of government, educational and private non–profit R&D reported in table QD1 (columns 2 to 4). Although undertaken by other institutional sectors, business enterprises funding R&D services are able to claim government support for such R&D in addition to any support that is available to own account R&D.

Table QD1: **Performance of R&D by initial benefiting industry, 1990–91** ($ million)

Industry	*Business enterprises*	*Common-wealth & State Govern-ments*	*Higher education institutions*	*Private non-profit institutions*	*Total*
Agriculture, forestry, fishing and hunting	32	478	79	..	589
Mining	125	101	27	..	253
Food, beverages and tobacco	78	na	na	na	78
Textiles	4	na	na	na	4
Clothing and footwear	4	na	na	na	4
Wood products	6	na	na	na	6
Paper, paper products and printing	35	na	na	na	35
Chemical petroleum and coal products	243	na	na	na	243
Non-metallic mineral products	27	na	na	na	27
Basic metal products	108	na	na	na	108
Fabricated metal products	62	na	na	na	62
Transport equipment	197	na	na	na	197
Other machinery and equipment	998	na	na	na	998
Miscellaneous manufacturing	54	na	na	na	54
Manufacturing unallocated	..	193	80	1	274
Total manufacturing	**1 816**	**193**	**80**	**1**	**2 090**
Electricity, gas and water	3	32	16	..	51
Construction	8	..	..	..	8
Wholesale and retail trade	25	39	26	..	90
Transport and storage	5	..	..	..	5
Communication	2	26	3	..	31
Finance, property and business services	53	35	30	2	120
Public administration and defence	..	253	58	..	312
Health	na	124	253	55	432
Education	na	99	649	9	756
Welfare and religious services	na	46	41	..	88
Other community services	na	109	66	..	175
Community services (unallocated)	9	na	na	na	9
Total community services	**9**	**378**	**1 009**	**64**	**1 461**
Recreation , personal and other services	4	..	..	..	4
Non-classified	..	117	21	..	138
Total	**2 082**	**1 651**	**1 351**	**67**	**5 151**

Notes following form part of this table.

.. Nil or less than $500 000.
na Not available
Shaded areas indicate data not available.
a Business R&D was classified to the industries shown in column 1 of this table on the basis of product field information provided in ABS, Cat. No. 8104.0. Where product field information could not be matched to the above industries (ie when R&D flows were classified to the category 'other nec', table 8 in ABS, Cat. No. 8104.0) industry of enterprise information published by the ABS (table 7) and Eligible R&D expenditure by product file of research (BIE 1993, table 3.4) was used to fill the gaps.
b R&D for the non-business sectors (columns 3 to 5) was assigned to industry on the basis of a link from industry to Socio-Economic Objective Classification (SEO) published by the ABS (Cat. No. 1297.0).
Sources: ABS, Cat. Nos 8112.0 and 8104.0; BIE 1993; and Commission analysis.

A single estimate of extramural R&D is not directly available from published sources. Nevertheless, the ABS provides estimates of total extramural activity of non-rural businesses (ABS 1992b, table 11) and intra-sectoral flows (ABS 1992b, table 2). By deducting intra-sectoral flows from total extramural activity, the Commission estimates that extramural, intersectoral R&D of non-rural enterprises was of the order of $131 million in 1990–91. In addition, rural industry enterprises fund R&D through financial contributions to rural R&D corporations and councils administered by the Department of Primary Industries and Energy. In 1990–91, the estimated industry contributions were around $63 million to R&D, in the main performed by the public sector (see IC 1995a). Total rural and non-rural extramural, intersectoral R&D is estimated to be $195 million in 1990–91 (see table QD2).

The total estimated level of business R&D is therefore $2277 million, that is, $2082 million of R&D performed by business, plus $195 million performed by non-business enterprises for business. The extramural component forms around 9 per cent of total business R&D. The reported total relates to the R&D performed by business enterprises or on contract to business enterprises. It does not include R&D undertaken by government agencies (eg rural research corporations and councils) and funded in part or whole by compulsory levies on industry

Table QD2: **Business R&D by benefiting industry, 1990–91** ($ million)

Industry	*R&D performed by business*	*R&D performed by others for business*	*Total*
Agriculture, forestry, fishing and hunting	32.3	29.4	61.6
Mining	124.6	7.9	132.4
Food, beverages and tobacco	77.8	7.6	85.4
Textiles	3.9	5.9	9.7
Clothing and footwear	4.2	0.6	4.8
Wood products	5.6	0.4	6.0
Paper, paper products and printing	35.1	2.2	37.3
Chemical petroleum and coal products	243.2	16.2	259.4
Non-metallic mineral products	27.0	1.7	28.7
Basic metal products	108.2	6.8	115.1
Fabricated metal products	61.9	3.9	65.8
Transport equipment	197.1	12.4	209.5
Other machinery and equipment	997.7	65.2	1 062.9
Miscellaneous manufacturing	54.1	4.1	58.2
Total manufacturing	**1 815.9**	**127.0**	**1 942.9**
Electricity, gas and water	3.1	0.2	3.3
Construction	7.6	0.6	8.3
Wholesale and retail trade	5.0	0.4	5.4
Transport and storage	2.3	0.1	2.5
Communication	24.9	3.3	28.3
Finance, property and business services	53.1	13.8	66.9
Public administration and defence	a	a	a
Community services	9.5	11.4	20.9
Recreation , personal and other services	4.0	0.3	4.3
Total	**2 082.4**	**194.5**	**2 276.8**

a Assumed zero.
Sources: ABS, Cat. Nos 8104.0 and 8104.0; and Commission analysis.

Business R&D by benefiting industry

R&D performed by business enterprises is classified by initial benefiting industry in table QD2. However, an industry classification of extramural R&D is not available. In order to complete the industry picture for business R&D, it has been assumed that R&D performed by others for non–rural business, benefits industries in proportion to R&D performed directly by business. Under this assumption, manufacturing industries would be the main benefiting industry group from extramural R&D of business (see table QD2).[4] R&D performed by others for rural industry businesses has been classified to initial benefiting industry after an examination of projects commissioned by the rural R&D corporations and councils (see IC 1995b). While the agricultural industry is the main benefiting sector, other industries supplying agriculture and marketing agricultural products are also significant beneficiaries.

Assistance to business R&D

Governments can assist the performance of business R&D (excluding the industry funded component of rural R&D) through official buying programs and through direct support to the performance of R&D by business.

Government purchasing programs can be used to fund business R&D. To do this, government purchasing contracts would need to be let at prices above relevant border price for equivalent goods and services. The purchases might be for R&D services or for goods and services embodying local R&D efforts. By paying a premium for local supplies, Government purchases would increase returns to local R&D (either directly or indirectly) and provide an incentive for local business to increase R&D efforts. Information on the extent of such assistance, if any, is not readily available. Nevertheless, programs that have the potential to afford such assistance include the Partnership for Development Program (box QD2) and Defence Procurement (box QD3).

4 Table QD1 shows that $273 million R&D expenditure by government and educational institutions benefits manufacturing. Table QD2 estimates that $127 million of these costs are incurred by business. Because of the approximations used in deriving these estimates, they should only be regarded as indicative of the level of cost recovery and intersectoral flows of R&D.

Box QD2: **Partnerships for Development Program**

As part of its strategy to develop an information technology industry in Australia, the Government initiated a Partnership for Development program in 1987. The program, which aims to encourage international corporations to undertake activities in Australia, is linked to government procurement of information technology. The program was extended in 1991. Partnerships for Development agreements are now mandatory for all international information technology firms with orders of over $40 million per year. Firms with smaller orders are also required to meet agreed targets. A company signing a standard Partnership agreement with government, commits by the seventh year to achieve targets associated with:

- expenditure on research and development equal to 5 per cent of turnover;
- exports of goods or services equivalent to 50 per cent of annual imports; and
- an average of 70 per cent local content in exports.

The level of R&D and export assistance associated with government procurement policies is not clear and may be difficult to determine. Nevertheless, to be effective in changing commercial outcomes, these arrangements have the potential to provide incentives for R&D to a few selected industries through higher contract prices paid by government.

Sources: DITAC 1991b, p. 34; and DITARD 1992, p. 17.

Box QD3: **Defence Procurement**

The Australian Industry Involvement (AII) Framework Interim Advice issued by Defence in June 1994 specifies Australian industry involvement in two components: Tier 1 which 'identifies the AII activities that are required by Australian industry to provide support for an important strategic asset'; and Tier 2 which describes activities which 'are aimed at the ... objective of broadening the industrial support base in key areas'. However, according to the Interim Advice, Defence will also provide industry with an 'overall target level of AII' for each project. The target, which will be expressed as a percentage of the contract price, will appear in the Request for Tender (RFT), and will 'represent the total AII (Tier 1 and Tier 2) expected for the project'. According to the Interim Advice, 'tenderers will be encouraged to exceed the target AII level specified in the RFT'.

In practice, such targets can act as de facto minimum levels of local content. This constrains tenderers' options to offer least-cost solutions, and restricts Defence's ability to estimate any premiums associated with Australian supply. Target local content provisions can flow on to support for business R&D as well as other industry services.

Estimating price premia arising from this approach and assigning it to R&D effort of firms would not be easy. Target percentage levels of local content mask competitive prices in tender bids and make the task much more difficult and uncertain. This would add to already considerable practical problems arising from the difficulty of comparing like with like, and the need to assess through-life costs as well as initial price premiums.

Sources: Department of Defence 1994e, chapters 4 & 5; and Industry Commission 1994b.

Governments also provide grants and concessions to business to increase the incentives for them to undertake R&D themselves or employ the R&D services of others. Programs providing this type of support include the Taxation Concession for Industrial R&D, the Discretionary Grants Scheme, the National Procurement Development Program, the Computer Bounty and the Factor f Scheme. Of these schemes, the taxation concession provides the highest level of funding to business R&D (see table QD3). The economic importance of the taxation concession is also heightened relative to other programs reported due to the taxation status of government payments. The taxation concession is provided on a post company taxation basis (see box QD4), whereas the other schemes are provided on a pre–taxation basis. The value of the tax concession to recipient companies varies depending on the taxation status of the company and the input composition of R&D. Although there are differences in taxation treatment between the schemes reported in table QD3, the relative magnitudes reported would not be affected significantly by adjustments to place the programs on a common company taxation basis (or indeed shareholder taxation basis).

Some grant schemes could provide a very substantial level of support to qualifying businesses. In particular, the Discretionary Grants Scheme funds up to 50 per cent of total R&D project expenditure for a period of up to three years. However, even though there may be a significant level of funding to an individual recipient, this does not imply that the value of the outlays under the schemes are significant at the industry-wide level.

The nominal rate of assistance for business R&D provides a measure of the significance of assistance to output. It is the percentage by which users' costs are decreased relative to the supply cost of R&D services. Overall, business returns to R&D are around 16 per cent above the market price of those services (see table QD4).[5] The nominal rate of assistance reported is less than the theoretical rate of assistance (ie the post tax nominal subsidy equivalent in box QD4) because not all business R&D is eligible for the concession (eg in-house computer software development, mineral exploration, quality control and market research).

As the taxation concession is the main government assistance measure used to benefit business R&D, nearly all of the recorded support comes from that program. There are variations in nominal rates reported in table QD4 and these are due to assistance afforded by other measures and the taxation status of

5 Direct estimates of the market price of R&D services are not available because most R&D services are performed by businesses on their own account. The market price of R&D is therefore estimated as the cost of materials, labour and capital less the value of government support. The producers supply price is equal to the cost of production.

business R&D. In particular, the nominal rate is relatively low for Agriculture, Textiles and Community services due to the substantial concentration of initial benefits of rural R&D in these sectors and the non–tax concessionary status of that R&D.

Assistance to R&D output may be offset by the higher cost of R&D inputs as a result of other government measures, such as tariffs. The effective rate of assistance is a measure of the net impact of assistance to outputs (usually positive) and assistance to inputs (usually negative) over value added (ie outputs less inputs) of an activity. In the case of R&D activities, the effective rates of assistance to value added in R&D are typically 50 per cent greater than nominal rates of assistance to outputs.

Table QD3: **Commonwealth Government programs assisting business R&D, 1989–90 to 1992–93** ($ million)

	1989-90	*1990-91*	*1991-92*	*1992-93*
Film Development Industry Assistance Program	0.9	0.7	0.4	0.7
Industry and Cultural Development Industry Assistance Program	2.9	3.1	3.4	3.6
Defence Industry Development Program	7.1	11.5	9.9	9.5
Commonwealth Serum Laboritories	2.1	1.9	1.9	-
Taxation Concession for Industrial R&D	250.0	290.0	370.0	395.0
GIRD Discretionary Grants Scheme	15.3	14.0	14.0	13.4
National Procurement Development Program	5.6	4.6	4.4	5.4
Advance Manufacturing Technology Development	-	-	0.1	0.6
National Teaching Company Scheme	0.8	1.9	1.8	1.3
Computer Bounty (a)	18.0	20.5	29.8	30.0
Factor f Scheme	0.2	3.4	3.6	8.3
Motor Vehicle and Components Development	4.7	2.3	-	-
Total	**307.6**	**353.9**	**439.3**	**467.8**

- Program not operating, or discontinued.

a Part of the payments under the Computer Bounty relate to operating costs and part to R&D performed. The component of the bounty payments relating to the performance of R&D is reported here.

