

The Allen Consulting Group

**The economic, social and environmental
impacts of the Cooperative Research
Centres Program**

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Final report to the Department of Industry, Innovation, Science, Research and Tertiary Education

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Acronyms and glossary

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ARC	Australian Research Council
CGE	Computable General Equilibrium
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DIISRTE	Department of Industry, Innovation, Science, Research and Tertiary Education
DoFD	Department of Finance and Deregulation
GDP	Gross domestic product
FTE	Full-time equivalent
GE	General Equilibrium
MMRF	Monash Multi Region Forecasting model
OECD	Organisation for Economic Co-operation and Development
PC	Productivity Commission
R&D	Research and development

Executive summary

This study estimates the economic, environmental and social impacts of the Cooperative Research Centres (CRC) program since it commenced in 1991 and out to 2017. Nearly 120 past and present CRCs have contributed to the study.

Between 1991 and 2017 almost \$14.5 billion of direct economic impacts are estimated to have accrued from CRC produced technologies, products and processes. This includes \$8.6 billion of impacts already materialised from 1991 to 2012 and a further \$5.9 billion of imminent impacts estimated to occur over the next five years.

Data was gathered through a survey of current CRCs (as well as other sources). CRCs were asked to report estimates of their economic, social and environmental impacts — as well as how those estimates were made. Data was cross-checked against annual reports and economic studies where possible.

These impacts were then assessed using a model of the Australian economy. This allowed for an objective comparison to a counterfactual case — in which no CRC program existed.

Using this model, it was estimated that the program generated a net benefit to the economy of \$7.5 billion over this period, or around 0.03 percentage points of additional GDP growth per annum. The majority of the increase in GDP has come about from increased export earnings.

Relative to the funds committed to the CRC program by the Australian Government, the CRC program has generated a net economic benefit to the community, which has exceeded its costs by a factor of 3.1.

Importantly, the benefits of the CRC program stem well beyond just economic measures. Where as previous studies have focussed on just the financial contribution of the CRC program, this study has identified significant:

- *environmental benefits including impacts on land, ecosystems, pollutants, natural resources, plants, animals and biodiversity; and*
- *social benefits that affect the Australian community, the health and well-being of individuals and any other social implications.*

The unique structure of the program has had a significant influence on the program's ability to produce high quality research and link researchers with industry. In particular:

- *long term commitments made by CRC partners, provide CRCs with the capacity to tackle ambitious projects that require more time and resources than normally available; and*
- *competition for CRC funding and the rigorous application process results in only the most prospective projects receiving support.*

The CRC program has proven to be highly important to the Australia R&D scene. By linking researchers with domestic and international end users, the program has delivered significant economic, environmental and social impacts.

The Cooperative Research Centres (CRC) program commenced in 1991 with the objective of delivering significant economic, environmental and social benefits to Australia. The Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE) has commissioned the Allen Consulting Group to evaluate the program's impacts to date. At 30 June 2012, the Australian Government has committed more than \$3.4 billion to the CRC program.

This study only examines the impacts identified from 117 CRCs of the 190 CRCs (62 per cent) that have existed over the life of the program to the end of 30 June 2012. However, the total impacts identified are for the period 1991 to 2017, accounting for both known and attributable anticipated impacts. For a number of reasons, obtaining a complete set all the impacts by all the CRCs has not been possible.

During this time, the CRCs have developed technologies and methods to reduce costs and increase productivity, as well as develop fee for service products. The study has identified some \$14.45 billion of direct economic impacts that have stemmed from these outputs. This includes nearly \$8.58 billion of impacts already materialised and a further \$5.87 billion of imminent impacts estimated to occur over the next five years.

This figure however, understates the total impact of the CRC program for a number of reasons.

- First, this number reflects only impacts identified from about three fifths of the CRCs that have participated in the program. It was not possible to identify the impacts of all the CRCs that have existed since the program began.
- Second, whereas previous analyses have tended to focus on just the economic impacts, the scope of this study is much broader. This study also considers the CRC program's:
 - *environmental impacts* that affect the natural environment. These may include impacts on land, ecosystems, pollutants, natural resources, plants, animals and biodiversity; and
 - *social impacts* that affect the Australian community, the health and well-being of individuals and any other social implications.

Similarly, this does not include the value of collaboration and networks, the increase in research capability or the high quality nature of the research as a result of the CRC program.

These impacts have been included in the analysis, but generally not monetised.

- And third, this figure does not include the indirect impacts on the Australian economy or impacts that occur internationally. The CRC program's investment in Australian R&D has widespread consequences for the community, affecting every industry and sector. These impacts have been assessed using a Computable General Equilibrium (CGE) model, which estimates a *net* benefit to the economy of \$7.5 billion over the period assessed — a contribution of around 0.03 percentage points to GDP growth per annum. Relative to the Australian Government's investment, the CRC program has been able to generate a net economic benefit to the community, that exceed its costs by a factor of 3.1.

Assessing the impacts of the CRC program

The impacts of a large-scale investment in R&D such as the CRC program are spread through many industries and regions of the economy. By and large however, these impacts are not casually observable. In many cases, the outputs of the CRC program are diffuse, indirect, cumulative and delayed. Like other investments in R&D, these outputs are often immeasurable.

The critical question that needs to be addressed here is: *what would the world look like in the absence of the CRC program?* To illustrate this difference it is useful to compare the following two states of the world.

- **The current state of the world** — in which the CRC program exists, and its impacts on the community have been realised.
- **A hypothetical counterfactual** — a state of the world in which the CRC program was never commissioned and its outputs never materialised.

The counterfactual case is not observable, nor easily deductable. It is necessary to make a number of assumptions about key parameters about what would happen in the absence of the program. The key assumptions for the core scenario are detailed in the table below.¹

One of the key differences between this study and previous analyses is the treatment of participant direct and in-kind funding. That is, how much of the contributions to the CRC program from CRC participant organisations would have been spent on R&D activities in the absence of the program?

Previous analyses had attributed in full, participant's contribution to the CRC program as a direct consequence of the CRC program. This assumption was criticised in a review of R&D expenditure by the Productivity Commission. The Commission remarked "it is highly improbable that many circumstances arise when the partners in CRCs would have produced research of zero value in the absence of the program" (PC 2007). Moreover, the Commission advocated that any assessment of the CRC program should not attribute any expenditure from participants on R&D to the existence of the CRC program.

Consultations undertaken with CRC participants throughout this study however, have indicated that the real story is somewhere in between: participants would have spent some monies on R&D, but the CRC program induced some as well. How much exactly, remains uncertain. The amount of spending the program induced is likely to differ for different industries and in accordance with the nature of the CRC. A public good CRC is probably less likely to raise as much participant support in the absence of the program, than a CRC based around improving manufacturing productivity. This study has taken a deliberately moderate position and assumed that the CRC program has induced participants to spend 50 per cent more on R&D than they would have in the absence of the program.

¹ A sensitivity analysis has been conducted to gauge the extent to which these assumptions might affect the results of this study. The estimated net benefit of the CRC program varies substantially (but always positive) depending on the scenario assumed.

Table ES 1.1

KEY ASSUMPTIONS IN THE COUNTERFACTUAL CASE

Parameter	Assumption
Impacts and outputs	
The CRC's economic, social and environmental products	Do not materialise in the counterfactual scenario
Economic, social and environmental collaborative impacts	Do not materialise in the counterfactual scenario
Imminent economic, social and environmental impacts	Do not materialise in the counterfactual scenario
Economic, social and environmental preparedness	Do not materialise in the counterfactual scenario
CRC funding and contributions	
CRC program funding from the Australian Government	Returned in full to the economy as a reduction in income taxes
CRC industry participant direct and in-kind funding	50 per cent of industry expenditure on CRC activities returned to the economy on a sectoral basis as a reduction in costs — the remainder is redirected to other R&D activities*
CRC university participant direct and in-kind funding	50 per cent of university expenditure on CRC activities returned to the economy on a sectoral basis as a reduction in costs — the remainder is redirected to other R&D activities*
CSIRO direct and in-kind funding of CRC projects	100 per cent of expenditure on CRC activities reallocated to other R&D activities*
State and local government direct and in-kind funding of CRC projects	100 per cent of expenditure on CRC activities reallocated to other R&D activities*

* This is the critical assumption tested in the sensitivity analysis, outlined in Appendix E. Guidance on these assumptions was provided by DIISRTE. The estimated net benefit of the CRC program varies substantially (but always positive) depending on the scenario assumed.

Source: The Allen Consulting Group.

The majority of outputs and impacts have been self-identified by the CRCs through a survey developed specifically for this study. Where possible, additional impacts have been identified using data obtained through the following sources:

- stakeholder consultations with CRCs;
- previous studies on the impacts of the CRCs²;
- data obtained from CRC annual reports, exit reports, management data questionnaires and other documents;
- data and information provided by DIISRTE; and
- other available data sources from the literature.