Source: IC 1995a.

Box QD4: **The company taxation rate and the theoretical subsidy equivalent per unit of eligible industrial R&D**

The theoretical subsidy equivalent of the R&D concession, based on the level of deductibility and the rate of company income tax for a profit making concern, is:

	I989-90 to 1992-93	*1993-94 to 1994-95*	*Post-1994-95*
	%	%	%
Concessional rate of deduction (c)	150	150	150
Company taxation rate (t)	39	33	36
Nominal subsidy equivalent (post-tax basis)	19.5	16.5	18.0
Nominal subsidy equivalent (pre-tax basis)	32.0	24.6	28.1

The nominal subsidy equivalent (post-tax basis) is estimated as: $\frac{(c-100)*t)}{100}$, where *c* is the concessional rate of deduction and *t* is the company tax rate. The pre-tax value is estimated as: $\frac{Post-tax\ value}{(1-t)}$.

However, this assumes that the deduction of 100 per cent of expenditure in the year in which it is incurred constitutes neutral taxation. It also assumes that the performance and funding of the R&D occur simultaneously with the granting of the concession. In practice, the performance of R&D, its funding and the granting of the concession can occur in different periods and the value of the concession to R&D performers can vary according to the taxation status of the company concerned. In particular,

- for purchases of R&D services from Registered Research Agencies, eligible research expenditure can be claimed at the time of project commitment rather than the time of project completion (IR&D Board 1994a, p. 182). This could provide a benefit to the R&D funder and performer by advancing the period of deductibility ahead of the period of performance;
- firms in tax profit that undertake their own R&D can claim eligible expenses once they are incurred. This provides a cost due to the lag between performance and the eventual taxation claim;
- firms in tax loss that undertake their own R&D can claim eligible expenses once the firm moves into tax profit. This provides a cost due to the lag between R&D performance and the taxation claim when the company moves to tax profit;
- dividend imputation which causes some of the tax savings realised by the concession recipients to be clawed back through taxation of shareholders thereby reducing the benefit of the concession to the owners of R&D companies (BIE 1993c, Appendix 7);
- the concession is claimed for R&D plant and equipment over three years. The concession favours R&D that is more intensive in the use of materials and labour.

For these reasons, the value of the R&D concession differs somewhat between companies and from the general subsidy equivalent per unit of R&D reported above.

Table QD4: **Nominal and effective rates of assistance to business R&D by benefiting industry,[a] 1990–91** (per cent)

		Effective rate of assistance				
			Assistance to R&D			
Industry	*Nominal rate of assistance to R&D*	*Total*	*Taxation concession*	*Discretion-ary grants*	*Other assistance to R&D (b)*	*Taxes on material inputs*
			Market sector			
Agriculture, forestry, fishing and hunting	7.3	11.2	11.8	..	0.1	-0.7
Mining	13.2	17.8	18.1	..	0.1	-0.4
Food, beverages and tobacco	13.9	21.0	19.8	1.7	0.1	-0.6
Textiles	5.7	8.9	9.4	0.2	0.1	-0.8
Clothing and footwear	15.7	25.7	20.6	5.8	0.1	-0.8
Wood products	13.2	18.8	19.2	..	0.1	-0.5
Paper, paper products and printing	13.7	27.0	26.9	1.1	0.2	-1.2
Chemical petroleum and coal products	13.9	23.4	22.7	0.1	1.4	-0.8
Non-metallic mineral products	13.6	22.3	22.3	0.7	0.1	-0.8
Basic metal products	14.0	24.0	23.2	1.5	0.2	-0.9
Fabricated metal products	13.5	18.9	18.7	0.5	0.1	-0.5
Transport equipment	15.0	23.4	20.9	0.5	2.6	-0.7
Other machinery and equipment	19.1	29.3	20.6	1.4	8.0	-0.6
Miscellaneous manufacturing	16.0	25.3	21.1	3.5	1.4	-0.7
Total manufacturing	**16.9**	**26.5**	**21.0**	**1.2**	**5.0**	**-0.7**
Service industries	17.2	28.0	18.1	..	10.6	-0.8
Total market sector	**15.8**	**24.5**	**20.5**	**1.0**	**3.6**	**-0.7**
Finance, property and business services	13.4	20.5	17.5	..	3.7	-0.7
Community services	7.2	11.4	10.5	..	1.7	-0.8
Total, all industries	**15.6**	**24.3**	**20.4**	**1.0**	**3.6**	**-0.7**

Notes following form part of this table.

.. Nil or less than 0.05 per cent.
a Industries are grouped into market sector industries and non-market sector industries. The market sector comprises Agriculture, forestry fishing and hunting, Mining, Manufacturing and selected Service industries (namely, Electricity, gas and water, Construction, Wholesale and retail trade, Transport and storage, Communication, and Recreation, personal and other services).
b Includes Factor f grants to the Pharmaceutical industry (included in Chemicals, petroleum and coal products) and Computer Bounty and Motor Vehicle and Component Development payments.
Source: Commission analysis.

Table QD4 shows that the effective assistance to business R&D is around 24 per cent of R&D value added. A small negative contribution also occurs with the cost of tariffs on material inputs. There is some variation in the effective rate of assistance between industries. This variation is partly due to differing value added intensities in respect to R&D activities. Because assistance is awarded on the value of output, industries with high value added in R&D per unit of output (eg are relatively labour or capital intensive, such as mining) would receive proportionately less assistance to value added than industries that make more use of material inputs. In addition, assistance varies with the tax concession status of R&D.

There appears to be some clustering of assistance under the Discretionary Grants Scheme around Clothing and footwear and the Miscellaneous manufacturing industries. The assistance effects of Factor f, the Motor Vehicle and Components Development and the Computer Bounty is also evident with respect to results reported for the chemicals, vehicles and machinery industries.

QD.5 Assistance to industries benefiting from R&D

Sources of government support to industry

Government support to R&D is provided through:

- support for business R&D ($354 million in 1990–91, see table QD3); and
- government R&D undertaken by government agencies (eg CSIRO and AGSO), higher education institutions, and through ad hoc research programs. Government R&D is funded using a variety of arrangements including block funding to research organisations and educational institutions and spending on particular research objectives (cooperative research centres (CRCs).

According to table QD1, public expenditure on R&D performed by public sector establishments was around $3 billion in 1990–91. This estimate does not provide a comprehensive indication of the level of government support to industry through the funding of R&D. In order to relate these estimates to the level of government support to industry, a number of adjustments are required:

- R&D performed by government on contract to business (ie extramural R&D of businesses) needs to be deducted. This R&D is often eligible for direct government assistance (eg through the taxation concession). Assistance to business R&D is estimated separately and these flows need to be excluded from government R&D expenditure totals to avoid double counting. The estimated level of extramural R&D is $195 million;
- R&D performed by business on contract for government needs to be added. Such R&D is not assisted through government programs to support business R&D. Nevertheless, the R&D knowledge acquired by the community is available to benefit industry. To obtain a complete picture of government support to industry, this activity needs to be included in the total level of funds available for industry support. The Commission's estimate of the level of this activity in 1990–91 is $59 million[6];
- Government direct support for the performance of R&D by business needs to be added. This funding is not included in government expenditure on R&D and must be taken into account to obtain a comprehensive picture of the total level of support. The Commission's estimate of the level of such support in 1990–91 is $354 million (see table QD3).

Table QD4 shows that the effective assistance to business R&D is around 24 per cent of R&D value added. A small negative contribution also occurs with the cost of tariffs on material inputs. There is some variation in the effective rate of assistance between industries. This variation is partly due to differing value added intensities in respect to R&D activities. Because assistance is awarded on the value of output, industries with high value added in R&D per unit of output (eg are relatively labour or capital intensive, such as mining) would receive proportionately less assistance to value added than industries that make more use of material inputs. In addition, assistance varies with the tax concession status of R&D.

There appears to be some clustering of assistance under the Discretionary Grants Scheme around Clothing and footwear and the Miscellaneous manufacturing industries. The assistance effects of Factor f, the Motor Vehicle and Components Development and the Computer Bounty is also evident with respect to results reported for the chemicals, vehicles and machinery industries.

6 This value is equal to Commonwealth, State and local government funding of business R&D (excluding GIRD Scheme payments) reported in ABS 1992b, table 5.

Table QD5: **Government funding of R&D and the coverage of funding in the Commission analysis, 1990–91**
($ million)

Government R&D involvement	*Funding*
Public expenditure on R&D as reported in ABS statistics	
Commonwealth and State government	1 651
Higher education institutions	1 351
	3 002
less Business extramural R&D performed by the public sector institutions	- 195
plus Public R&D performed by business	59
plus Government support for business R&D	354
Total	**3 221**
Government programs not covered in analysis	936
Government funding programs analysed	**2 284**

Sources: ABS, Cat. Nos 8112.0 and 8104.0; and Commission analysis.

Table QD4 shows that the effective assistance to business R&D is around 24 per cent of R&D value added. A small negative contribution also occurs with the cost of tariffs on material inputs. There is some variation in the effective rate of assistance between industries. This variation is partly due to differing value added intensities in respect to R&D activities. Because assistance is awarded on the value of output, industries with high value added in R&D per unit of output (eg are relatively labour or capital intensive, such as mining) would receive proportionately less assistance to value added than industries that make more use of material inputs. In addition, assistance varies with the tax concession status of R&D.

There appears to be some clustering of assistance under the Discretionary Grants Scheme around Clothing and footwear and the Miscellaneous manufacturing industries. The assistance effects of Factor f, the Motor Vehicle and Components Development and the Computer Bounty is also evident with respect to results reported for the chemicals, vehicles and machinery industries.

This framework uses information from a number of sources. Because the Commission has employed ABS data collected by surveys and public account information, strict alignment and comparisons of the information is not possible.

In particular, programs of public spending may not relate to R&D as it is strictly defined in ABS series (see definitions in box QD5). Nevertheless, the Commission believes that the estimates reported in table QD5 provide a good guide to the magnitudes involved in government funding of R&D that benefits industry and is useful in facilitating the analysis of the effects of government support to R&D.

Box QD5: **Definition of R&D**

Research and experimental development is defined by the ABS in accordance with the Organisation for Economic Cooperation and Development (OECD) standard as comprising: 'creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications'.

The ABS categorises research and experimental development in the following way:

- *Applied research* is original work undertaken in order to acquire new knowledge with a specific application in view. It is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving some specific and predetermined objectives.
- *Basic research* is experimental and theoretical work undertaken primarily to acquire new knowledge without a specific application in view. It consists of pure basis research and strategic basic research. Pure basic research is carried out without looking for long–term benefits other than the advancement of knowledge. Strategic basic research is directed into specified broad areas in the expectation of useful discoveries. It provides the broad base of knowledge necessary for solution of recognised practical problems.
- *Experimental development* is systematic work using existing knowledge gained from research or practical experience for the purpose of creating new or improved products or processes

Activities encountered in the analysis of 'research organisations' and 'research programs' include industry extension services, market research and model presentation. These activities have been included in the analysis on the basis that they are undertaken by organisations with a predominantly research focus. It is possible that upon further scrutiny, some of activities would not qualify as research according to the ABS/OECD definition.

Source: ABS, Cat. No. 8112.0.

Table QD6: **Government funding of R&D by benefiting industry**, **1990–91** ($ million)

Industry	*State support (a)*	*Commonwealth support for* Business R&D	Public research agencies	Other R&D programs	Total	*Total*
Market sector						
Agriculture, forestry, fishing and hunting	179.6	4.5	126.2	52.3	183.0	362.7
Mining	na	17.5	84.4	4.9	106.7	106.7
Food, beverages and tobacco	na	11.8	12.3	3.3	27.5	27.5
Textiles	na	0.6	0.6	..	1.1	1.1
Clothing and footwear	na	0.8	12.9	4.8	18.5	18.5
Wood products	na	0.8	5.4	..	6.2	6.2
Paper, paper products and printing	na	5.1	5.6	..	10.7	10.7
Chemical petroleum and coal products	na	39.5	34.5	5.1	79.1	79.1
Non-metallic mineral products	na	3.9	9.1	1.1	14.1	14.1
Basic metal products	na	16.1	5.9	0.9	22.9	22.9
Fabricated metal products	na	8.9	5.7	..	14.6	14.6
Transport equipment	na	31.5	37.6	0.7	69.8	69.8
Other machinery and equipment	0.6	182.1	30.8	18.5	231.4	232.1
Miscellaneous manufacturing	na	9.3	5.4	3.0	17.7	17.7
Manufacturing, unspecified	na	..	4.4	0.2	4.6	4.6
Total manufacturing	**0.6**	**310.4**	**170.0**	**37.7**	**518.2**	**518.8**
Electricity, gas and water	na	0.4	21.1	2.6	24.1	24.1
Construction	1.0	1.6	0.1	1.0	2.6	3.6
Wholesale and retail trade	na	3.5	3.1	1.8	8.4	8.4
Transport and storage	na	0.8	12.6	0.5	13.9	13.9
Communication	na	0.3	2.0	4.0	6.3	6.3
Recreation , personal and other services	na	4.4	8.4	10.4	23.2	23.2
Total market sector	**181.2**	**343.5**	**427.9**	**115.1**	**886.5**	**1 067.8**
Financial and business services						
Finance, property and business services	na	8.9	18.1	11.7	38.7	38.7
Total market and financial services	**181.2**	**352.4**	**445.9**	**126.8**	**925.2**	**1 106.5**
Government and community services						
Public administration and defence	4.0	..	186.3	2.8	189.1	193.1
Community services	0.2	1.5	708.2	274.9	984.6	984.8
Total gov’t and community services	**4.2**	**1.5**	**894.5**	**277.7**	**1 173.7**	**1 177.9**
Total, all industries	**185.4**	**353.9**	**1340.4**	**404.5**	**2098.9**	**2284.3**

Notes following form part of this table.