² These include: Insight Economics 2006, *Economic Impact Study of the CRC Program* and Allen Consulting Group 2005, *The Economic Impact of Cooperative Research Centres in Australia*

Broader, economy-wide impacts of the CRC program were estimated using the Monash Multi Region Forecasting (MMRF) model³. The MMRF model is a Computable General Equilibrium Model (CGE) of the Australian economy and has been used in a wide range of policy studies, including the analysis of state tax reforms, the National Reform Agenda and the Garnaut Climate Change Review. The CGE analysis accounts for interconnections and relationships that exist throughout the economy.

Direct economic impacts

The direct economic impacts of the CRC program are the consequence of outputs produced by the CRCs. These include cost saving technologies, revenue opportunities, spin-off companies and efficiency gains.

This study has identified a total of \$14.45 billion of direct economic impacts from the CRC program, based on the sample of CRCs (62 per cent) included in the analysis. Over \$8.58 billion of impacts have already been realised (59 per cent), with a further \$5.87 billion of impacts estimated to occur between 2012 and 2017 (39 per cent).

The CRC program has had the greatest impact in the agriculture sector, with an estimated direct impact of \$6.15 billion. This represents average annual direct economic benefits in the agriculture sector of \$237 million from 1991 to 2017. Approximately 59 per cent of the direct economic impacts in the agriculture industry (CRC products and collaborative impacts) have been realised. The services sector has also benefited considerably from the CRC program, with a total of \$5.68 billion of direct economic benefits identified. The CRC program has also impacted significantly on the mining and manufacturing industries, with direct economic impacts in these industries totalling \$1.55 billion and \$1.07 billion respectively.

One of the key outputs of any CRC is the number of research postgraduate students that have completed their studies with the support of the CRC. Between 1991-92 and 2009-10, approximately 4,400 doctorate and masters degrees by research were awarded to students who had received industry focussed training as part of their studies with the support of a CRC (DIISRTE 2011c). Insight Economics (2006) estimates an output premium of around \$37,000 per annum per research postgraduate in Australia (in \$2012). The cumulative value of education outcomes achieved under the program is \$163 million in total.

The direct economic impacts of the CRC program in each of these industries⁴ are summarised in the table below. The table illustrates the total economic benefits identified by this study in each sector of the economy. Importantly, it is not meant to show the relative performance of CRCs within each sector of the economy, nor is it intended to provide information for a cost benefit analysis. Over the years, the focus of the CRC program has shifted and support for each sector has varied. Considerations about the rationale for funding, particularly public good elements of CRCs, mean comparisons should not be made based on these results.

³ The modelling was undertaken by Professor Philip Adams from the Centre for Policy Studies.

⁴ The sectoral split is based on the ABS Australian and New Zealand Standard Industrial Classification (ANZSIC) system (2006, cat no. 1292.0). The agriculture sector/industry refers to the Agriculture, Forestry and Fishing industry. For the purposes of this report, the services sector/industry encompasses all industries excluding Agriculture, Forestry and Fishing, Mining and Manufacturing.

Table ES 1.2

DIRECT ECONOMIC BENEFITS OF THE CRC PROGRAM BY SECTOR (\$ MILLION 2012 DOLLARS)

Sector	1991-2012	2013-2017	Average annual	Total current value
Agriculture	3,649	2,501	237	6,150
Services	3,125	2,558	219	5,683
Mining	1,177	372	60	1,549
Manufacturing	628	440	41	1,068
Total	8,580	5,872	556	14,452

Note: It should be noted that in addition to reflecting on the relative performance of CRCs in different sectors, these impacts have also been influenced by changes in program objectives over the years and the availability of data.
 Source: Allen Consulting Group analysis.

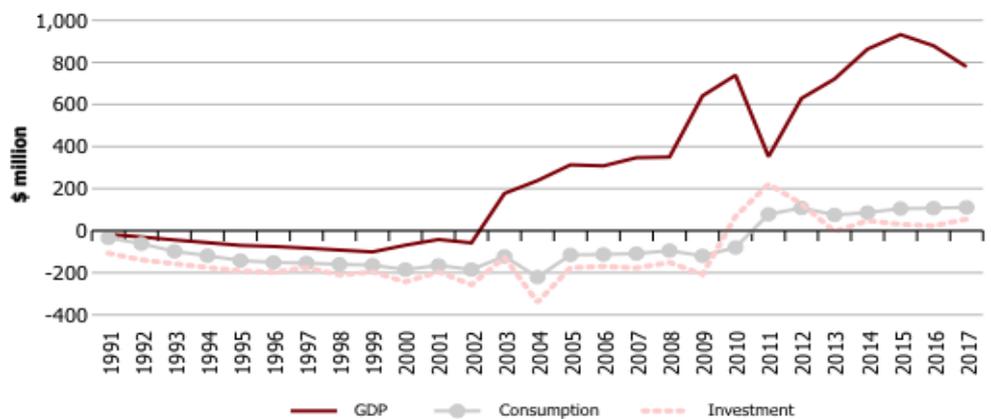
Indirect economic impacts

The impacts of the CRC program are likely to spread throughout the economy in a number of different and unexpected ways. Assessing these impacts and understanding their interconnections requires a CGE model of the Australian economy.

Figure ES 1.2 and Table ES 1.2 below present the results of the CGE modelling as calculated using the MMRF model. The figure and the table report on how Australia’s total income changes over time. Also reported are changes in how that income is earned — be it from consumption spending, investment or export income. Results in the table can be interpreted as the difference between the current state of the world and the counterfactual — having accounted for both direct and indirect impacts. The modelling is consistent with the assumptions detailed in Table ES 1.1.

Figure ES 1.2

ESTIMATED NET IMPACT ON KEY MACRO VARIABLES, 1991-2017



Note: GDP is the sum of income earned from final consumption, government expenditure, investment and net exports. Here, with the exception of funding for the CRC program, government expenditure is assumed constant. The difference in the chart therefore, between the income earned from consumption and investment and total GDP, is the income earned from net exports.

Source: The Allen Consulting Group and COPS.

Table ES 1.1

ESTIMATED NET IMPACT OF THE CRC PROGRAM ON THE AUSTRALIAN ECONOMY, DEVIATION FROM THE COUNTERFACTUAL

Indicator	Average annual impact	Average annual impact	Cumulative impact
	Percentage points	\$ millions	\$ millions
GDP	0.03	278.9	7,530.7
Consumption (private and public)	-0.01	-71.3	-1,924.8
Investment	-0.05	-112.0	-3,025.1
Trade balance	na	480.0	12,479.8

Source: The Allen Consulting Group and COPS.

The dynamics of the CGE results illustrate the lagged nature of the R&D investment. This is consistent with the findings in the Allen Consulting Group's 2005 study, which observed time lags between commencement of research and realisation of a measurable economic impact of, on average, nine years (Allen Consulting Group 2005). The CRC program follows a typical investment profile — outlays are incurred in the early years of the program in order to reap future gains.

It can be seen in Figure ES1.2 that the CRC program detracted during the “investment” phase, but began to realise positive results from around 2003. Consumption (public and private) and investment flows, by and large follow national income. As the program began to reap positive rewards, consumption and investment have also begun to increase. Although consumption is cumulatively nearly \$2 billion less than would have otherwise been the case, it has been steadily rising since 2004. The same is true for investment.

It should be noted that the reduction in consumption and investment, in this context, should not necessarily be interpreted as an adverse outcome. Each of these elements, together with net exports, reflects a *source of income* — and, on the whole incomes are rising. The changes in consumption, investment and the trade balance, therefore, simply reflect a change in how and where Australia earns its income.

Over the period 1991 to 2017, the net effect of the CRC program was to grow the economy by more than \$7.5 billion. This equates to an average increase of around 0.03 per percentage points per annum.

In other words, the economic benefits to the broader community generated by the CRC program exceed Australian Government funding by a factor of 3.1. How this result has been estimated is reported in Table ES 1.2.

Previous studies on the impact of Australian research institutes have demonstrated that they are able to generate significant increases in GDP. A study on research institutes at the University of Queensland for example, estimated that the institutes were able to generate increases in GDP that were as high as 7.1 times the initial outlay (Allen Consulting Group 2011). Comparing the CRC program to those studies however, does not adequately reflect the additional social and environmental impacts inherent to the CRC program, nor its public good nature.

Table ES 1.2

NET ECONOMIC BENEFIT FROM AUSTRALIAN GOVERNMENT FUNDING

Item	Amount
Cumulative Australian Government commitment to the CRC program (for those CRCs included in the study sample) ^A	\$2.42 billion
Cumulative increase in GDP ^B	\$7.53 billion
Benefit to cost ratio	3.1

Notes: These results are based on the impacts identified by this study through the data and information gathering stages, with the majority of impacts self-identified by CRCs. It is noted that this may underestimated the impacts of the CRC program due to difficulties identifying all impacts as discussed previously. The return on investment is based on the assumption that the CRC program has induced participants to spend 50 per cent more on R&D than they would have in the absence of the program. A — This includes only the funding associated with those CRCs for which benefits were identified. B — This is based on CGE modelling of the identified impacts and represents the net changes to the Australian economy as a result of the CRC program.
 Source: The Allen Consulting Group and COPS.

Environmental impacts

The environmental impacts of the CRC program are wide-ranging: from reducing greenhouse gas (GHG) emissions and energy consumption to protecting areas of land and endangered species. As with economic impacts, environmental impacts range from those that have been delivered and directly attributable to the CRC, indirect impacts and those that relate to preparedness. For some CRCs, the primary objective is to achieve positive environmental impacts. For others, this is secondary to commercial objectives, with impacts occurring as a result of a broader research program. Many of these CRCs focus on public good research.

Some of the positive environmental impacts of the CRC program are listed below. It should be noted that this list is not exhaustive or definitive given the broad scope of the program.

- Reduced green house gas (GHG) emissions.
- Avoidance of the emission of pollutants.
- Reduced energy consumption.
- Reduced water consumption.
- Reduced environmental costs.
- Protection of areas of environment.
- Protection of endangered species.

Social impacts

The CRC program affects a wide range of social outcomes: from the establishment of international collaborations and increasing local business diversity, to improving health and wellbeing and increasing participation in community services. For some CRCs, their primary objective is to achieve public good impacts. For others, this is a secondary objective, with impacts occurring as a result of a broader research program. Some of the social impacts of the CRC program are listed below.

- Improved health and wellbeing.
- Establishment of international collaborations.
- Provision of education and training.
- Labour force participation.
- Business diversity.
- Participation in community services.
- Change in character of local communities.
- Improved safety.
- Social costs saved or avoided.

Preparedness

The CRC program also produces impacts related to preparedness, which result from outputs involving forewarning or mitigating risks. The preparedness outputs identified in this study range from preparing for the impacts of bushfires to the management of disease in vineyards. These outputs result in economic, environmental and social impacts that will only transpire in the event that certain circumstances occur. The reported preparedness outputs represent significant economic impacts, especially with respect to potential cost savings. In addition, preparedness outputs achieve environmental and social impacts. For example, preparing accurate climate change models enables effective and timely mitigation and adaptation strategies by farmers, which avoids loss of their livelihood and protects the environment.

The overall impact of the CRC program

The CRC program differs significantly from other R&D support measures. The program's medium to long term funding, its funding scale, and requirement for engagement with end users of the research, make the program a unique mechanism to pursue relevant research to address major industry challenges in any industry throughout the economy.

This unique structure has a significant influence on the program's impacts.

- Medium to long term commitments made by CRC partners, as required by the program, provide the CRCs with the capacity to tackle ambitious projects that require more time and resources than otherwise attributed to traditional R&D within science or industry community alone.

- Competition for CRC funding and the rigorous application process results in only the most prospective proposals receiving support.
- The experience of researchers and staff working with industry in the CRC program provides education and training that produces graduates that are attractive to industry.

As a result of R&D undertaken by CRCs, a variety of impacts have occurred. These have accrued to CRCs themselves in the form of additional revenues and direct payments, to industry participants in the form of cost savings and increases in revenue and profitability and across industries in the form of efficiency gains, the development of new technology and productivity improvements.

The environmental and social impacts achieved by the CRC program are also diverse and reflect the broad scope of research activities undertaken across the CRCs.

This study has demonstrated that the CRC program is highly important within Australia. By linking researchers with domestic and international end users, significant economic, environmental and social impacts have been produced.

Chapter 1

This study

The Cooperative Research Centres (CRC) program commenced in 1991. While the objective of the program has changed over the years, the program's current objective is to deliver significant economic, environmental and social benefits to the community. The CRC program seeks to achieve this by supporting end user driven research partnerships between publicly funded researchers and end users to address clearly articulated, major challenges that require medium to long term collaborative efforts.

The Department of Industry, Innovation, Science, Research and Tertiary Education (DIISRTE) has commissioned the Allen Consulting Group to evaluate the impacts of the CRC program. Whereas previous analyses have tended to focus on just the economic impacts, the scope of this study is broader — it considers the CRC program's economic, environmental and social impacts.

The study's objective is provided in the box below.

Box 1.1

OBJECTIVE OF THE STUDY

The objective of the CRC program impact study is to provide an assessment of the economic, social and environmental net impacts, both monetary and non-monetary, of the CRC program to Australia.

The study should ensure that:

- benefits are layered or grouped according to the robustness of their 'measurement';
- the counterfactual situation is considered in a robust way;
- only those benefits that are attributable to the program are considered – the benefits must have been unlikely to have occurred in the timeframe in the absence of the program, or unlikely to have occurred in Australia;
- opportunity costs, costs of implementation are considered;
- results from research that are not 'additional' are excluded and that 'crowding out' is taken into account; and
- spillovers that are likely to occur are included.

Source: Adapted from DIISRTE RFQ, 2011.

Since its inception, there have been a number of reviews of the CRC program. Most have focused on its overall effectiveness, while some recent studies have assessed the economic impacts of the CRC program. There have been at least five specific reviews of the effectiveness of the CRC program and two impact studies. These are outlined in Table 1.1.

Table 1.1

REVIEWS OF THE CRC PROGRAM

Study	Year	About
O'Kane	2008	As part of the broader review of the National Innovation System (NIS), the Department of Innovation, Industry, Science and Research commissioned a discrete review of the CRC program in 2008, chaired by Professor O'Kane. The O'Kane study examined the issue of how the CRC program fits with other programs in the NIS in contributing to national productivity and social good through collaboration. The review found that the CRC program had become less attractive to some important participant groups and some significant end users. It made recommendations aimed at involving more end user industries and service providers being involved in CRCs; and diversifying the industry, service type and size of end users (O'Kane 2008). Its recommendations also aimed to diversify the CRCs in terms of size, structure and longevity.
Insight Economics	2006	Insight Economics' study extended and updated the Allen Consulting Group study. It included quantitative assessment of the wide range of benefits from the CRC program in Australia out to the year 2009-10. The evaluation produced three tiers of benefits that progressively encompassed three types of CRC arrangements. The third tier estimate therefore gave the most complete measure of the CRC program, and suggested that for every dollar invested in the CRC program, GDP is cumulatively \$1.16 higher than it would otherwise have been (Insight Economics 2006). The main reason for the much higher magnitude of benefits compared with Allen Consulting Group's study was due to the identification and quantification of a number of additional delivered benefits (Productivity Commission 2007). The first tier was equivalent to the Allen Consulting Group study, and yielded an increase in GDP of \$0.50 per dollar invested in the CRC program.
The Allen Consulting Group	2005	This study assessed the economic impacts of the program. The study identified twenty-five measured and verified economic impacts. The study found that for every \$1 spent by the Australian Government on the CRC program, GDP was cumulatively \$0.60 higher than it would have been had that \$1 instead been allocated to general Government expenditure. The study also found, on average, a nine-year period from initial expenditure to realizing the benefit of investment in science and innovation.
Howard Partners	2003	Howard Partners' review of the CRC program focussed on its effectiveness, efficiency and appropriateness. Their evaluation indicated that research outputs had been implemented and were expected to lead to economic and environmental benefits (Howard Partners 2003). However, they noted that quantification of benefits was difficult in the absence of a market transaction between research findings and end user application.
University of Wollongong	2002	Garrett-Jones and Turpin at the University of Wollongong assessed the CRC program's framework for measuring its outcomes. The study was not intended to be an evaluation of the CRC program, but rather to assess the extent to which the 'performance framework' was able to: <ul style="list-style-type: none"> • evaluate the effectiveness of the CRC program in terms of the extent to which program objectives are being met; and • provide a baseline for comparison with future outcomes studies in order to assess the program's impact over time (Garrett-Jones and Turpin 2002).
Mercer and Stocker	1998	Mercer and Stocker's 'Review of Greater Commercialisation and Self Funding in the CRC program' found that the CRC program represented an effective investment in R&D and was a successful mechanism for linking users with research organisations (O'Kane 2008). However, the review concluded that whilst there are examples of significant technological developments and of technology transfer in many sectors, and some outstanding examples of the commercial benefits of CRC research, the major impacts of the program would not be evident for some years. The methodology for the review comprised extensive stakeholder consultations with major R&D performers in Australia as well as 10 cases studies of individual CRCs.
Myers Committee	1995	The first external review of the program occurred in 1995, when 61 CRCs had been established. This evaluation of the CRC program identified various successes and concluded that the main achievement of the program had been in producing a major culture change in Australian research (Changing Research Culture in Australia 1995 in Harman 1999).

Source: Various.

1.1 Methodology

The primary objective of this study is to assess the difference the CRC program has made to the economy and the community at large. The critical question that needs to be answered in making this assessment is: *what would the world look like in the absence of the CRC program?*

The impacts of a large-scale investment in R&D such as the CRC program will spread through many industries and regions of the economy. By and large however, these impacts are not casually observable. In many cases, the outputs of the CRC program are diffuse, indirect, cumulative and delayed. Like other investments in R&D, these outputs are often immeasurable.