.. Nil or less than $50 000.
na Not available.
a State assistance to industry undelying these estimates reflects: current expenditure on agricultural research, and State contributions to the Australian Road Research Board and the Federalism Research Centre. It therefore only represents a partial coverage of State programs. A discussion of State involvement in R&D is provided in appendix QE.
Source: Industry Commission 1995a.

About three-quarters of government funding to R&D ($2284 million: table QD5) flows to Commonwealth Government R&D programs (see columns 3 & 4, table QD6). Nearly 10 per cent is expended through State Government programs while the remainder (around 15 per cent) is support for business R&D.

Of the total level of support analysed, about 50 per cent ($1068 million) benefits industries in the market sector (including agriculture, mining, manufacturing and selected services). Most of the remainder ($985 million) benefits Community service industries (including health, education, environmental and other community welfare services). Financial and business services, and Public administration and defence also receive substantial benefits, although less in total than the broadly defined market sector and community services.

The State assistance information obtained relates almost entirely to support for agriculture. A further study of State involvement in R&D is provided in appendix QE.

For industries in the market sector, about two-thirds of government support to industry is provided through government R&D such as that performed by public research agencies (eg CSIRO and grants to education institutions) and other public granting programs (eg grants to primary industry research corporations and councils). However, there are some important differences between industries within the sector. Agriculture and mining mainly benefit from R&D undertaken by public research agencies, whereas manufacturing benefits mainly from government support for business R&D efforts (eg the taxation concession). Service industries in the market sector mainly benefit from public R&D.

As would be expected, Public administration and defence and Community services benefit mainly from public R&D.

Rates of assistance to benefiting industry

Introduction

Measures of the value of government support classified by industry indicate where the initial benefits of government support fall. However, they do not indicate the importance of that support to the industries receiving the benefit. In addition, because the R&D funding is not generally expressed in an economy-wide framework, it is not possible to relate government R&D support to industry with support through other government programs.

The Commission's model of industry assistance makes it possible to summarise the level of assistance to industry.[7] The model is based on an economy–wide framework and it is appropriate to express support for industry through R&D in conjunction with assistance provided through other programs (eg through tariffs and bounties). The fact that it is appropriate to report assistance from all sources in the model does not imply that the various forms of assistance are substitutes for one another or have the same economic effects. Because the model is partial equilibrium, it does not take into account any production and consumption effects of the various assistance measures but rather, it provides a starting point for considering quantitatively, the broader economic effects of alternative forms of assistance. The model also relates to economic transactions in a single period of time. Assistance afforded to industry is therefore recorded in the period in which the concession is conferred.

The Commission already publishes estimates of the nominal and effective rates of assistance to the agricultural , mining and manufacturing sectors. Estimates published for the agricultural sector include the effects of assistance provided through agricultural R&D (mainly through R&D corporations administered by the Department of Primary Industry and Energy, and through selected research divisions of the CSIRO). Traditionally, mining and manufacturing estimates have focused on support afforded through bounties and tariffs and have not generally taken into account support for R&D. An exception is the Computer Bounty which makes payments on R&D costs as well as other production costs.

The current study brings support to industry through R&D into this framework. To do this, the following steps have been taken:

- agricultural sector estimates shown in the Commission's annual report (ie nominal rate of 6 per cent and effective rate of 15 per cent for 1990–91) have been adjusted to show separately the effect of R&D support measures

[7] Annex 2 outlines the main assumptions underlying the Commission's general model of assistance. Annex 3 provides a formalised description of the modified model used to analyse support to R&D.

and other measures, and reweighted to form a sub-component of the industry sector Agricultural, forestry, fishing and hunting;

- special calculations of nominal and effective rates of assistance to service industries have been undertaken. These calculations take into account the price raising effects of tariff support for material inputs and support to industry through R&D; and
- nominal and effective rates of assistance have not been calculated for the public administration and defence and community services industries because these sectors do not, in the main, produce marketed goods and services, and hence production decisions are not based purely on input and output prices — the focus of nominal and effective rate theory.

The industry structure used to extend the estimates of nominal rates to include R&D support and services industries is based on the 1989–90 ABS input-output tables. Activity levels were updated to 1990–91, the benchmark year for this study, using information from the Australian National Accounts, and national income and expenditure estimates.

Assistance estimates

Support to R&D lowers the cost of R&D knowledge to industry. In doing so, it raises the returns to value adding factors employed in industry. Higher returns to value adding factors is reflected by positive effective rates of assistance (see table QD7, columns 3 to 6). Higher effective rates relative to other activities are generally interpreted as indicating that government support has raised the incentive for business to enter (or remain in) assisted activities.

In the market sector, R&D support raises returns to value added by around 0.5 percentage points. That support is most important for the Agriculture, forestry, fishing and hunting sector. As noted above, most assistance for this sector comes from Commonwealth and State Government R&D programs rather than government support for business R&D. Within manufacturing, R&D is more important for the Machinery and equipment and Clothing and footwear industries than for other manufacturing industries. The machinery industry receives a relatively high level of government support for business R&D. It also receives a significant level of support through other government R&D programs. This arises because there is substantial spending through a wide variety of programs (eg AGSO, CSIRO, rural research organisations, university research) directed at improving machinery and equipment technology and applications. Relatively high assistance to Clothing and footwear is mainly due to R&D by CSIRO.

The Finance, property and business services industry does not appear to be a major initial beneficiary of government support to R&D. Indirectly, the sector would benefit from R&D induced improvements in office machinery and equipment (including computers) and building technologies.

Economy–wide analysis

The effective rate of support reported in table QD7 indicates the percentage points by which industry assistance is raised by government support to R&D. Support afforded by other industry measures which, in the main, are concerned with directly affecting output prices (eg tariffs, subsidies and market support schemes) is also reported in table QD7 (column 6).

The agricultural and manufacturing industries are the main beneficiaries of such government support. Mining and service industries are generally not supported by output assistance. However, mining and service industries must absorb the cost of higher priced inputs (due to tariffs). The cost to industry of tariffs is reflected by negative effective rates for those industries.

In 1990–91, assistance to textiles is dominated by high tariffs and quotas under the textile clothing and footwear programs. Assistance through R&D, although possibly important for some elements of the industry is not an important element in the overall level of support to the industry (in value terms). R&D support for machinery and equipment manufacture is significant in relation to tariff support (6.2 percentage points compared to 16.4 per cent in 1990–91).

In making comparisons between different forms of industry assistance, it is important to note the economic similarities and differences between the various forms of assistance. The support programs are similar in that assistance afforded industry provides positive incentives for business to engage in the assisted activities. However, the community welfare implications of the various measures may differ substantially. In particular, border protection in the form of tariffs and import quotas raise domestic costs above international levels and reduce the competitiveness of the local economy relative to the rest of the world. Import and export levels would be lowered by assistance. On the other hand, successful R&D makes local industry more competitive internationally and potentially raises the level of international trade. Because individual firms cannot always recover all of the costs of their R&D efforts, government provides additional incentives to industry to perform R&D in-house or to use the increased supply of R&D made available from government programs.

It is a matter of judgement to determine the appropriate level of support. The nominal and effective rates model informs that judgement.

Table QD7: **Effective rates of assistance to benefiting industry, 1990–91**[ab] (per cent)

	Assistance through R&D					
		Commonwealth support for				
Industry	*State assistance (c)*	*For business R&D*	*Research agencies*	*Other R&D programs*	*Total*	*Non-R&D support*
Market sector						
Agriculture, forestry, fishing and hunting	1.7	..	1.2	0.5	3.4	9.9
Mining	na	0.1	0.5	..	0.6	-2.8
		..	..	..	..	
Food, beverages and tobacco	na	0.1	0.1	..	0.3	3.5
Textiles	na	0.1	0.1	..	0.1	50.7
Clothing and footwear	na	0.3	4.7	1.7	6.7	113.3
Wood products	na	..	0.3	..	0.3	13.6
Paper, paper products and printing	na	0.1	0.2	..	0.3	7.5
Chemical petroleum and coal products	na	0.7	0.6	0.1	1.4	7.5
Non-metallic mineral products	na	0.2	0.4	0.1	0.7	3.7
Basic metal products	na	0.3	0.1	..	0.4	8.3
Fabricated metal products	na	0.3	0.2	..	0.5	17.6
Transport equipment	na	0.9	1.1	..	2.0	34.1
Other machinery and equipment	..	4.9	0.8	0.5	6.2	16.4
Miscellaneous manufacturing	na	0.5	0.3	0.2	0.9	19.3
Total manufacturing	**na**	**0.7**	**0.4**	**0.1**	**1.2**	**14.3**
Electricity, gas and water	na	..	0.2	..	0.2	-3.5
Construction	..	..	..	..	..	-6.1
Wholesale and retail trade	na	..	..	..	..	-3.7
Transport and storage	na	..	0.1	..	0.1	-4.0
Communication	na	..	..	..	0.1	-1.7
Recreation , personal and other services	na	..	..	0.1	0.1	-3.5
Total market sector	**0.1**	**0.2**	**0.2**	**0.1**	**0.5**	**1.0**
Other non-government and community services						
Finance, property and business services	na	..	..	..	0.1	-3.6
Total market and financial services	**0.1**	**0.1**	**0.2**	**..**	**0.4**	**0.2**

Notes following form part of this table.

.. Nil or less than 0.5 per cent.
na Not available.
a In order to complete the estimate of non-R&D support to Agriculture, forestry, fishing and hunting, the Commission's estimates of assistance to agriculture reported in its annual report (ie nominal rate of 6 per cent and effective rate of 15 per cent) have been adjusted to remove the effect of R&D support measures and reweighted to form a sub–component of the agriculture, forestry, fishing and hunting industry sector.
b Manufacturing industry estimates published in the annual report do not contain an explicit allowance for assistance to industry through R&D measures. The nominal and effective rates shown as cited in the Commission's annual reports except that the cited estimate for Machinery and equipment has been reduced by 0.5 percentage points to remove double counting of the R&D component on the Computer Bounty.
c See footnote a to table QD6.
Sources: Industry Commission 1995b and Commission analysis.

QD.6 Conclusion

Direct assistance to the performance of R&D by business is substantial and is dominated by the effects of the tax concession for industrial R&D. Assistance to the performance of business R&D also assists industries in their role as users of R&D knowledge.

Industry also benefits from the quantitatively more significant R&D performed by public research agencies and other government funded programs.

When government support for industry is placed in an economy–wide framework, R&D can be seen as one of a number of measures available to assist industry. However, the community welfare implications of the measures differ. Some forms of assistance (such as tariffs) raise domestic cost levels and the benefits gained by the protected activities may not offset the losses to others. Assistance that raises domestic cost levels potentially leads to lower community welfare. Assistance through R&D is provided in recognition of the public good nature of R&D, which provide benefits to the wider community which can exceed the cost of supporting individual activities. Thus, government support for successful R&D can provide a means of improving community welfare.

Annex QD1: Standard measures of assistance

There are several standard measures used by the Commission to report levels of assistance. The following measures reflect the different aspects of the price effects of assistance and are summarised as follows:

- *gross subsidy equivalent to output (GSE)* is an estimate of the change in producers' gross returns from assistance. It is the notional amount of money, or subsidy, necessary to provide an industry with the same gross returns as is provided by existing government interventions;
- *tax equivalent on materials (TEM)* is an estimate of the change in cost of intermediate inputs (ie materials and services) due to government interventions. It is the notional amount of money, or tax, that would change the cost of intermediate inputs by the same amount as existing government interventions;
- *subsidy to value adding factors (SVA)* is an estimate of the change in returns to labour, land and fixed capital (and R&D knowledge), due to government interventions targeting the use of those factors in production. It is the notional amount of money that would change the cost of the use of value adding factors in production by the same amount as existing government interventions; and
- *net subsidy equivalent (NSE)* is the net effect of government interventions on the use of resources in an activity. It is the notional amount of money necessary to provide the same net increase in returns to value adding factors as is provided by existing arrangements. The net subsidy equivalent is obtained by adding together the subsidies to output and value adding factors and deducting the tax equivalent on materials.

These measures are used in the estimation of summary rates of assistance:

- *nominal rate of assistance on outputs (NRA)* is the percentage change in gross returns per unit of output relative to the (hypothetical) situation of no assistance. Some forms of assistance (such as tariffs) increase producers returns by raising prices, while others enable producers to sell their goods and services at a price lower than the cost of production (such as product subsidies and government support for the performance of R&D by business);
- *nominal rate of assistance on intermediate inputs (NRM)* is the percentage change in the cost per unit of intermediate input relative to the (hypothetical) situation of no government intervention. Some interventions raise the cost of intermediate inputs (such as tariffs) while others lower them (such as a subsidy to inputs). Measures which assist the production of goods and services used as intermediate inputs but which do not effect the proce of those inputs (such as output subsidies) are not included in the calculation of the NRM; and
- *effective rate of assistance (ERA)* is the percentage increase in returns to an activity's (or industries) value added per unit of output relative to the (hypothetical) situation of no assistance.