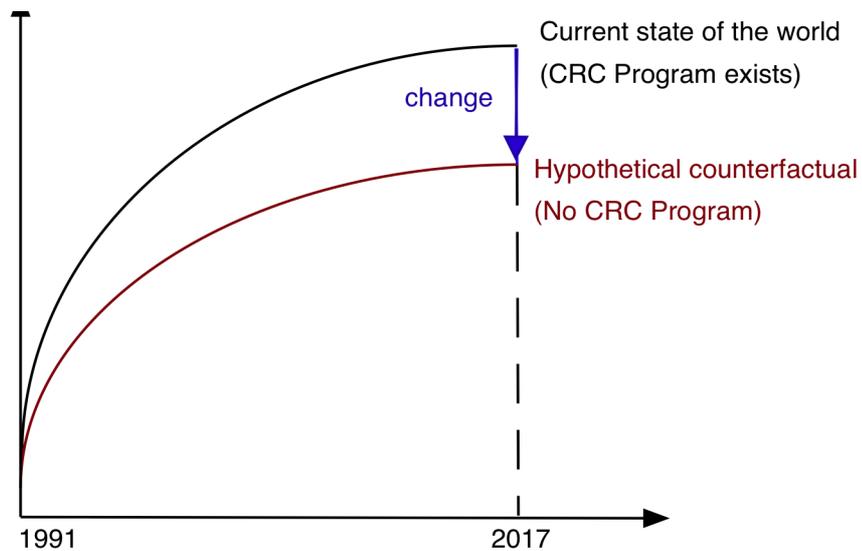
Conceptually, the impact of the CRC program can be thought of as the difference between two states of the world.

- **The current state of the world** — in which the CRC program exists, and its impacts on the community have been realised.
- **A hypothetical counterfactual** — a state of the world in which the CRC program was never commissioned and its outputs never materialised.

This is illustrated in the following figure.

Figure 1.1

APPROACH TO ASSESSING THE IMPACTS



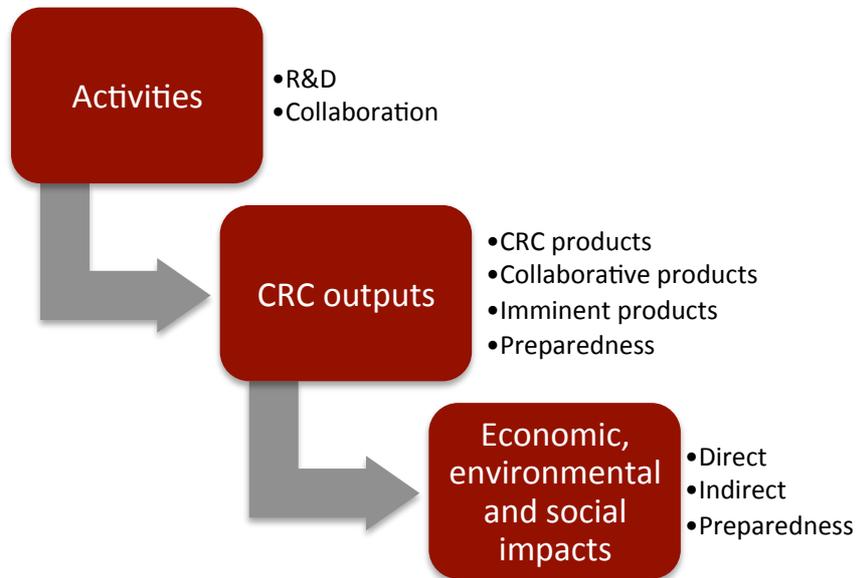
Source: The Allen Consulting Group.

Evaluation framework

The impacts of the CRC program are the result of R&D activities undertaken by the CRCs. These activities produce outputs, which may then materialise as an impact on the community.

The difference between ‘CRC outputs’ and the ‘impacts of the CRC program’ is in many cases a subtle one. It is helpful to think of a CRC output as the product that leads to, for example, a cost saving, and the impact as the value that saving generates to the community. Figure 1.2 illustrates this mapping.

Figure 1.2

MAPPING CRC ACTIVITIES TO IMPACTS


Source: The Allen Consulting Group.

CRC outputs

CRC outputs were segregated first according to type (economic, social or environmental) and then grouped according to the robustness of their measurement. Consistent with previous analyses, four tiers of robustness were used to classify the outputs. These being:

- **Tier 1: CRC products** — those outputs which have been delivered, and have been quantified;
- **Tier 2: Collaborative outputs** — those outputs where part of an outcome is attributable to the CRC program, with an appropriate attribution rate applied;
- **Tier 3: Imminent outputs** — those outputs which are anticipated to occur over the next five years (out to 2016-17), where technology or output has been “proved-up” and the route to market is clear; and
- **Tier 4: Preparedness** — those outputs which involve forewarning or mitigating risks. They relate to impacts associated with CRCs only in the event that certain circumstances occur.

Impacts of the CRC program

It is also useful to think of the impacts of the CRC program according to the following classifications. First there are the *direct impacts* of the CRC program. They include the direct impacts of CRC's outputs (Tiers 1, 2 and 3). Examples include productivity improvements, cost savings, increases in revenue, royalty payments, the value of spin-off companies formed, reduced GHG emissions, reduced water consumption, the provision of education and training and improved health and well-being.

Second, the CRC program will have a generate number of *indirect impacts*. The nature of R&D investments is such that significant indirect benefits and spillovers are likely to arise — in addition to the program's direct impacts. For example where a CRC has improved the productivity of a certain sector, the economy will enjoy additional benefits as that sector is able to produce its services more efficiently, leading to costs savings elsewhere.

The indirect economic impacts of the program have been assessed using a CGE model of the Australian Economy, the MMRF model. The MMRF model is a high-level representation of the Australian economy. It facilitates measurement of the wider effects of changes in economic activity in key industries and regions. To the extent that economic activity is interlinked, the MMRF model captures any second round effects that arise from the direct impacts. (A brief discussion on CGE modelling can be found in Box 1.2 and more detail on the MMRF model can be found in Appendix D.) While the program may have indeed produced some indirect environmental and social impacts, there is no general framework to assess their scale and scope. Consequently, the indirect impacts considered here have been limited to economic impacts.

And third, some of the impacts of the CRC program will not materialise — except under certain circumstances. For example, a CRC may successfully develop a control for a particular disease. This control may significantly reduce mortality rates, associated costs and other effects of the disease and therefore have a considerable economic impact if the disease was to occur in Australia. However, the key point is that the impact will only transpire if the disease occurs in Australia.

This work involves mitigating future risks and work in relation to forewarning. While this work is highly important and can lead to large impacts, there remains uncertainty as to whether they will occur. It is possible that the circumstance or event to which these impacts relate may never occur. Due to the uncertainty of these *preparedness impacts*, this study has not included such impacts in the aggregation of the direct impacts or in the CGE modelling of the indirect impacts.

Box 1.2

CGE MODELLING AND THE MMRF MODEL

A Computable General Equilibrium (CGE) model can estimate the impacts of research investments on key macroeconomic aggregates such as GDP, exports, imports, consumption and investment and can provide valid measures of changes in consumer welfare or living standards so that the CRC program impacts can be correctly evaluated in terms of public interest.

By using a CGE model the indirect or flow on benefits to the economy of the CRC program can be examined. For example, the work of a CRC may increase sales revenue within an industry. This is identified as a direct economic benefit. However, this increased sales revenue will flow through the economy and have an effect on other aspects within the economy. This effect is known as a multiplier effect. Increased sales revenue may lead to additional employment or higher wages or profit for employees and businesses. Under any of these scenarios consumers will have more money to spend. This in turn influences the activity in other industries or has flow on effects. This cycle continues, and as a result a direct economic impact can have a much larger indirect effect throughout the economy.

The Monash Multi Region Forecasting (MMRF) model is a CGE model of Australia's regional economies developed by the Centre of Policy Studies (CoPS) at Monash University (CoPS, 2008). It is a model of the entire Australian economy and it captures the interactions between different regions and sectors. For a detailed description of the theoretical structure of the model (see Peter et. al., 1996).

The MMRF model is used for a wide range of policy studies, including the analysis of state tax reforms and the potential benefits of the National Reform Agenda. More recently, the Department of the Treasury and the Garnaut Climate Change Review applied the MMRF model to the national climate change modelling to assess the impacts of the proposed Carbon Pollution Reduction Scheme on the Australian economy.

The results of the MMRF modelling simulations are estimated as deviations from the baseline. The baseline case represents a scenario that depicts the best estimate representation of the state of the world. This includes expected demographic, economic and policy changes over time. Reporting impacts in this way allows the discussion to focus on the 'change' that the investment can be expected to deliver (rather than on how the economy will develop over time).

The use of CGE models in policy and program analysis also imposes a discipline in which model structures can be easily compared and contrasted and model results can be interpreted using a well-understood and rigorously developed theoretical framework. In addition, the use of a CGE framework allows capturing both the direct and indirect impacts of the CRC program. A CGE model is a high-level representation of the Australian economy that allows measuring the wider effects of changes in economic activity in key industries and regions. To the extent that economic activity is interlinked, a CGE model will capture any flow-on effects that arise from CRC program outcomes, including upstream and downstream impacts.

CGE models are widely used by government, industry and academics to evaluate the worth of policy actions, programs and projects. This means that CGE modelling results are well understood and accepted by a wide range of stakeholders.

Source: The Allen Consulting Group.

The counterfactual case

The counterfactual state of the world without the CRC program is hypothetical. What it encapsulates is necessarily the product of a number of assumptions. The key assumptions for the core scenario are detailed in Table 1.2. These assumptions are also important when estimating the indirect impacts. A sensitivity analysis has been conducted to gauge the extent to which these assumptions might affect the results of this study (see Appendix E). (The estimated net benefit of the CRC program varies substantially (but always positive) depending on the scenario assumed.)

Table 1.2

KEY ASSUMPTIONS IN THE COUNTERFACTUAL CASE

Parameter	Assumption
Impacts and outputs	
The CRC's economic, social and environmental products	Do not materialise in the counterfactual scenario
Economic, social and environmental collaborative impacts	Do not materialise in the counterfactual scenario
Imminent economic, social and environmental impacts	Do not materialise in the counterfactual scenario
Economic, social and environmental preparedness	Do not materialise in the counterfactual scenario
CRC funding and contributions	
CRC program funding from the Australian Government	Returned in full to the economy as a reduction in income taxes
CRC industry participant direct and in-kind funding	50 per cent of industry expenditure on CRC activities returned to the economy on a sectoral basis as a reduction in costs — the remainder is redirected to other R&D activities*
CRC university participant direct and in-kind funding	50 per cent of university expenditure on CRC activities returned to the economy on a sectoral basis as a reduction in costs — the remainder is redirected to other R&D activities*
CSIRO direct and in-kind funding of CRC projects	100 per cent of expenditure on CRC activities reallocated to other R&D activities*
State and local government direct and in-kind funding of CRC projects	100 per cent of expenditure on CRC activities reallocated to other R&D activities*

* This is the critical assumption tested in the sensitivity analysis, outlined in Appendix E. Guidance on these assumptions was provided by DIISRTE. The estimated net benefit of the CRC program varies substantially (but always positive) depending on the scenario assumed.

Source: The Allen Consulting Group.

The difference between this study and the Insight Economics report is the treatment of participant direct and in-kind funding. In the Insight Economics report, it was assumed that private sector CRC participants spent no monies on R&D in the absence of the CRC program. In other words, Insight Economics assumed that the CRC program was responsible for inducing 100 per cent of participant direct and in-kind support. The assumption of full additionality means that in the absence of the CRC program, research firms would not have been able to achieve similar outcomes. The PC however, argued that this was unlikely to be the case, suggesting

...it is highly improbable that many circumstances arise when the partners in CRCs would have produced research of zero value in the absence of the program. (PC 2007)

The PC then adjusted Insight Economics results in a way that suggested the complete opposite - that the CRC program induced no additional expenditure from participants on R&D⁵.

⁵ It is noted that the PC only adjusted Insight Economics' first tier estimates.

Consultations undertaken with CRC participants throughout this study have indicated that the real story is perhaps, some where in between: industry and universities would have spent some monies on R&D, but the CRC program induced some as well. How much exactly, remains uncertain. The amount of spending the program induced is likely to differ for different industries and in accordance with the nature of the CRC. A public good CRC is probably less likely to raise as much participant support in the absence of the program, than a CRC based around improving manufacturing productivity.

This study has taken a deliberately moderate position and assumed that in the absence of the CRC program, industry and university participant expenditure on R&D would only amount to 50 per cent of what was spent on CRC activities. It is further assumed that all state government and CSIRO expenditures would have been spent on other R&D activities in the program's absence.

Given the differences⁶ in the assumptions of this report and those of Insight Economics, figures reported here are not directly comparable. A sensitivity analysis of this assumption has been included in Appendix E. The sensitivity analysis allows for a comparison with previous analyses. These assumptions follow the development of previous CRC impact studies and the advice of the PC (see Box 1.3).

⁶ A second difference relates to the treatment of Australian Government funding. Despite having data on only a sample of CRC impacts, Insight Economics analysis was made relative to the total Australian Government funding commitment for the program. This would have the effect of overstating the program's costs relative to benefits observed.

Box 1.3

PREVIOUS IMPACT STUDIES OF THE CRC PROGRAM**The Allen Consulting Group (2005)**

A 2005 report by the Allen Consulting Group for the CRC Association assessed the economic impacts of the program. The 'with CRC program' scenario is compared to the counterfactual scenario that assumes that the CRC program had never been created and that the Australian Government funds that had been allocated to the round one to seven CRCs had instead been available for other general Government expenditure. In this study, 25 measured and verified economic impacts of the CRC program were identified. In the counterfactual 'without CRC program' scenario in the economic modelling, it is assumed that each of the twenty-five measured economic impacts of the CRC program that had been identified would not have occurred.

The study found that over the 1992 to 2010 period, the Australian economy's overall performance has been considerably enhanced when compared to the performance that would have occurred in the absence of the Australian Government investment provided between 1992 and 2005 (Allen Consulting Group 2005). The study identified that for every \$1 spent by the Australian Government on the CRC program, GDP was cumulatively \$0.60 higher than it would have been had that \$1 instead been allocated to general Government expenditure. The study also found, on average, a nine-year period from initial expenditure to realizing the benefit of investment in science and innovation.

Insight Economics (2006)

Insight Economics' study expanded on the 2005 Allen Consulting Group study. It included quantitative assessment of the wide range of benefits from the CRC program in Australia out to the year 2009-10. The evaluation developed three tiers of benefits that progressively encompassed three types of CRC arrangements. The third tier estimate, the most complete measure of the CRC program, suggested that for every dollar invested in the CRC program, GDP is cumulatively \$1.16 higher than it would otherwise have been (Insight Economics 2006). The main reason for the much higher magnitude of benefits compared with Allen Consulting Group's study was due to the identification and quantification of a number of additional delivered benefits (Productivity Commission 2007). The first tier was equivalent to the Allen Consulting Group study, and yielded an increase in GDP of \$0.50 per dollar invested in the CRC program. The Insight Economics counterfactual assumed that taxes would have been lower in the absence of the program, whereas the Allen Consulting Group study assumed that government raised the same level of taxes and spent the CRC program funding on other things.

Productivity Commission (2007)

The Productivity Commission (PC) considered Insight Economics' treatment of grant financing under the counterfactual to be more appropriate than the Allen Consulting Group's. However, it criticised both studies' method for apportioning benefits, which assumed full additionality. The assumption of full additionality means that in the absence of the CRC program, research firms would not have been able to achieve similar outcomes. They argue that it is improbable that the partners in CRCs would have produced research of zero value in the absence of the CRC program. As a result, the PC substituted assumptions that it believed had more validity and estimated revised, lower, benefits (O'Kane 2008).

Source: Allen Consulting Group (2005), Insight Economics (2006) and Productivity Commission (2007)

1.2 Data

Impacts were identified from the reports by Allen Consulting Group (2005) and Insight Economics (2006). However, the majority of data about the activities and outputs of the CRCs was obtained through a survey where the current CRCs were asked to report on the outputs they have produced. In both cases, impacts have largely been self-identified by the CRCs. Where possible, these responses were verified⁷ using the following sources:

⁷ A sample of reported impacts were verified against annual reports, exit reports and through consultation with CRCs. Refer to Appendix C.

- stakeholder consultations with CRCs (see Appendix A);
- previous studies on the impacts of the CRCs⁸;
- data obtained from CRC annual reports, exit reports, management data questionnaires and other documents;
- data and information provided by DIISRTE; and
- other available data sources from the literature.

Survey respondents were provided with an evaluation framework to assist with the classification of their outputs. The evaluation framework helped to provide consistency in the evaluation process and that all outputs were assessed in a comparable manner.

In addition, the framework allows consideration of the effects of a range of factors, such as:

- the nature and scale of outputs;
- the timing of the outputs;
- the attribution of the output; and
- the incidence of the output.

The economic impacts of the program were generally easier to quantify. Some difficulties arise however, when assessing the program's environmental and social impacts. These have been quantified where possible, but for the most part, monetising environmental and social impacts remained outside the scope of the study.⁹

1.3 Limitations of this study

Data about the output and impact a CRC produces is not readily available. This study has had to rely on consultations with the current CRC community and the findings of previous impact studies for past CRCs.

To 30 June 2012 there have been 190 CRCs funded through the CRC program. Of these, the survey and other data gathering undertaken for this study identified impacts from 117 CRCs. The results reported in this study therefore, reflect only the impacts made by some 62 per cent of CRCs in the program.¹⁰ More than 81 per cent of current CRCs provided input into this study.