These measures are applied in the evaluation of assistance to R&D and industries benefiting from R&D. The relationship between these measures are provided in annex QD2.

Annex QD2: Derivation of nominal and effective assistance to the performance of business R&D

Nominal rate of assistance to output

The nominal rate of assistance for the performance of R&D is defined as the percentage by which producers' gross returns (ie the value of R&D performed) per unit of output are increased by assistance to that activity.[8]

In the case of R&D, nominal rates of assistance have been calculated by comparing the subsidies afforded R&D undertaken by businesses to the cost of performing R&D activity carried out by an organisation on its own behalf, or on behalf of other organisations, institutions or individuals (ie intramural R&D). The cost of R&D service provision represents the unassisted price, since that would be the maximum price that domestic producers could obtain if assistance were removed.[9]

ABS surveys of R&D expenditure provide a readily available measure of the cost of intramural R&D activity. Costs included in those surveys that, when aggregated, provide a measure of the value of production are:

- non-labour current expenditure which includes materials, fuels, rent and leasing expenses, commission and subcontract work expenses, payments for data processing and testing facilities. Excluded are R&D contract expenses where the major research project is conducted by another enterprise;
- labour costs, relating to researchers, technicians and staff directly and indirectly supporting R&D staff. Labour costs include wages, salaries and supplements, inclusive of superannuation payments, fringe benefits tax, payroll tax and workers compensation; and
- capital costs, relating to capital expenditure on land, building and other structures, and vehicles, plant machinery and equipment. Repairs and maintenance and depreciation are excluded.

Non-labour and labour costs are inputs to current production while capital expenditure contributes to the investment in capital for use in production. In order to estimate the value of current production, an estimate of consumption of capital and a return on capital employed should be made. In the absence of comprehensive estimates of capital stocks used in R&D and a measure of depreciation and rate of return on those assets, capital expenditure is used as a proxy to the consumption of capital plus the return on funds employed, ie inputs of capital. Algebraically, the unassisted value of output can therefore be represented as:

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8 When the concept is applied to goods and services entering into inter-enterprise transactions, gross returns refers to the value of sales plus increases in trading stocks.

9 This treatment differs from the treatment of subsidies to import competing goods and services. For those goods and services the unassisted benchmark price is equal to the prevailing market price, that is, the cost of production less the value of the subsidy, since that would be the maximum price that domestic producers could obtain if assistance were removed. The effect of trade orientation on the benchmark price has been discussed earlier in the appendix.

$$UVO = AM + W + K$$

where

UVO is the unassisted value of output derived form cost information;

AM is the cost of inputs of goods and services;

W is labour costs; and

K is the cost of capital inputs.

The value of output so defined is unassisted as it excludes the effect of any government assistance measures on the price paid by the user of the service. It is assumed that R&D performers are price takers, that is, they have no influence on the domestic price of material, labour and capital inputs.

In the case of R&D, the nominal rate of assistance estimates have been calculated by expressing the subsidy provided by R&D support measures as a percentage of the unassisted value of output. Algebraically, that is:

$$NRA = \frac{PS}{UVO},$$

where

NRA is the nominal rate of assistance to research and development;

UVO is defined above; and

PS is the production subsidy afforded to each unit of domestic output by government measures to support the business performance of R&D.

By referring to assistance afforded outputs as the 'gross subsidy equivalent' (GSE), a standard term in assistance evaluation terminology, and defining it as:

$$GSE = PS,$$

the nominal rate formula can be redefined to the general standard:

$$NRA = \frac{GSE}{UVO}.$$

Nominal rate of assistance to material inputs

The non-labour component of current expenditure includes material inputs which are subject to border protection in the form of tariffs. Tariffs raise the cost of material inputs to industry and therefore provide negative assistance to the R&D process. Algebraically, the nominal assistance to materials is:

$$NRM = \frac{TEM}{UVM},$$

where

NRM is the nominal rate of assistance to material inputs (ie intermediate goods and services). A positive value indicates that government support raises the cost of material inputs;

TEM is the tax equivalent on material inputs due to government support measures for activities providing those supplies; and

UVM is the unassisted domestic value of material inputs into R&D production defined as:

$$UVM = AM - TEM ,$$

where AM is defined above.

The tax equivalent on materials is derived from information on the price raising effects of border protection on industry costs. In principle, a detailed mapping should be made between input groups, the source of these - imports or domestic supplies - and the price effects of government measures on the cost of commodities from each of those sources. In practice, detailed information about the commodity composition of material inputs to R&D is not available and proxy measures based on total border assistance to manufacturing industry are adopted.

Effective rate of assistance

The effective rate of assistance is defined as the proportional increase in returns to value adding factors accruing to R&D providers due to the assistance. A subsidy raises the value added accruing to R&D factors (ie labour and capital) relative to the assisted cost incurred by users (ie returns to labour and capital less the value of the subsidy to R&D). This notion can be represented algebraically[10] as:

$$ERA = \frac{|VA - UVA|}{UVA}.$$

where

ERA is the effective rate of assistance. It is defined as positive when assistance provides a net incentive to employ value adding factors in an activity and is otherwise negative;

UVA is the estimated unassisted value added at market prices. It is defined as:

$$UVA = W + K,$$

where $W \text{ and } K$ are defined above;

VA is value added at assisted market prices. It is defined as,

$$VA = UVA - GSE + TEM .$$

Assistance to the performance of R&D can also be affected through programs that directly benefit the employment of value adding factors (eg labour market interventions, and a special depreciation allowance on assets used in R&D activity or concessional finance). In principle, allowance also needs to

[10] The use of absolute values in the algebraic presentation of assistance calculations is novel and not usually employed. The convention is introduced here because the subsidy to R&D lowers value added from the unassisted case to the assisted case (ie the market price is less than factor cost). In the case of the more regularly reported border protection, assisted value added is raised relative to unassisted value added and the subsidy equivalent of the border protection measures (eg tariffs on imports). Application of the absolute values convention in the assessment of assistance to non-traded goods and services avoids reporting a negative subsidy equivalent from government support measures.

be made in the formal exposition of the assistance model for support through such measures. The more general definition of the effective rate which encompasses the effect of those additional measures is:

$$ERA = \frac{|VA - UVA| + SVA}{UVA},$$

where the additional term SVA is assistance to value adding factors through assistance to labour and capital inputs or by income transfers.[11]

By referring to assistance afforded value adding factors as the 'net subsidy equivalent' (NSE) to an industry, and defining it as:

$$NSE = GSE - TEM + SVA,$$

the effective rate formula can be simplified to:

$$ERA = \frac{NSE}{UVA}.$$

[11] From this definition, an alternative version of the effective rate formula can be derived based on nominal rates of assistance calculation. This is,

$$g = \frac{df - x.dm + i}{1 - x},$$

where df is the nominal rate of assistance; dm is the nominal rate of assistance on material and other inputs; x is the input to output ratio expressed in unassisted prices and i is assistance to value adding factors. This form is often used in effective rate calculations.

Annex QD3: Derivation of nominal and effective assistance to industries benefiting from R&D

In this section, an overall framework of assistance to industry is developed according to the nominal and effective rates model. In the model industry assistance through R&D support is one element in the level of support afforded industry. Assistance is also provided to industry through tariffs, subsidies and other measures.

The concepts of nominal and effective rates of assistance are applied in generality in order to take into account the effects of R&D support as well as other industry support measures. The definition of nominal and effective assistance relates to industries providing marketed goods and services.

The economy-wide orientation of this study places additional requirements on industry information about outputs and industry inputs. It is desirable to have this information for all industries on a common basis using common concepts and definitions. Neither the Commission's agriculture nor manufacturing assistance measurement systems could easily be adapted to provide industry information on that basis. For the R&D study, industry activity levels and industry costs are provided by ABS input-output tables. The latest tables available are for the reference year 1989-90 (ABS 1994c). The input and output information provided in those tables has been projected forward to 1990-91, the benchmark year for this study, on the basis of trends in factor payments provided in the Australian National Accounts (ABS 1993b).

Assistance to output

As defined above the nominal rate of assistance for an activity is defined as the percentage by which producers' gross returns per unit of output are increased by assistance to that activity. Examples of interventions that alter output returns include:

- tariffs
- production subsidies
- local content schemes
- quantitative import restrictions
- export subsidies or taxes
- variable levies

The assistance afforded output is the notional amount of money that would give the same amount of assistance to an activity that is provided by existing government interventions. Algebraically,

$$GSE = \left| AP - UP \right|$$

where,

GSE is the gross subsidy equivalent of assistance. It is defined to be positive when assistance provides a positive incentive to output and is otherwise negative;

AP is the assisted value of Australian production, and

UP is the unassisted value of production.

For the traded goods sectors, the GSE would increase gross returns as government intervention enables the cost of production per unit of output to exceed the international reference price. For the non-traded goods sectors, positive assistance would lower the selling cost of the commodity relative to the cost of inputs to production (see annex 2).

The nominal rate of assistance on outputs (*NRA*) is the GSE expressed as a percentage of the value of unassisted production, that is,

$$NRA = \frac{GSE}{UP} \ .$$

Assistance to material and service inputs

The nominal rate of assistance on intermediate inputs is the percentage increase in the cost of intermediate inputs per unit of input relative to a situation of no assistance. Examples of interventions that alter intermediate input costs are:

- tariffs
- local content schemes
- commodity taxes

which act to raise the cost of intermediate inputs, and

- input subsidies and
- output subsidies to non-traded goods and services

which tend to lower the cost of intermediate goods and services.

The assistance afforded intermediate inputs is the notional amount of money that would increase (or lower) the cost of intermediate inputs by the same amount as the existing government interventions. Algebraically,

$$TEM = AM - UM$$

where

TEM is the tax equivalent on material and service inputs due to government support measures for activities providing those supplies. Its measure is positive when assistance increases the price of intermediate inputs relative to the unassisted case and otherwise negative;

UM is the unassisted value of intermediate inputs into industry; and

AM is the assisted value of material and service inputs.

The nominal rate of assistance to intermediate inputs (*NRM*) is the tax equivalent on materials (*TEM*) divided by the unassisted value of inputs (*UM*), that is,

$$NRM = \frac{TEM}{UM} \ .$$

Assistance to value adding factors

The assistance effects of government interventions that directly target returns to the value adding factors of labour, fixed capital, land and intangible capital (such as R&D knowledge) in particular activities may be measured as the notional amount of money, or subsidy equivalent, necessary to yield the same increase in returns to value adding factors as is provided by assistance. Assistance to value adding factors that alters the returns to labour and owners of capital include:

- income tax concessions
- concessional credit
- special depreciation allowances
- special employment allowances.

In the current study, government finding to R&D is treated as assistance to value adding factors. The assistance is afforded to the industry in the period in which the concession is conferred.

The subsidy equivalent to value adding factors is labelled *SVA*.

Net assistance to value added and the effective rate of assistance

The net incentive effect of all forms of intervention on the use of resources in a particular activity is indicated by adding up the assistance to outputs, intermediate inputs and value adding factors. The total subsidy equivalent is the notional amount of money necessary to provide the same increase in returns to value adding factors as is provided by existing assistance. The net subsidy to industry is defined as,

$$NSE = GSE - TEM + SVA$$

The effective rate of assistance is defined as the proportional increase in returns to value added by an activity, due to the assistance. This notion can be represented algebraically as,

$$ERA = \frac{NSE}{UVA} \ .$$

where

unassisted value added is defined as the unassisted value of production less the unassisted value of intermediate inputs, that is,

$$UVA = UP - UM$$

APPENDIX QE: STATE GOVERNMENT INVOLVEMENT IN R&D

QE.1 Introduction and summary

The documentation of Commonwealth Government support for R&D is based on a detailed study of the expenditures of Commonwealth R&D agencies and programs (IC 1995b). Similar, comprehensive information is not readily available on State R&D programs. Some information is available from ABS R&D surveys about the level of State funding and expenditure on R&D. In addition, most States made submissions to the inquiry which included summary information on their R&D policy framework and their involvement in R&D. Tasmania and the Northern Territory did not provide data to the Commission.

The approach taken in this appendix is to draw on each of the above sources, in addition to the Commission's analysis, to provide an overview of State R&D activities. The reference year for the analysis is 1992–93, as this is the year for which most State data are available. Nevertheless, in order to complete the framework, in some cases adjacent year data have been used as a proxy for 1992–93.

According to ABS data, the States contributed $616 million to R&D expenditure in 1992–93 through general government (for example, departmental) R&D programs (table QE1). The performance of R&D by State government departments forms part of their overall involvement in R&D. Other components include R&D performed by State trading enterprises, contracting out of R&D, involvement in cooperative arrangements (for example, through CRCs) and grants to business (and others) to perform R&D.