No information is available to indicate the scale and nature of the impacts made by CRCs not included in the study. The majority of CRCs "missing" from the analysis include those that are no longer in existence. Unless impacts were identified in previous studies, or documented elsewhere, their impacts are unknown. Furthermore, there is no evidence to suggest how the relative performance of those "missing" CRCs differs from those included in the study or that there is any degree of selection bias in the sample.

⁸ These Include: Insight Economics 2006, *Economic Impact Study of the CRC Program* and Allen Consulting Group 2005, *The Economic Impact of Cooperative Research Centres in Australia*

⁹ Difficulties arise when valuing a number of these impacts as well as determining attribution to the Program.

¹⁰ The CGE modelling has been adjusted to reflect this by accounting for a pro rata estimate of resources dedicated to the CRC Program.

The study might be considered a conservative account of the full impact of the CRC program, for a variety of other reasons including:

- the long lag times between the period in which research occurs and the time when impacts are realised. As a consequence, some benefits from the program cannot be identified, much less quantified at this point in time;
- CRCs surveyed were only asked to identify impacts of a value greater than \$0.5 million (the same threshold used by Insight Economics). Thus CRCs could have a number of outcomes that fall just below this threshold which taken together could amount to significant omissions;
- the data gathering constraints associated with the study mean that not all realised impacts have been able to be identified. This is a particular issue for impacts resulting from CRCs which no longer exist;
- some research will not lead to direct economic impacts — rather it will form the basis of further research and when impacts are realised the CRC program may not be acknowledged as a source of those impacts; and
- the data only reflect the impacts directly attributed to, and benefited by, the CRC. It does not include the economic impacts (e.g. revenue) generated by licensees and other non-participants (e.g. broader national and international revenues/benefits generated from CRC innovations).

1.4 Report structure

This report summarises the results of a study on the impacts of the CRC program. It is not a formal review of the CRC program in accordance with the Department of Finance and Deregulation (DoFD) guidelines. The outcomes of this study can be used to inform a program evaluation, which will have a much broader scope including the examining the program's efficiency and effectiveness.

The remainder of this study is structured as follows.

- Chapter 2 provides an overview of the CRC program.
- Chapters 3, 4 and 5 respectively detail the economic, social and environmental impacts of the program.
- Chapter 6 draws the impacts together and provides an overall analysis of the impacts of the CRC program.

Throughout the report, a number of case studies have been used to illustrate the range and nature of impacts the CRC program has produced. These case studies are outlined in the following table.

Table 1.3

CASE STUDIES USED IN THIS REPORT

Case study	About	Reference
CRC for High Integrity Pork	Illustrates direct economic impacts in the agriculture sector	Box 3.1
The CRC for Rail Innovation	Illustrates direct economic impacts in the services sector	Box 3.2
CRC for Advanced Composite Structures	Illustrates direct economic impacts in the manufacturing sector	Box 3.3
CRC for National Plant Biosecurity	Demonstrates an example of a preparedness economic impact	Box 3.5
Bushfire CRC	Demonstrates an example of a preparedness economic impact	Box 3.6
CRC for Greenhouse Technologies	Illustrates a direct environmental impact (reduced GHG emissions)	Box 4.1
Parker CRC for Integrated Hydrometallurgy Solutions	Illustrates a direct environmental impact (avoidance of the emission of pollutants)	Box 4.2
Australian Seafood CRC	Illustrates a direct environmental impact (reduced water consumption)	Box 4.3
Invasive Animals CRC	Illustrates a direct environmental impact (avoidance of the emission of pollutants)	Box 4.4
CRC for Asthma and Airways	Illustrates a direct social impact (improved health and wellbeing)	Box 5.1
HEARing CRC	Illustrates a direct social impact (establishment of international collaborations)	Box 5.3
Smart Services CRC	Illustrates a direct social impact (change in character of local communities)	Box 5.4
Antarctic Climate and Ecosystems CRC	Illustrates a direct social impact (social costs saved or avoided)	Box 5.5

Key points

The impacts of a large-scale investment in R&D such as the CRC program will spread through many industries and regions of the economy. This study examines the economic, social and environmental impacts of the CRC program between 1991 and 2017.

The program's impacts can be classified into direct, indirect and preparedness impacts. The framework identifies four tiers of outputs to assess the direct, indirect and preparedness impacts.

This study has taken a moderate position and assumed that the CRC program has induced industry and university participants to spend 50 per cent more on R&D than they would have in the absence of the program.

Chapter 2

The CRC program

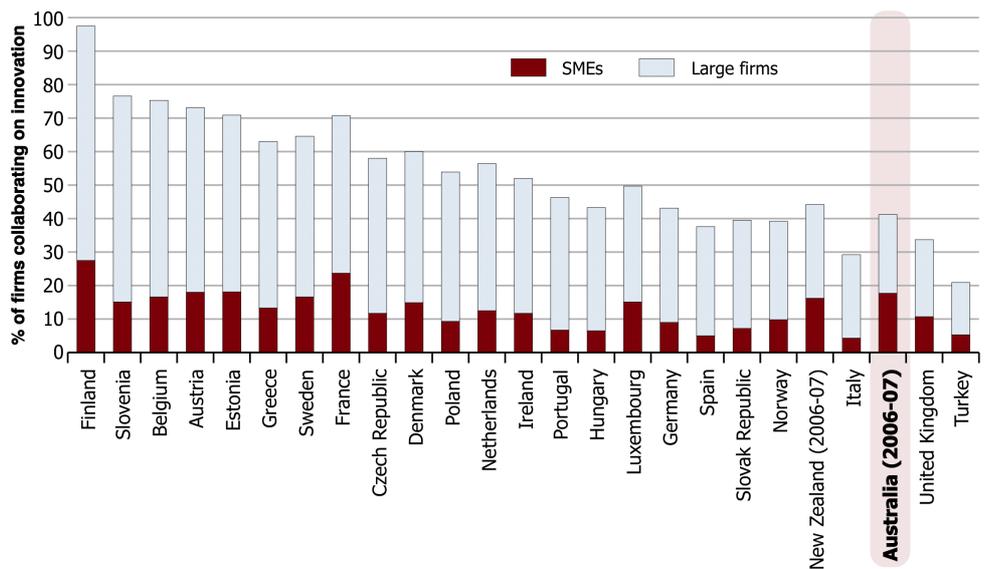
The case for public sector support for research and development (R&D) is well established. The Productivity Commission (PC) for example, found strong rationales for public funding support of science and innovation in its 2007 research report. Public investment in R&D is a key contributor to innovation in the functions performed by government. This is because governments need to invest in research to improve the products and services they offer or to better discharge their functions.

Investments in innovation are different to other types of government investment. Returns from innovation are medium to long term and difficult to quantify ahead of time (DIISR 2008). The potential for successful innovation can outweigh the risk of failure. While only a small proportion of innovation may succeed, these can be so large that costs of failed innovation are dwarfed. However, the willingness to experiment and risk failure is an integral part of the innovation process. Government has a key role in encouraging investment of capital in the innovation process.

The CRC program fulfills an important role in Australia’s national innovation system. While Australia’s public sector research performance is strong, the links with the private sector are limited. Australia ranks near the bottom of the list in terms of collaboration on innovation, as seen in Figure 2.1 (Stevens 2011). The CRC program is one of only a few generally available Australian Government programs that mandate cooperation (another is the ARC Linkage Program).