Submissions made by five States and the ACT to this inquiry looked at their involvement in R&D in this broader context. From that information, the Commission estimates that their involvement in R&D in 1992–93 was valued at around $701 million (table QE1), funded jointly through State budgets and external sources. About one-quarter of this total ($190 million) was funded form external sources, with the remainder ($511 million) funded from State Consolidated Revenue Funds (CRFs) and the balance sheets of State trading enterprises.

While the totals reported from State (including the ACT) submissions represent a substantial coverage of State R&D, some differences in data concepts mean that the estimates are not strictly comparable with those of the ABS. For example, the ABS reports that $244 million R&D was performed by public business enterprises operating from State locations (table QE1). However, this reported total includes both Commonwealth and State owned organisations and cannot be used as a direct proxy for the involvement of State business enterprises in R&D. The broader coverage of ABS data relative to State involvement may be an important contributor to data differences for NSW and Victoria with respect to total R&D by State of location. Secondly, State funding of R&D reported in submissions include transfers to businesses and others to undertake R&D; the costs of contracting out the R&D task; and contributions to cooperative research programs. The performance of R&D funded in these ways by State R&D programs would not be attributed (correctly) to the performance of R&D by State general government agencies or business enterprises in ABS series.

The differences between ABS data and the coverage of R&D provided in State submissions reflect the difficulty in maintaining consistent information systems about the performance and funding of R&D. Notwithstanding differences evident in table QE1, the State information provides a reasonable basis for reviewing the nature of State involvement in R&D and the funding afforded those programs.

Based on the information provided to the Commission, this study also examines more closely State funding (as opposed to total outlays or performance) of R&D by departmental group. A summary is presented in table QE2.

There are a number of common elements that emerge from the State submissions.

State government R&D resources are concentrated in departments and agencies with responsibility for agricultural and other primary industry matters (table QE2). Overall, agriculture, forestry and fishing accounts for around 55 per cent of State funding to R&D. A number of submissions grouped agricultural, natural resource and environmental R&D together to emphasise the collective importance of natural resource and environmental issues to State involvement in R&D. When this is done, those activities comprise over two-thirds of State support for R&D.

The importance of agricultural R&D varies between States. For example, agricultural research in NSW, Queensland and Western Australia accounts for around two-thirds of State R&D funding, and approximately 50 per cent in South Australia. In Victoria, however, agricultural research accounts for around 25 per cent of R&D funding.

Table QE1: **Comparison of ABS and submission data on expenditure and funding of State government R&D,[a]** 1992-93 ($ million)

	NSW	*Vic.*	*Qld*	*WA*	*SA*	*ACT*	*Other States & Terr.*	*Total*
ABS R&D surveys								
State general government R&D expenditure by State of location	148.4	124.7	149.2	79.5	69.4	0.1	44.3	615.5
Public business enterprise R&D expenditure by State of location	107.2	118.9	3.4	3.7	9.2	na	1.5	243.9
Total	**255.6**	**243.7**	**152.5**	**83.2**	**78.6**	**0.1**	**45.8**	**859.5**
Inquiry submissions								
R&D outlays by state authorities	215.6	151.4	164.8	88.3	79.9	0.5	na	700.5
R&D funded from State gov't sources	160.6	126.7	114.6	69.5	38.8	0.5	na	510.7
Funding from Commonwealth & other sources	55.0	24.7	50.3	18.8	41.1	na	na	189.8

na not available.

a Data are generally available for 1992–93. However, some State and some departmental data are not available for this year and information from an adjacent year is taken as a proxy for 1992–93. Source information is shown in detail in the discussion of the respective States. Data for Tasmania and the Northern Territory were not provided to the inquiry.

Sources: ABS Cat. No. 8104.0, table 7; ABS Cat. No. 8109.0, table 7; Commission analysis of State submissions.

The remainder of the State funding is mainly absorbed by utilities, transport and community service and health activities. In 1992–93, these areas accounted for around $140 million or 26 per cent of State government funding of R&D. Of all the States, Victoria reported the largest funding to R&D in these areas.

Complementing funding available from State budgets are the funds received from external sources — principally the Commonwealth Government. While there is a significant degree of variation between the States, common elements to emerge are that: in most States, rural research is predominantly funded from State resources, although there is an important contribution from rural RDCs; and the Commonwealth makes substantial (and sometimes the main) funding contribution to environmental research undertaken by the States.

With respect to rural R&D, the Commission's analysis (IC 1995a) of the activities of rural RDCs shows that State R&D departments are major performers of R&D projects commissioned by the RDCs. For example, the analysis shows that over the 1991–93 period, 40 per cent of projects sponsored by the RDCs were awarded to State departments of agriculture.

The division of funds between in-house and out-sourced R&D differs between areas of responsibility. Most R&D relating to agriculture is performed in-house by State departments of agriculture and other authorities. On the other hand, there is a tendency for R&D in the areas of transport and utilities to be contracted out to organisations such as the CSIRO and universities. Health, environmental protection agencies and some community services both provide and outsource their R&D requirements.

Table QE2: **State Government funding of R&D by government department or agency, 1992-93**[a] ($ million)

Department function or agency	*New South Wales*	*Victoria*	*Queensland*	*Western Australia*	*South Australia*	*ACT*	*Total*
Agriculture, forestry and fishing	108.8	33.0	78.3	40.7	18.0	-	278.8
Mining and energy resources	4.9	9.0	11.3	11.4	-	-	36.6
Environmental protection	3.0	8.7	6.0	8.4	0.7	0.4	27.2
Utilities	21.1	36.0	-	3.2	4.0	-	64.3
Transport	13.3	3.0	0.8	-	1.3	-	18.4
Community services and health	8.6	22.0	9.2	5.8	12.1	..	57.7
Public works	0.9	-	-	-	2.5	0.1	3.5
Business services	-	14.0	6.3	-	0.2	-	20.5
Tourism	-	-	0.1	-	0.1	-	0.2
Other	-	1.0	2.6	-	-	-	3.6
Total	**160.6**	**126.7**	**114.6**	**69.5**	**38.8**	**0.5**	**510.7**

\- Nil or not provided.

a Data is generally available for 1992–93. However, for some States and some departments data is not available for this year and information from an adjacent year is taken as a proxy for 1992–93. Source information is shown in detail in the discussion of the respective States. Data for Tasmania and the Northern Territory were not available.

Source: Commission analysis of State submissions.

The motivation behind State research involvement is generally towards solving particular State management problems. Thus, when there is an involvement in basic research, an applied management problem will normally be the underlying motivation. Where comments were provided on developments in priority setting, these often related to the adoption of a more applied focus, in terms of departmental priorities, to the efforts of individual researchers.

In general, most States described their R&D system in terms that showed that research priorities are implicitly set through the State budgetary process in which funds are allocated to individual departmental portfolios. Detailed research programs are established within the portfolios using a variety of priority-setting procedures. An exception is South Australia, which in 1993 established the South Australian Research and Development Institute (SARDI) to coordinate, promote and fund public sector research in the State. Though SARDI initially has a primary industry focus, it is envisaged that in the longer term it will have a wider role in research and research management in South Australia. The South Australian Development Council (SADC) is to establish economic development priorities and subsequent overall R&D objectives for the State, and SARDI will be responsible for implementing and facilitating those objectives.

Within portfolios, priority-setting procedures often involve expert committees or councils comprised of departmental and industry representatives. Cost-benefit assessments are used by a number of States as a core part of the priority-setting process, particularly in the primary industry areas. Nevertheless, administrative structures supporting priority setting differ between States. For example, in the Victorian Department of Agriculture a centralised approach is adopted to departmental priority setting. A chief scientist has been appointed to coordinate research within the department and industry teams, comprised of departmental and industry representatives, have just completed a five-year forward plan for R&D. On the other hand, the Western Australia Department adopts a more decentralised approach. In that State, there is no dedicated research unit(s): research responsibility is integrated into commodity programs managed by a program leader. Specialist commodity committees have been appointed to assist in the management task.

The CRC program was mentioned frequently in State submissions. The program was reported as directing State research efforts through the requirement for members of individual CRCs to contribute funds or resources. They also provided access to additional research programs that would not be available within stand-alone State programs.

An overview of R&D spending by States is provided below for New South Wales, Victoria, Queensland, Western Australia, South Australia, and the Australian Capital Territory. Although no quantitative information is provided for Tasmania, a submission from that State provides information on priority setting which is included in this analysis. No submission was received from the

Northern Territory and it therefore has not been possible to include it in the analysis.

QE.2 New South Wales

The main source of information about government involvement comes from a snapshot survey of the largest providers of R&D in NSW.

The survey looked at the R&D involvement of 17 of the largest government providers of R&D. The survey and follow up interviews of eleven organisations, were undertaken jointly by the Office of Public Management and Office of Economic Development within the NSW Premier's Department. The survey collected information about the current level of government R&D in NSW and about R&D priority-setting procedures (Sub. 264, p. 1).

In 1992–93, total R&D funds managed by the NSW Government departments and agencies surveyed amounted to around $216 million (Sub. 264, p. 2). Of this total, $161 million was sourced from the State Government Consolidated Fund and public trading enterprise balance sheets (table QE2). The remainder ($55 million) came from other sources such as Commonwealth and industry R&D funding bodies, including rural RDCs (Sub. 264 p. 4). NSW Government funding of R&D increased from 1992–93 levels by over $7 million, or 4.5 per cent, to $168 in 1993–94 (table QE3).

Coverage of State involvement in R&D

The NSW submission indicated that its estimate of the R&D involvement of State authorities would, if anything, understate the total involvement. A number of reasons were given for this assessment:

- not all State agencies involved in R&D were covered by the survey, although the survey attempted to cover the main R&D providers;
- agencies account for their R&D in different ways. For instance, the Department of Agriculture, which is a major direct provider of research and extension services, includes a portion of its overhead in its R&D costs; whereas, the Office of Energy, which achieves its objectives through the administration of the State Energy Research and Development Fund (SERDF) includes only moneys transferred to the fund;
- some agencies (for example, the Health Department) do not have systems to identify and record R&D activity accurately;

Table QE3: **State government funding of R&D, New South Wales,[a] 1992-93 and 1993-94** ($ million)

Agency	*1992-93*		*1992-93*	
	$m	*per cent*	*$m*	*per cent*
Agriculture, forestry and fisheries				
Department of Conservation & Land Management	3.0	1.9	3.0	1.8
Department of Agriculture	95.4	59.5	86.5	51.6
Department of Fisheries	4.3	2.7	4.2	2.5
Department of Water Resources	6.1	3.8	6.1	3.6
Subtotal	**108.8**	**67.8**	**99.7**	**59.5**
Mining and energy resources				
Energy	2.3	1.4	1.0	0.6
Mineral Resources	2.6	1.6	3.0	1.8
Subtotal	**4.9**	**3.0**	**4.0**	**2.4**
Environmental protection				
Environment Protection Authority	0.5	0.3	1.2	0.7
National Parks and Wildlife Service	2.5	1.6	3.3	2.0
Subtotal	**3.0**	**1.9**	**4.5**	**2.7**
Utilities				
Sydney Electricity	1.3	0.8	1.3	0.7
Prospect Electricity	0.1	0.1	0.2	0.1
Pacific Power	6.7	4.2	14.1	8.4
Water Board	13.0	8.1	8.5	5.1
Subtotal	**21.1**	**13.2**	**24.0**	**14.3**
Transport				
Road Transport Authority	13.3	8.3	12.9	7.7
Public works				
Department of Public Works	0.9	0.5	1.1	0.7
Community services and health				
Health	7.6	4.7	21.0	12.5
Waste Services	1.0	0.6	0.5	0.3
Subtotal	**8.5**	**5.3**	**21.5**	**12.8**
Total	**160.5**	**100.0**	**167.8**	**100.0**

a NSW Government funding of R&D expenditure was estimated by deducting external funding of expenditure from total expenditure on R&D. Estimates reported relate to general government agencies (eg departments) and public trading enterprises (eg utilities) that are the main funders of R&D in NSW. Some of the smaller funders are not included in the NSW Government study on which these estimates are based.
Sources: Commission estimates based on NSW Government, Sub. 264, p. 2.

- despite formal definitions of R&D, there is a lack of clarity with respect to expenditures that should be recorded as R&D, particularly at the development/implementation end of the spectrum; and
- spending agencies perceive that central coordinating agencies (for example, State treasuries) see R&D as a 'soft' item of expenditure and may attempt to disguise it (for example, as consultancies on contract) (Sub. 264 p. 3).

Another source of information about R&D in NSW is provided by ABS R&D statistics. The ABS estimates that State funded research in NSW by general government organisations was $148 million in 1992–93, with a further $107 million by public business enterprises operating in NSW (table QE1). The total of the two ($256 million) is a fraction above the estimated State involvement in R&D reported in the NSW Government submission. The two sets of numbers may be regarded as being broadly consistent: the NSW submission only covered the State's main R&D involvement; some business enterprise activity could relate to Commonwealth enterprises operating in NSW (which tends to raise ABS estimates relative to NSW Government estimates); and the State estimates contain some elements of R&D contracted out (which tends to raise NSW Government estimates relative to those of the ABS).

The NSW submission's estimates of funding and accompanying discussion are the central reference in the following discussion.