Figure 2.1

FIRMS COLLABORATING ON INNOVATION BY SIZE, 2006-07



Source: OECD 2009

2.1 About the CRC program

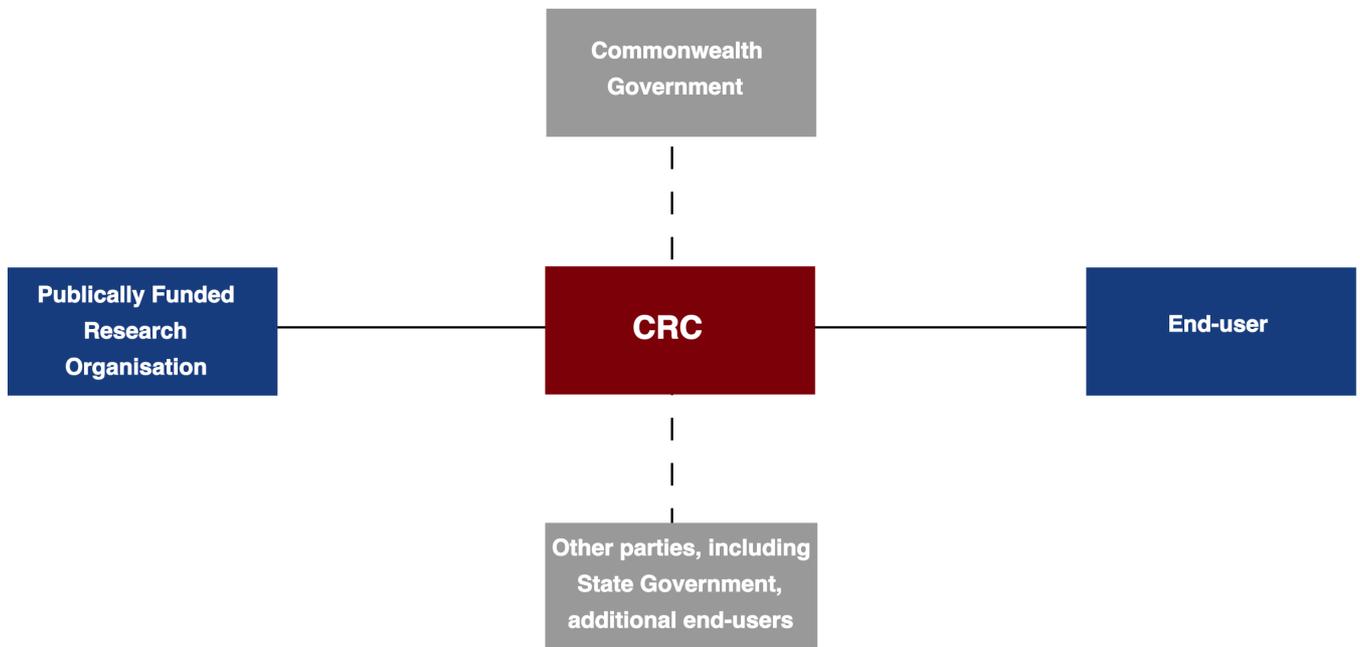
The former Chief Scientist, Professor Ralph Slatyer designed the CRC program to encourage collaboration in research between the private sector and the public sector research bodies, but also to address research concentration for world-class teams and prepare PhD graduates for non-academic careers (O’Kane 2008). It was established in 1990, with the first selection round announced in 1991. The program was established in response to a number of perceived weaknesses in the institutional framework for Australia’s R&D effort. Over the last 20 years, following decisions by The Australian Government and recommendations of reviews, the CRC program has evolved through adaptation and initiatives.

The CRC program links researchers with industry to focus R&D efforts on progress towards utilisation and commercialisation (CRC 2011b). The close interaction between researchers and the users of research is a key feature of the program. Research groups from universities and public research agencies across a range of disciplines are linked with users (typically but not exclusively private firms) that can apply research outcomes through commercialisation or other forms of adoption (a relevant distinction for CRCs focused on ‘public good’ research).

CRCs can be incorporated or unincorporated organisations formed through collaborative partnerships between publicly funded researchers and end users (CRC 2011a). CRCs must comprise at least one Australian end user (either from the private, public or community sector) and one Australian higher education institution (or research institute affiliated with a university) as shown in Figure 2.2.

Figure 2.2

STRUCTURE OF A CRC



Source: The Allen Consulting Group

The CRC program is acknowledged as an effective means of developing innovation in order to stimulate economic growth (DIST 1995, 1998 in Beesley 2003). There are three broad models of application and use of research outcomes across the CRCs (Howard Partners 2003).

- CRCs that operate primarily as national benefit centres have a strong focus on public good research in areas including resource sustainability, maintenance of biodiversity, environmental health and national disaster research.
- CRCs involved in industrial research have a strong focus on collective industry outcomes concentrating on mature, commodity-based industries with research aimed at raising productivity, product quality and international competitiveness.
- CRCs that focus on commercial benefits through expanding and creating new businesses based on the transfer or sale of intellectual property and reflected in new products or services.

Since the commencement of the CRC program there have been 14 CRC selection rounds completed (CRC 2011a). Selection rounds were conducted in two-year intervals between 1996 and 2006. Following the review of the program in 2008¹¹ annual selection rounds were implemented. Box 2.1 explores the governance of the CRC program in further detail.

To 30 June 2012 there have been a total of 190¹² CRCs that have been funded by the Australian Government (CRC 2011b). Since the program commenced in 1991, the Australian Government has committed more than \$3.4 billion to the CRC program and CRC participant organisations have contributed a further \$10.9 billion in cash and in-kind support.

In the 2012-13 Federal Budget, the Australian Government allocated \$625 million to the CRC program over four years from 2012-13 to 2015-16.

¹¹ O’Kane 2008, *Collaborating to a Purpose: Review of the Cooperative Research Centres Program*

¹² Including both new and extended CRCs. Six new CRCs will be funded from July 2012. These CRCs have not been included in this analysis.

Box 2.1

ADMINISTRATION OF THE CRC PROGRAM

The Minister for Tertiary Education, Skills, Science and Research has overall responsibility for the CRC program. DIISRTE administers the program on behalf of the Australian Government and the Minister appoints an independent expert advisory committee (the CRC committee) to provide advice on the administration of the program. The CRC committee advises on the selection and evaluation of CRCs and on the conditions to apply to the provision of funds under the program (CRC 2011b).

CRC committee members are selected to ensure the committee has a broad range of expertise relevant to the needs of the program in research, education, utilisation, research management, the needs of industry and other end users. Committee members are drawn from industry, research providers and Australian Government departments and agencies responsible for innovation and research. The role of the CRC committee is to provide recommendations to the Minister about:

- applications for CRC funding;
- performance, monitoring and review of individual CRC's activities during their period of operation; and
- the planning, monitoring and evaluation of the CRC program.

When applying for entry into the program, organisations must identify and make a realistic, transparent and defensible assessment of the intended impacts and benefits of the proposed CRC in a way that is clear, robust and simple to understand through the use of an Impact Tool template (CRC 2011d). Information in the Impact Tool informs the development of the key milestones and outputs that will be included in the CRCs funding agreement with the Australian Government. The milestones are used to monitor a CRC's performance over time, including through annual reports and formal reviews.

The Impact Tool aims to identify the potential impact of a CRC proposal by articulating the process by which research leads to impacts on the end user and/or the broader community. For each research program within a proposal, applicants identify key outputs, key usages of outputs, and key impacts that are associated with the usage(s) of output(s). Particular focus is placed on risk assessment and risk mitigation strategies.

Proposals that are largely public good in nature are able to value the impact of the public good benefit as a monetary value or describe the impact in non-monetary terms. Therefore the assessment of the potential impacts of a proposed CRC will be weighted towards the thoroughness and quality of thinking articulated within the application that underpins the numbers, rather than towards the numbers themselves.

Source: The Allen Consulting Group analysis.

Source: Information provided by DIISRTE

2.2 Objectives and role of the CRC program

The objectives of the program have changed over time. The early ideals of enhancing and expanding the nation's overall scientific and technological research capability to support broadly stated national objectives were briefly replaced by a heavy emphasis on supporting end user driven research and research capable of producing commercial return (O'Kane 2008).

Following the O'Kane review, while the focus on end user driven research was maintained, the need for the program to deliver public good outcomes as well as commercial outcomes was re-instated as a core objective of the CRC program.

The current objective of the CRC program is to:

deliver significant economic, environmental and social benefits to Australia by supporting end user driven research partnerships between publicly funded researchers and end users to address clearly articulated, major challenges that require medium to long term collaborative efforts (CRC 2011b).

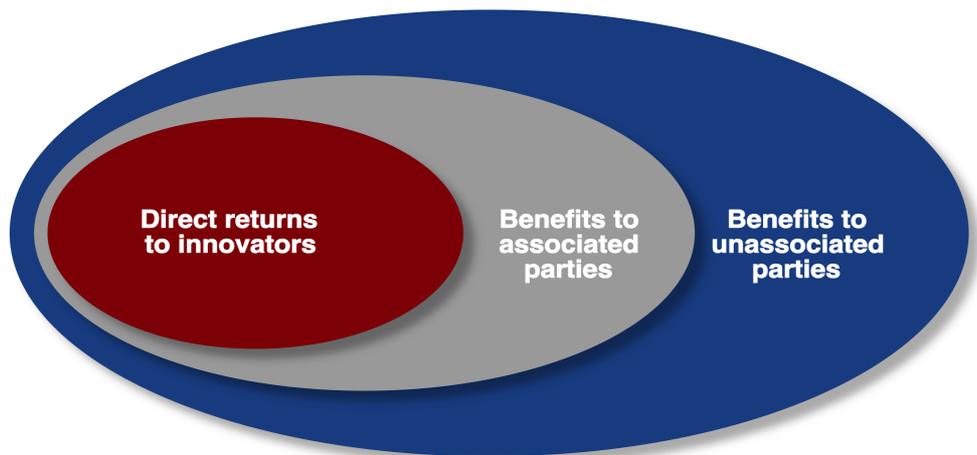
One of the key strengths of the CRC program is the requirement to include potential users of the research within the CRC itself. This is intended to help drive the focus on practical and usable outcomes. The competitive process used to select new CRCs is intended to ensure that only the best proposals are funded. The period of funding (up to 10 years in the first instance) is intended to ensure that CRCs have sufficient time to produce the outcomes that they seek from research to utilisation.