Concentration of State involvement in R&D

NSW State funding of R&D is dominated by five organisations. By far the largest contributor is the Department of Agriculture which alone manages over half of the R&D funds analysed. The other four organisations individually contributed more than 5 per cent of State funding: these organisations include the Health Department, Pacific Power, the Road Transport Authority, and the Water Board. Collectively, these organisations manage approximately 85 per cent of the NSW State funds.

The concentration of funding can also be examined by broad area of responsibility. There is a concentration of State R&D funding on agricultural, natural resource and environmental issues. Around two-thirds of State funding is directed to departments and agencies with direct responsibilities in these areas (table QE3). The concentration of activity in these areas is further enhanced:

- by the concentration of outside funding towards these areas. For example, the NSW submission draws attention to the fact that around 75 per cent of

R&D funds managed by the State (regardless of source) is concerned with such issues (Sub. 264, p. 2); and

- other agencies (for example, Pacific Power and Waste Services) that do not have direct responsibilities in these areas nevertheless have significant resource and environmental components in their activities (Sub. 264, p. 2). Utilities taken together account for around 14 per cent of State involvement in R&D.

Notwithstanding the State's welfare and educational responsibilities, virtually no social or educational research was reported in the snapshot survey. Furthermore, little R&D into secondary or tertiary industry was reported (Sub. 264, p. 16).

Sources of funds

The source of funds for R&D programs varies significantly from agency to agency. State funding contributes more than 75 per cent of funding towards R&D expenditures by organisations as diverse as the Department of Agriculture, Pacific Power, Conservation and Land Management (CaLM), Waste Services, Mineral Resources and the power utilities of Sydney and Prospect. On the other hand, external sources form the major sources of funds for R&D expenditure undertaken by the Water Board, Departments of Water Resources, Fisheries, Energy, Public Works and the Environmental Protection Authority (EPA). The main external sources of funds are bodies such as the rural RDCs (Sub. 264 p. 4).

Funding of internal and external R&D

Funds are used to undertake in-house R&D and to contract others to undertake R&D tasks for the State Government. The departments of Agriculture, Health and Fisheries, which control about 65 per cent of total NSW State R&D expenditure, conduct their R&D either in-house or through State funded institutes. At the other end of the spectrum, agencies such as the Office of Energy, Pacific Power, Road Transport Authority and Sydney Electricity predominantly fund others to undertake the R&D that they require. Other agencies such as Health, CaLM, EPA and Waste Services, both provide and outsource their R&D requirements depending on the task and availability of in-house expertise/resources (Sub. 264, p. 4).

Overall, the NSW Government carries out much of its own R&D, rather than outsourcing its research requirements (Sub. 264, p. 14).

The balance between applied and basic research

NSW Government agencies spend around 95 per cent of their R&D budget on solving specific problems rather than basic research. The small proportion that is spent on basic research is specifically undertaken in order to eventually address known applied problems (Sub. 264, p. 4). This observation was reiterated in the submission by the NSW Science and Technology Council which noted:

> ... the States, being closer in some respects to users of R&D such as primary producers and SMEs, are primarily concerned with applied research and its implementation through extension services in contrast to many Commonwealth agencies such as CSIRO (Sub. 446, p. 1).

State priority setting

Broadly, priority setting in NSW has traditionally been decentralised to departments and agencies with these organisations undertaking R&D in conformity with portfolio responsibilities. In the case of public trading enterprises, R&D is oriented to the business objectives of the enterprise.

Within the decentralised framework, the New South Wales Science and Technology Council (NSWSTC) has been established to provide policy advice to the NSW Government on matters relating to science and technology (Sub. 260). Within portfolios a variety of priority-setting approaches prevail with most agencies having internal planning mechanisms to set priorities (Sub. 264 p. 5). For example:

- the Department of Agriculture has a two stage R&D priority-setting process. The first stage looks at corporate objectives and the second looks at the relationship between the project and the priorities of various national industry bodies (Sub. 264, p. 5);
- in an attempt to improve the uptake of research findings, the NSW Office of Energy (OOE) established the Energy Research Advisory Committee (ERAC) in 1992. ERAC involves end users in identifying priority areas and strategies for energy research and development in NSW as a basis for funding energy R&D projects through the State Energy Research and Development Fund (SERDF) (Sub. 260, p. 9);
- the Natural Resources Audit Council (NRAC) has allocated $5.8 million to research in various agencies as part of an effort to improve inter-agency cooperation (Sub. 264, p. 16);
- however, it was noted that the Health Department has no systematic priority-setting mechanisms.

Overall:

> It is apparent from the survey that agencies set their own priorities, on different bases, in different ways and with varying degrees of rigour (Sub. 264, p. 16).

Nevertheless, the NSW State Government survey also suggested that NSW departments and agencies have, in recent years, attempted to improve both their priority-setting processes and their R&D project management procedures. This improvement has been oriented to linking R&D to organisational goals rather than the interests of researchers (Sub. 264, p. 5). However, R&D programs remain mostly agency and/or issue specific and it has been concluded that there is a lack of central guidance mechanisms and few State based coordinating programs to ensure a cooperative approach between agencies dealing with allied problems (Sub. 264, p. 16).

However, the wider R&D policy environment also influences State R&D involvement. For example:

- about 27 per cent of R&D funds comes from non-State sources — mostly from bodies such as the rural RDCs (Sub. 264, p. 4). The R&D funding decisions of these organisations impacts on the conduct of R&D in NSW State organisations. In the case of rural research:

  > ... the RDCs are increasingly driving the agenda in agricultural research (Sub. 446, p. 2); and

- the process of matching funds is being used to channel research activity and priorities:

  > ... it was apparent that State funds were also being used to match other private or non-State R&D funds. In this way State funds are being used to influence others to spend their funds on R&D projects of benefit to the State (Sub. 264, p. 4).

  For example, the Department of Agriculture assists in the funding of three Cooperative Research Centres in the Tamworth–Armidale region.

QE.3 Victoria

The main source of information about Victorian Government involvement in R&D comes from a Victorian Government study of State funding and conducting agencies (Sub. 241).

The study looked at thirteen of the largest government organisations involved in R&D and some minor providers. Information about the level of R&D involvement in 1991–92 (or an adjacent year) and the nature of that involvement was provided.

In 1991–92, total R&D managed by Victorian State organisations amounted to $151 million (Sub. 241, p. 55). Of this total, $127 million (table QE4) was sourced from State funds while a further $25 million was sourced from Commonwealth and other providers of R&D.[1]

Coverage of State involvement in R&D

The Victorian Government included in its analysis Commonwealth and other funding to universities and other educational institutions, and medical research agencies (see footnote 1). These grants have been excluded from this analysis in order to achieve consistency with the data from other States. However, the different treatment of Commonwealth education and health expenditures between the States indicates varying perceptions of the degree to which State Government agencies exercise management or control of these funds.

In ABS statistics, the estimated State contribution to general government R&D in Victoria is $124.7 million for 1992–93 and there is a further public sector contribution to business enterprise R&D expenditure in Victoria of $119 million (table QE1). The sum of $244 million is well over the estimate of $151 reported in table QE4 for 1991–92. Business enterprise R&D could contain contributions from Commonwealth agencies and therefore overstate State activity. In addition, the ABS estimates relate to a later year and could reflect some growth. After taking these two factors into account, the Victorian Government estimate of State management/control of R&D activity appears to be conservative.

Despite this reservation, State Government funding as reported in the submission is used to consider the scope and nature of State involvement in R&D.

Concentration of State involvement in R&D

The five major research funding and conducting agencies in Victoria are the Department of Agriculture, State Electricity Commission, the Department of Business and Employment, Melbourne Water and the Department of Conservation and Natural Resources. The Department of Agriculture is the largest contributor by a substantial margin, providing around one-quarter of total expenditure. Together the five largest R&D funders account for over two-thirds of State managed R&D funding.

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1 These totals exclude Commonwealth and other funding to universities and other educational institutions, and medical research agencies, which amounted to $199 million (1991) and $113 million (1991–92), respectively.

Funding for agricultural, natural resource and environmental responsibilities directly accounted for around one-third of total funding, while a further 28 per cent of funding is contributed by utilities which have indirect responsibilities in these areas (for example, R&D into the use of brown coal for the generation of electricity and the supply of irrigation water).

Table QE4: **State government funding of R&D, Victoria, 1991-92[a]** ($ million)

Agency	*$m*	*per cent*
Agriculture		
Department of Agriculture	33.0	26.0
Mineral and energy resources		
Coal Corporation of Victorian (1990-91)	1.0	0.8
Department of Energy and Minerals (1990-91)	4.0	3.2
Subtotal	**5.0**	**3.9**
Environmental protection		
Department of Conservation and Natural Resources	8.0	6.3
Environmental Protection Authority (1990-91)	0.7	0.6
Subtotal	**8.7**	**6.9**
Utilities		
Melbourne Water (1990-91)	11.0	8.7
Rural Water Corporation (1990-91)	1.0	0.8
State Electricity Commission (1990-91)	24.0	18.9
Gas and Fuel Corporation (1990-91)	4.0	3.2
Subtotal	**40.0**	**31.6**
Transport		
VicRoads (1993-94)	3.0	2.4
Business services		
Department of Business and Employment	14.0	11.0
Community services and health		
Education (1991)	10.0	7.9
Medical research agencies	12.0	9.5
Subtotal	**22.0**	**17.4**
Other	1.0	0.8
Total	**126.7**	**100.0**

a Data are for the years 1991–92 unless otherwise stated.
Source: Commission estimates based on Victorian Government, Sub. 241, p. 55.

Sources of funds

With a number of prominent exceptions, most Victorian Government R&D is funded from the State Budget (or in the case of public trading enterprises, company balance sheets). Nevertheless about one-fifth of funding in agricultural research is provided by the Commonwealth with a further 15 per cent coming from other non-State government sources (Sub. 241, p. 55). In addition, nearly one-quarter of funds for R&D managed by the Department of Conservation and Natural Resources comes from Commonwealth sources.

Funding of internal and external R&D

There is a mixture of approaches taken by the various State research organisations to the division of research between in-house activity, contracting out and cooperative research.

Within the group of the main State researchers, the Departments of Agriculture, and Conservation and Natural Resources, and the SEC maintain large research establishments. Agriculture employs 600 research scientists, Conservation and Natural Resources 230 researchers, and the SEC operates the Herman Research Laboratory that employs 100.

On the other hand, Melbourne Water and the Rural Water Corporation conduct their R&D in cooperation with or through other research providers. For example, Melbourne Water is involved in cooperative programs with the CSIRO, the Urban Water Research Association of Australia, the CRCs for Catchment Hydrology and Freshwater Ecology and the Centre for Water Quality Research. In the area of cooperative research, Victorian Government organisations which have large in-house R&D programs are also involved with cooperative programs (for example, the SEC is involved in the CRC for New Technologies for Power Generation of Low-rank Coal at Monash University).

The Department of Business and Employment delivers a range of assistance programs targeted at private sector R&D (Sub. 241, p. 46). To do this, the Department funds collaborative market-driven R&D and training facilities in the areas of marine engineering, information technology, telecommunications and automotive technology (Sub. 241, p. 61). Recently, the Strategic Industry Research Foundation (SIRF) was established to:

> ... facilitate and support industry driven collaborative research and development projects in technology areas with long term benefits for Victoria and Australia (Sub. 241, p. 61).

Overall, because of the large research units managed by the biggest State R&D organisations, Victorian Government R&D is predominantly carried out in-house. Nevertheless, a significant minority is contracted out or undertaken in cooperative programs.

Type of research and principal objectives

R&D is managed by departments with industry/operational responsibilities. In this environment, any basic research undertaken is most likely to be directed towards some specific problem or area. For example:

- the Department of Agriculture:

  ... conducts research into problems and opportunities facing all major agricultural, grazing and horticultural industries in the State as well as some new and developing industries (Sub. 241, p. 58);

- the Department of Business and Employment's:

  ... funding of research and development is aimed at assisting business to improve competitiveness and productivity at the enterprise level and improving efficiency of the business infrastructure (Sub. 241, p. 61);

- the Herman Research Laboratory, within the former SEC (now Generation Victoria):

  ... has conducted strategic research programs aimed at substantially increasing the efficiency of electricity generation from brown coal. Environmental issues are also researched (Sub. 241, p. 60); and

- Melbourne Water:

  ... views R&D as an essential strategic business activity (Sub. 241, p. 62).

State priority setting

Priority setting is undertaken within the context of portfolio and business responsibilities. Although little information was provided about organisational priority-setting procedures, a number of examples provide some insight:

- the Department of Agriculture employs a Chief Scientist who is responsible for:

  ... the quality and direction of research and development in the Department. He is supported by a small science unit. Ten industry teams have been appointed to coordinate research and development for each industry and improve quality. In the past year and a half each team has worked with industry to develop a five year program plan for R&D (Sub. 241, p. 58);

- in the health area, the introduction of the casemix funding formula has enabled research expenditure in the public hospital system to be unbundled from other service provision expenditures. A research allocation is now part of the funding formula (Sub. 241, p. 58); and

- the SIRF has an independent board consisting of industry representatives. There is no government representation of the board. Under the Funding Agreement with government, the Minister must approve the organisation's Strategic Plan However, the Board has full authority to assess activities and projects on a commercial basis and allocate resources (Sub. 241, p. 70).

Victorian Government involvement in R&D is also influenced by national R&D policies. For example, Commonwealth funding is an important source of finance for research into the areas of agriculture, natural resources and the environment. In addition, Victorian based researchers are involved in the operation of 16 CRCs with a further two approved and in the process of being established (Sub. 241, p. 54). Other inter governmental commitments are also reported to influence research priorities: for example, the State reported contributions to the Australian Accounting Research Foundation, the Federalism Research Centre, the Australian Council for Education Research (ACER), the National Institute of Forensic Science, the National Police Research Unit and the Australian Roads Research Board.

QE.4 Queensland

The Queensland Government submissions (Subs 253 & 257) were based on input from industry, higher education facilities and several departments which are actively involved in R&D activities. The data provided were sourced from budget papers and annual reports of departments and government agencies conducting R&D.

Data from Queensland Government agencies and departments reveal that in 1992–93 R&D funds managed by the Queensland Government totalled $165 million (Sub. 253, attachment 1). Of this total, $115 million was State funded while a further $50 million was externally funded (table QE5).

Coverage of State involvement in R&D

The Queensland Government submission provides information on all research covered by State Government programs (Sub. 253, p. 2).

Information on general government involvement in R&D in Queensland is also available from the ABS which estimates that general government R&D in Queensland was $149 million in 1992–93, with a further $3 million being provided by public business enterprises operating in Queensland (table QE1).

The sum of these two State R&D contributions, ($153 million) is comparable with the total R&D expenditure ($165 million) reported by the Queensland Government. Discrepancies between ABS and Queensland Government estimates of R&D may result from definitional differences but the two estimates are broadly consistent.

The Queensland Government results are used below to report on State Government involvement in R&D.

Table QE5: **State government funding of R&D, Queensland, 1992-93** ($ million)

Agency	*$m*	*per cent*
Agriculture, forestry and fisheries		
Primary Industries	78.3	68.4
Minerals and energy resources		
Minerals and Energy	11.3	9.8
Environmental protection		
Environment and Heritage	3.7	3.3
Lands	2.3	2.0
Subtotal	**6.1**	**5.3**
Transport		
Transport	0.8	0.7
Business services		
Business Industry and Regional Development	6.3	5.5
Community services and health		
Administrative Services Department	0.6	0.5
Department of Housing, Local Government and Planning	1.6	1.4
Department of Police and Emergency Services	0.6	0.6
Health	6.4	5.6
Subtotal	**9.1**	**8.0**
Tourism		
Department of Tourism, Sport and Racing	0.1	0.1
Other		
Queensland Treasury	0.5	0.4
Department of the Premier, Economic and Trade Development	2.1	1.8
Subtotal	**2.6**	**2.2**
Total	**114.5**	**100.0**

Source: Commission estimates based on Queensland Government, Sub. 253, attachment 1.

Concentration of State involvement in R&D

The Department of Primary Industries is the largest contributor to State involvement in R&D. Its R&D spending amounted to $78 million in 1992–93 or 68 per cent of total funding of R&D by the Queensland Government. The next most significant Queensland research agency was the Department of Minerals and Energy which accounted for $11 million or 9.8 per cent of total funding in 1992–93. The significant amount of State research funds allocated to these departments reflects Queensland's strong dependence on its resource-based sectors for much of its wealth generation (Sub. 257, p. 1).

Sources of funds

In 1992–93, the Queensland Government funded around 70 per cent of all State Government R&D activities, two-thirds of which was allocated to the Queensland Department of Primary Industries. In addition, around $50 million was received from external sources for Queensland Government departments and agencies to undertake R&D activities (Sub. 257, p. 5). The main recipients of external funding were the Departments of Primary Industries and Health, with each organisation receiving around $20 million in 1992–93. For Queensland Health, this level of funding constituted about 75 per cent of research funding while for the Department of Primary Industries, it constituted about 20 per cent. External funding to Primary Industries is dominated by rural RDCs. External funding is also significant for the Departments of Environment and Heritage (55 per cent) and Lands (36 per cent).

Current funding arrangements are being changed in favour of a greater contribution from external sources:

> Following the Review of DPI Rural Research (1993), a commitment by DPI has been made to increase the contribution to the research carried out by the Department coming from external sources. This target applies particularly to mature industries — the specific needs of new and infant industries and resource sustainability justifying variations in funding levels associated with such activities (Sub 253, p. 4).

Funding of internal and external R&D

The Department of Primary Industries is the major research provider in Queensland, with most of its R&D involvement being undertaken in-house. Other major R&D providers in Queensland, including the Department of Lands and the Department of Minerals and Energy, also maintain in-house research programs. However, the Government's R&D is not confined to in-house activities. For example:

- the Queensland Government through the Department of Primary Industries, is a partner in six CRCs engaged in rural research (Sub. 257, attachment, p. 5);
- Queensland Health supports research through the Queensland Institute of Medical Research (QIMR) and the National Centre for Research in Environmental Toxicology. It also supports R&D indirectly through major hospital infrastructure (Sub. 257, attachment); and
- some State R&D funding is used to support business R&D. The Department of Business, Industry and Regional Development operates the Queensland Grants for the Industrial Research and Development Scheme (QGRAD). The primary aim of QGRAD is to boost industrial R&D in Queensland from its relatively low level. QGRAD provides grants that partially fund promising applied research and product development projects which are likely to provide significant returns to Queensland's economy. R&D by both individual firms and private-public sector cooperative ventures is encouraged. Since the start of the scheme in 1990, over $5 million has been committed to fund projects (Sub. 257, attachment, p. 3).

Type of research and principal objectives

As noted by the Queensland Department of Primary Industries:

> Traditionally, CSIRO and the Universities have been focused on the pure basic and strategic basic end of the spectrum. State Governments have generally directed funding to programs that focus on regional objectives, developing and maintaining the states resources and promoting the competitiveness of industries. This research is applied problem oriented work with specific regional applications, generated by consultative processes with industry (Sub. 257, p. 5).

While this indicates a strong orientation towards applied research, there are some areas of research that are oriented towards basic research. For example, the Geological Survey Division (of the Department of Minerals and Energy) carries out basic geological research. This work is undertaken to acquire new information with the expectation of future discoveries having a specific regional orientation (Sub. 257, p. 3).

State priority setting

Broadly, research priorities are set within portfolio responsibilities rather than at a State-wide level. Research priorities are settled in a number of different ways within departments. The process for determining project priority in the Department of Primary Industries involves:

- screening research proposals for DPI involvement according to criteria such as alignment with government policies and program goals;
- grouping short-listed projects according to common elements (for example, methodology, point targeted in the production chain, and type of industry);
- undertaking a cost-benefit study in financial or qualitative terms for ranking and final selection by departmental management; and
- once projects are under way, monitoring and assessing the research program (Sub. 253, attachment).

In addition, the Department is participating in six CRCs and receives 20 per cent of its research funding from external sources. Cooperative linkages such as these influence the structure and content of the State program.

In the Department of Lands, broad priority decisions are made on the basis of funding source. Consolidated Revenue and Trust funding is used principally for applied research within the department, while external funds are primarily used for basic research (Sub. 257, attachment, p. 2).

Both these approaches reflect direct involvement in priority setting. However, other approaches are also adopted. For example, Queensland Health's institutional funding is not formally directed, although the department is represented on relevant management structures and, in the case of the Queensland Institute of Medical Research, chairs the council which oversights the organisation's activities (Sub. 257, attachment. p. 1).

The Queensland Government also provides assistance for commercialisation of R&D: the QGRAD scheme has made grants totalling $5 million for this purpose (Sub. 257, p. 3).

QE.5 Western Australia

A comprehensive report on Western Australian State involvement in R&D was prepared for the Department of Commerce and Trade by Dr Dora Marinova. This report was commissioned in response to the Commission's request for information.

In 1992–93, total R&D funds included in the program budgets of Western Australian departments and agencies amounted to around $88 million. Of this total, funds sourced to the State Government Consolidated Fund (and public trading enterprise balance sheets) were of the order of $70 million (table QE6). The remainder ($19 million) came from other sources such as the Commonwealth and industry R&D funding bodies.

Table QE6: **State government funding of R&D, Western Australia, 1992-93[a]** ($ million)

Agency	*$m*	*per cent*
Agriculture		
Department of Agriculture	39.6	56.9
Department of Fisheries	1.1	1.6
Subtotal	**40.7**	**58.5**
Mining and energy resources		
Department of Minerals and Energy (1993-94)	9.0	12.9
Geological Survey of Western Australia (1993-94)	2.4	3.5
Subtotal	**11.4**	**16.4**
Environmental protection		
Department of Conservation and Land Management (1993-94)	7.3	10.5
Department of Land Administration (1994-95)	1.1	1.6
Environmental Protection Authority	na	na
Subtotal	**8.4**	**12.1**
Utilities		
Water Authority of Western Australia	1.3	1.9
State Energy Commission of WA	1.9	2.7
Subtotal	**3.2**	**4.6**
Transport		
Stateships	na	na
Public works		
Department of Main Roads	na	na
Community services and health		
Department of Health	na	0.0
Kings Park and Botanic Gardens (1994-95)	0.4	0.5
Perth Zoo (1994-95)	2.1	3.0
Western Australian Museum	3.4	4.8
Subtotal	**5.8**	**8.4**
Total	**69.5**	**100.0**

na Not available.

a For some departments, data are not available for this year and information for an adjacent year is taken as a proxy for 1992–93. Proxy years are reported in brackets as appropriate. In addition, source data did not always distinguish clearly between State and external funding for R&D. Where no distinction was made, State funding was assumed.

Source: Commission estimates based on Marinova 1994.

Coverage of State involvement in R&D

Marinova (1994) provides information on 17 government organisations which are listed as carrying out research in Western Australia according to the Directory of Research and Development in Western Australia (DCT 1994). However, coverage of departmental funding for R&D was dependent on the availability of information from budget sources and, as a result, some programs were omitted. For example, the Health Department does not have a separate R&D budget (Marinova 1994, p. 13) and information research is not shown explicitly for the Environmental Protection Authority (Marinova 1994, p. 11).

The ABS estimates that the State contribution to general government R&D in Western Australia amounted to $80 million in 1992–93, with a further contribution of $4 million by public business enterprises operating in the State (table QE1). The sum of these two State R&D contributions, $83 million, compares closely to the Marinova estimate of $88 million.

While the two estimates are similar, there are a number of conceptual and definitional differences between them. In particular, the ABS estimate for public trading enterprises includes both Western Australian State organisations and Commonwealth public trading enterprises located in Western Australia. On the other hand, the State authority estimates include funding for R&D contracted out and R&D grants that are not included in ABS data. The relative significance of these effects is not easily resolved.

For this discussion of Western Australian Government involvement in R&D, the information on departmental activity summarised in Marinova is adopted.

Concentration of State involvement in R&D

The Department of Agriculture is the largest single departmental user of State R&D funding, accounting for around half of the recorded total (table QE6). Other important R&D funders in the State include the Departments of Minerals and Energy, and Conservation and Land Management. Taking these activities together, funding for agricultural, natural resources and environmental responsibilities accounts for around three-quarters of budgeted funding.

Nevertheless, the importance of the activities of the Department of Health are not recognised in this comparison. It does not have a separate R&D budget although it undertakes some research, and it operates a number of specific-purpose funds which support medical research (Marinova 1994, p. 13).

Sources of funds

In 1990–91, the Western Australian Government funded nearly 80 per cent (that is, $70 million) of the State's R&D involvement. In addition, around $19 million was received from external sources such as rural RDCs.

External funding was highly concentrated on primary industry and natural resource-based areas. The Department of Primary Industry absorbed 70 per cent of the external funding while the Departments of Fisheries and Conservation and Land Management absorbed nearly all of the remainder.

The importance of external funding to departmental programs differed between organisations. For example, external funding contributed about one-quarter of program R&D funds for the Department of Agriculture whereas it contributed two-thirds of program funding for the Department of Fisheries.

Funding of internal and external R&D

Approximately 90 per cent of Western Australian Government R&D funding was allocated to in-house research (Marinova 1994, p. 2). The remaining R&D funds were directed towards the higher education sector (6 per cent), business enterprises (3 per cent), and a negligible amount to non-profit organisations (Marinova, p. 16).

Of the proportion of R&D funded by the Western Australian Government and carried out by universities, companies and individuals, the most important funding programs are conducted by the Department of Commerce and Trade (DCT) and the Minerals and Energy Research Institute of Western Australia (MERIWA). These funding programs are oriented towards science and technology issues, which is encouraged through matching grant programs (Marinova 1994, p. 22). The innovation programs operated by DCT are the Western Australian Innovation Support Scheme, the Neville Stanley Bursaries Scheme, and the Neville Stanley Studentships Scheme.

MERIWA is a statutory authority responsible to the Minister for Mines. Its function is to encourage the development of the minerals and energy industries within Western Australia (Sub. 22, p. 1). Ninety eight projects have commenced under the auspices of MERIWA since its inception in 1988, with 55 of these in the field of minerals and 43 in energy (Marinova 1994, p. 33). The ratio between government support and industry funds varies amongst projects. In the minerals area, however, the policy is to have 60–70 per cent industry participation and the remainder provided by government (Marinova 1994, p. 35). In 1992–93, the State Government provided around $700 thousand or

38 per cent of MERIWA's total funding for industry grants (Marinova 1994, p. 37).

Type of research and principal objectives

Although not specifically discussed in the report, Marinova (1994, p. 17) assesses that applied research is the major component of State research programs. To the extent that basic research is undertaken, it is likely to be complementary to immediate portfolio responsibilities. For example, in the Department of Agriculture, research is carried out in parallel with other functions such as policy development and extension services. In the State Energy Commission of Western Australia, research funding is provided on a project basis with projects often including commercial aspects.

State priority setting

There is no formal mechanism to set R&D priorities at the State Government level in Western Australia. While the Deputy Premier and the Minister for Trade and Commerce, and the Department of Trade and Commerce, are mainly responsible for science and technology issues, most R&D funding is provided through departments with primary industry, natural resource or environmental responsibilities (Marinova 1994, p .16). A variety of priority-setting procedures apply. For example:

- in the Department of Agriculture, there is no dedicated research agency and research activities are integrated with departmental functions. R&D funding is reported, in the first instance, on a commodity basis and program leaders are responsible for reporting on and delivering outcomes for programs. Each program has an industry committee to advise on priorities and is subject to formal cost-benefit analysis;
- the Chemistry Centre is part of the Western Australian Department of Mines. The centre is a client-driven organisation providing research services to about 30 government departments. Priority setting has not been pursued in the centre's activities mainly because of the client basis of service provision. Evaluation techniques are not applied either;
- in the Department of Fisheries, links are maintained with industry through management advisory committees. Funds are centralised and research resources are shifted from one fishery to another on the basis of need and the value of the fishery to the State. Thus, the research division manages its own research priorities; and
- the Department of Conservation and Land Management is reviewing its research program and is currently preparing a five-year strategic plan, part

of which will address its in-house research in conservation and land management.

QE.6 South Australia

The main source of information about South Australian Government R&D performance is from an internal review of R&D activities conducted in 1994.

In 1992–93, $80 million was spent from all sources on public sector research (Sub. 289, p. 5). Of this total, R&D funding from South Australian State Government sources amounted to $39 million with the remainder ($41 million) coming from the Commonwealth and other sources (table QE7). The South Australian Government supports 32 R&D funding and conducting agencies engaged in the areas of primary industries, environment and natural resources, medical and public health, education, services (electricity, water, gas, transport) supply, community services (family and social) and tourism (Sub. 289, p. 5).

Coverage of State involvement in R&D

An audit of South Australia’s public sector research in 1992–93 indicated that 32 agencies in the public sector were involved in R&D. Separate details of research activities for primary industry and health sector research and 17 government agencies were reported. However, quantitative information on public sector research relating to mines and energy was excluded (Sub. 289, p. 5).

The ABS estimates the State contribution to general government R&D in South Australia amounted to $69 million in 1992–93, with a further $9 million by public business enterprises operating in South Australia (table QE1). The sum of these two R&D contributions, $79 million, is close to the total R&D expenditure ($80 million) reported by the State Government. Nevertheless, there are definitional differences between the two estimates. For example: business enterprise R&D may contain contributions from Commonwealth enterprises operating in South Australia (raising ABS estimates relative to State Government estimates); State Government estimates contain some elements of R&D contracted out and grants funding the R&D of others (raising State Government estimates relative to ABS numbers); and the State Government estimates do not cover some activities (for example, mines and energy).

While noting these differences, the South Australian Government information is adopted in the following analysis of State government involvement in R&D.

Table QE7: **State government funding of R&D, South Australia, 1992-93** ($ million)

Agency	*$m*	*per cent*
Agriculture		
Departments of Agriculture and Fisheries, and SARDI (a)	18.0	46.4
Mining and energy resources (b)	b	b
Environmental protection		
Environment and Natural Resources	0.7	1.9
Utilities		
Electricity Trust of SA	2.4	6.1
Engineering and Water Supply	1.6	4.0
Pipelines Authority of SA	0.1	0.1
Subtotal	**4.0**	**10.2**
Business services		
Industrial Affairs	0.0	0.1
State Government Insurance Commission	0.2	0.4
Subtotal	**0.2**	**0.5**
Transport		
State Transport Authority	0.2	0.5
Transport	1.1	2.8
Subtotal	**1.3**	**3.2**
Public works		
South Australian Housing Trust (Environment Geo-Tech Service)	0.1	0.1
Community services and health		
Arts and Cultural Development	1.0	2.6
Education and Children's Services	2.0	5.2
Family and Community Services	0.1	0.4
SA Health Commission	8.8	22.7
Multicultural and Ethnic Affairs	0.0	0.1
Police Department	2.3	5.9
SA Sports Institute	0.1	0.1
State Services (Forensic Science, State Chemistry Laboratories)	0.3	0.6
Subtotal	**14.6**	**37.5**
Tourism		
South Australian Tourism Commission	0.1	0.2
Total	**38.8**	**100.0**

For footnotes, see next page.

a Referred to as funding to the Primary industry and Health sectors in Sub. 289. Assigned to Department of Agriculture and Fisheries/SARDI on the basis that SARDI was created in 1993 primarily from the research resources of the former Departments of Agriculture and Fisheries (p. 13); and on the basis that the SA Health Commission is responsible for the main components of health research funding (p. 7).
b Excluded from the coverage of quantitative information included in the Submission.
Source: Commission estimates based on South Australian Government, Sub. 289, p. 6 and appendix 5.

Concentration of State involvement in R&D

Approximately 46 per cent of R&D funding by the South Australian Government in 1992–93 was directed towards primary industries, and around 23 per cent to health. The remaining 31 per cent of State Government funding of R&D was allocated to other government departments and agencies (Sub. 289, p. 2).

Sources of funds

Of the total funding to public sector R&D in South Australia, 51 per cent ($41 million) was provided by external sources such as the Commonwealth and industry R&D funding organisations. The main recipient of external funding was health research, for which Commonwealth grants contributed one-quarter ($10 million) of total health funding and other external sources (for example, NHMRC, Anti-cancer Federation, the National Heart Foundation and the Royal College of Surgeons) contributed 52 per cent ($21 million). For primary industries, one-third of funding ($9 million) was contributed by external sources such as the rural RDCs.

Funding of internal and external R&D

Across the government organisations surveyed, two-thirds of funding ($54 million) was directed at State Government expenditure on R&D (including salaries and wages, equipment and other operating expenses). The remainder funded R&D undertaken by others. With respect to individual sectors, funding to primary industry and other non-health sectors was absorbed by in-house R&D efforts. On the other hand, only one-quarter of health funding went to in-house research, the remainder ($29 million) being channelled to research in hospitals and health-related research organisations.

State priority setting

Research patterns had developed in South Australian Government so that new expenditure was largely determined by historical patterns rather than perceived growth areas for the South Australian economy (Sub. 289, p. 17). One development to improve the focus of State funded research was the establishment of the South Australian Research and Development Institute (SARDI) in 1993.

SARDI was established to:

> create a better focus and direct the State’s research capacity,
>
> ensure that research outcomes are more relevant and available to industry,
>
> ensure that research and its management operate with commercial and industry standards, and
>
> increase South Australia’s national R&D profile and influence (Sub. 289, p. 13).

SARDI was formed primarily from the research resources of the former Departments of Agriculture and Fisheries. However, SARDI’s longer-term objectives are to have a wider role in research and research management in South Australia.

In 1994, the South Australian Government undertook an internal review of public sector research, in particular focusing on the status and function of SARDI. As a result, the Minister for Primary Industries advised in December 1994 that:

> SARDI’s headquarters will be on the Waite Research Precinct, and it will continue as a separate unit to coordinate, promote and fund public sector research, initially with a primary industry focus.
>
> The SARDI Strategic Management Board will be renamed the SARDI Board and will report to the Minister of Primary Industries. The Board will change from advisory to managerial and the CEO of SARDI will be responsible to the Board for the performance of the organisation. The Board will also be responsible for the allocation of research funds through SARDI, Primary Industries SA, Treasury and other sources (Sub. 289, p. 13).

It is also envisaged that as part of the new arrangements the South Australian Development Council (SADC) will establish economic development priorities and subsequent overall R&D objectives for South Australia, while SARDI will be responsible for implementing those objectives (Sub. 289, p. 17).

The operation of CRCs and rural RDCs is also reported to be influencing priority setting and research in a number of ways:

- organisations have benefited from preparing formal CRC applications even if they have not been successful (Sub. 289, p. 21);

- it is believed that CRCs have been successful in increasing the transfer of technology in South Australia (Sub. 289, p. 21);
- the rural RDCs provide a consistent supply of research funding and enable the industries they serve to contribute to the direction and outcomes of research (Sub. 289, p. 21).

In addition, the South Australian Government submission suggested that there is an increasing reliance on external funding sources and that there is a clear redirection of effort within agencies to capture a greater proportion of research funding from these sources (Sub. 289, p. 22).

QE.7 Tasmania

The Tasmanian Government has provided submissions (Subs 254 & 277) to the inquiry indicating that it is engaged in R&D through government departments and agencies. However, quantitative information on its activities was not provided. Also, R&D data for general government organisations in Tasmania is not shown separately by the ABS. Therefore, it was not possible to carry out an analysis of R&D activities in Tasmania, similar to that provided for other States and the ACT.

However, the Tasmanian Government provided some information on priority setting, specifically in relation to the Department of Primary Industries and Fisheries (DPIF) (Sub. 277, p. 9). The strategic plan of the DPIF identifies two major areas of activity: the economic development of Tasmania's rural, water and marine sectors; and sustaining Tasmania's water, rural and marine resources. In addition, three-year industry plans are currently being developed by the DPIF branches of agriculture and fisheries, which will lead to establishing R&D priorities in these areas (Sub. 277, p. 10).

Within the DPIF, industry branch R&D programs are primarily developed on a commodity basis, where R&D priorities are identified in consultation with industry (Sub. 277, p. 9). In addition, the proposed establishment of the Tasmanian Institute of Agricultural Research will help to consolidate the State's research effort and will, in effect, separate its prioritising and funding functions. This is designed to allow research to be more client focused, and also aid the transfer of knowledge from basic to applied research (Sub. 277, p. 10).

QE.8 Australian Capital Territory

The ACT Government's involvement in R&D stems from the activities of ACT Government agencies, which largely carry out their R&D in conjunction with institutions such as CSIRO, universities and other higher education institutions. The main source of information is provided by individual ACT Government agencies, through the coordinating efforts of the Economic Development Division of the Chief Minister's Department. ACT Government funding of R&D amounted to around $485 000 in 1993–94 (table QE8).

Table QE8: **ACT Government funding of R&D, 1993-94** ($ million)

Agency	*$m*	*per cent*
Department of the Environment, Land and Planning	0.375	77.3
Department of Urban Services	0.060	12.4
Chief Minister's Department	0.050	10.3
Total	**0.485**	**100**

Source: Commission estimates based on ACT Government Sub. 256.

Coverage of ACT involvement in R&D

The ABS reports that the estimated contribution to general government R&D in the ACT was $107 thousand in 1992–93 (table QE1). This contrasts to that reported in table QE8. Part of the discrepancy between the two estimates could be accounted for by the different reference years (that is, 1992–93 compared to 1993–94). The higher estimate from ACT Government sources could also arise from factors such as: the performance of R&D outside of the ACT and the performance of R&D by organisations outside ACT Government administration (for example, by universities and the CSIRO).

The estimates provided by the ACT Government are used in this study as the most appropriate indicators of ACT Government support for R&D activities.

Concentration of ACT involvement in R&D

The Department of the Environment, Land and Planning is the single most important funder of R&D activity within the ACT Government. It accounted for three-quarters of total R&D in 1993–94.

Sources of funds

The R&D reported in the ACT Government submission is funded mainly from ACT budget sources. Nevertheless, some funding, such as for the Monitoring River Health Initiative (MRHI), is provided by the Commonwealth for spending on local programs.

Funding of internal and external R&D

While some R&D is undertaken in-house, research is mostly undertaken through cooperative research arrangements and by consultant researchers (Sub. 256). For example:

- the main research program of the Department of the Environment, Land and Planning is undertaken through its collaborative membership in the CRC for Freshwater Ecology. Collaboration in the CRC involves the ACT Government contributing a total of $700 thousand in cash and $1.75 million in-kind (staff, administrative overheads, data collection, field equipment) over the seven year period of the CRC's life;
- the Monitoring River Health Initiative (MRHI) involves a combination of new research by consultant researchers (such as the Water Research Centre at the Canberra University) and the use of extensive water quality and water quantity archives and modelling work already undertaken by the ACT Planning Authority;
- the Youth Organisation Research and Development (YORAD) program provides one-off grants for community research and development projects;
- as a member of the South East Region Recycling Group, the ACT Government is funding worm farm research undertaken by the Canberra Institute of Technology at Braidwood in NSW; and
- the ACT Department of Urban Services is currently involved in a project being jointly undertaken by the ACT Government and the University of New South Wales (Australian Defence Force Academy).

ACT priority setting

In general, research priorities of the ACT Government are set at the departmental level and largely reflect their policy objectives. Commonwealth funding and programs influence ACT Government research priorities through the provision of seed funds for organisations such as the CRC for Fresh Water Ecology and Commonwealth funding of the Monitoring River Health Initiative.

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