Public-private sector links are critical to receiving a dividend from Australia’s public investment in research. The dividend, in the case of the CRC program, comes in the form of economic, social and environmental benefits. While CRC program participants capture some benefits of the program, many flow more broadly to the Australian community as spillovers.

Spillovers occur from research and development activities that cannot be captured by the innovator. Where research has significant spillovers, the returns to the wider community can be many times that of the returns to the primary innovators (see Figure 2.3). In many cases, the work of individual CRCs results in substantial spillovers. For example, while the work of a CRC may focus on increasing the productivity of an industry, increases in productivity have wider benefits such as increasing incomes, employment and output.

Figure 2.3

R&D SPILLOVERS



Source: The Allen Consulting Group

In some cases the size and nature of direct benefits is such that returns to innovators are still sufficient for investment to occur. In other circumstances, where direct benefits are small and hard to capture by innovators, spillovers result in an under-investment in R&D. It is in these cases that public sector support is critical.

By linking researchers with industry, the CRC program aims to produce high quality, collaborative research and development that is focused on the needs of industry and business. The program also provides for postgraduate and undergraduate education and training opportunities through individual CRCs. This industry contribution to CRC education programs aims to produce industry-ready graduates. Public funding support is provided for up to 10 years (in exceptional circumstances funding may be extended for a period that does not exceed 15 years), after which it is anticipated that the collaboration will continue collaborating independent of the program, evolve and become self-financing or consider its role or aim complete. While the CRC program does not stipulate the transition arrangement post CRC funding, there is an expectation that there will be an enduring legacy in some form.

Effective collaboration is important for Australian research. The CRC program delivers genuine collaboration between researchers and end users, with the goal that successful partnerships stimulate economic growth. At 1 July 2011, 62 per cent of organisations collaborating with CRCs as essential participants were industry/private sector organisations (CRC 2011e).

2.3 Current CRCs

In 2011-12 there are currently 44 CRCs, classified by their industry of operation, are outlined in Figure 2.4:

- agriculture, forestry and fishing (11);
- mining (4);
- manufacturing (5); and
- services (24) (CRC 2011b).

In November 2011 the outcome of the 14th selection round was announced, with six CRCs, listed below, announced as successful applicants (CRC 2011c).

- Plant Biosecurity CRC.
- Invasive Animals CRC.
- CRC for Low Carbon Living.
- Automotive Australia 2020 CRC (AA2020CRC).
- CRC for Water Sensitive Cities.
- CRC for Polymers.

Almost \$148 million in funding was allocated to these CRCs to continue the Australian Government's investment in innovation and collaboration supporting the implementation of the Innovation Agenda — Powering Ideas. The successful CRCs are expected to commence operations in July 2012.

Figure 2.4

CURRENT CRCS (AS AT 30 JUNE 2012)



Source: CRC 2011a.

2.4 Other research policies and programs in Australia

The most obvious way for governments to be involved in R&D is through direct funding programs such as the CRC program and others (O’Kane 2008).

In addition to the CRC program, the Australian Government supports collaboration between researcher and end users through a number of programs. Some of the major programs are listed in Table 2.4.

Key points

The CRC program links researchers with industry to focus R&D efforts on progress towards utilisation and commercialisation. The close interaction between researchers and the users of research, over long time frames, is a key feature of the program.

Up to 2011-12 there have been a total of 190 CRCs that have been funded by the Australian Government. The Australian Government has committed around \$3.4 billion in CRC program funding, and is exceeded substantially by cash and in-kind contributions from CRC participants (approximately \$10.9 billion).

Public-private sector links are critical to receiving a dividend from Australia's public investment in research. The dividend, in the case of the CRC program, comes in the form of economic, social and environmental benefits. While CRC program participants capture some benefits of the program, many flow more broadly to the Australian community as spillovers.

Table 2.1

MAJOR AUSTRALIAN GOVERNMENT COLLABORATIVE RESEARCH PROGRAMS*

Program	Description
CSIRO National Research Flagships	The Flagship programs were officially launched in 2003. They aim to help shape the future of an industry or sector in Australia or address a major national challenge by identifying opportunities that require a research solution (Productivity Commission 2007). They represent some of the largest directed research efforts ever undertaken in Australia and the largest ever redirection of CSIRO funding. They involve partnerships with other research providers and users of research outputs including leading scientists, research institutions, firms, government agencies and selected international partners.
Rural Research and Development Corporations	Rural Research and Development Corporations (RRDCs) were first established in 1989 under the Primary Industries and Energy Research and Development Act (Productivity Commission 2007). There are 15 RRDCs covering nearly all of the agricultural industries. The RDCs bring industry and researchers together to establish research and development strategic directions and to fund projects that provide industry with the innovation and productivity tools to compete in global markets (Council of Rural Research & Development Corporations 2011). As a group, they plan, fund (primarily from compulsory industry levies and public support) and manage much of the agricultural R&D conducted in Australia (CIE 2003 in Productivity Commission 2007).
Australian Research Council programs	The Australian Research Council (ARC) is an independent statutory agency established under the Australian Research Council Act 2001. The ARC administers the National Competitive Grants Program (NCGP) under which funding is made available for research conducted in universities and other eligible organisations across all fields of research except for clinical medical and dental research which is only supported under the Future Fellowships scheme. The majority of it's the ARC's funding is directed towards research conducted in universities. The NCGP comprises two main elements: Discovery and Linkage. Linkage supports collaborative research projects and infrastructure undertaken with partner organisations outside of the university sector (eg in the private sector and government). A component of Linkage provides funding for centres of excellence in research areas of national priority. Such funding can be valuable in contributing to the utilisation and commercialisation of research outputs.
National Health and Medical Research Council Program Grants	The National Health and Medical Research Council (NHMRC) is an independent statutory agency established under the National Health and Medical Research Council Act 1992. The NHMRC is Australia's peak body for supporting health and medical research (NHMRC 2011). NHMRC manages research support and funding through a variety of mechanisms, including grants for individual specific research projects and broad programs of research. Program grants support teams of researchers to pursue broadly based collaborative research activities (Productivity Commission 2007).
Joint Research Engagement	The purpose of Joint Research Engagement (JRE) is to encourage and support collaborative research activities between universities, industry and non-government sectors, where those activities are not specifically supported by competitive grants. The JRE Grant – Engineering Cadetships enable higher education providers to support the research training costs associated with higher degree by research students undertaking a cadetship in relevant areas of engineering or science. Cadetships involve a combination of formal research training with the higher education provider and concurrent employment with a business to carry out R&D activities.

*This is not an exhaustive list but is included to illustrate that there are a range of funding mechanisms currently available to support collaborative research.

Source: The Allen Consulting Group.

Chapter 3

Economic impacts

The CRC program has had a significant impact on the Australian economy since it began over two decades ago. A diverse range of CRCs have led to significant impacts both within a CRC's industry of operation, as well as outside of it.

This chapter explores the economic impacts of the CRC program. It examines the:

- **direct economic impacts** — these relate to the specific impact on an industry as a result of CRC funding (outputs relating to Tier 1, 2 and 3);
- **indirect economic impacts** — these are flow-on impacts to other areas of the economy that are not be captured by the reporting of only direct impacts (Tier 1, 2 and 3 outputs); and
- **preparedness** — these relate to economic impacts, which will transpire only in the event that certain circumstances occur (Tier 4 outputs).

It should be noted that this chapter reports on the sector *where* the impacts occurred rather than on the sector classification attributed to the CRC. For example, the CRC for Asthma and Airways is classified as a CRC in the services sector, however it has a wide range of impacts across the economy that can be observed in other sectors, such as manufacturing.

3.1 Direct economic impacts

The direct economic impacts of the CRC program are the consequence of outputs produced by the CRCs. These include cost saving technologies, revenue opportunities, spin-off companies and efficiency gains.

This study has identified a total of \$14.45 billion of direct economic impacts from the CRC program. This reflects the outputs by only a limited a sample of CRCs (62 per cent), with data limitations ultimately meaning that the study has been unable to identify the full impact of the program. While the majority of current CRCs have been consulted as part of this analysis (see Appendix A), the outputs of previous CRCs have come from Insight Economics (2006) and Allen Consulting Group (2005). Both of which sampled an incomplete set of CRCs.

Over \$8.58 billion of impacts have already been realised (59 per cent), with a further \$5.87 billion of impacts estimated to occur between 2012 and 2017 (41 per cent). This reflects a number of factors.

- First, the CRC sample included here and previous analyses has progressively increased over time. As a result each study has identified a growing number of outputs and impacts — which gives the appearance that impacts have increased over time.
- Second, the nature of R&D inherently means that any impacts are likely to be delayed. Some investments made in the early years of the program are only being realised now.
- Third, in the early years of the program many CRCs were public good in nature, with limited quantifiable economic impacts.

- And fourth, as the CRC program has matured over time. From an administrative perspective, the process employed to assess competitive applications has become more robust and rigorous with respect to assessing the potential for a CRC proposal to deliver impacts. Similarly, participants (and potential participants) have become better at articulating the impacts they expect to produce.

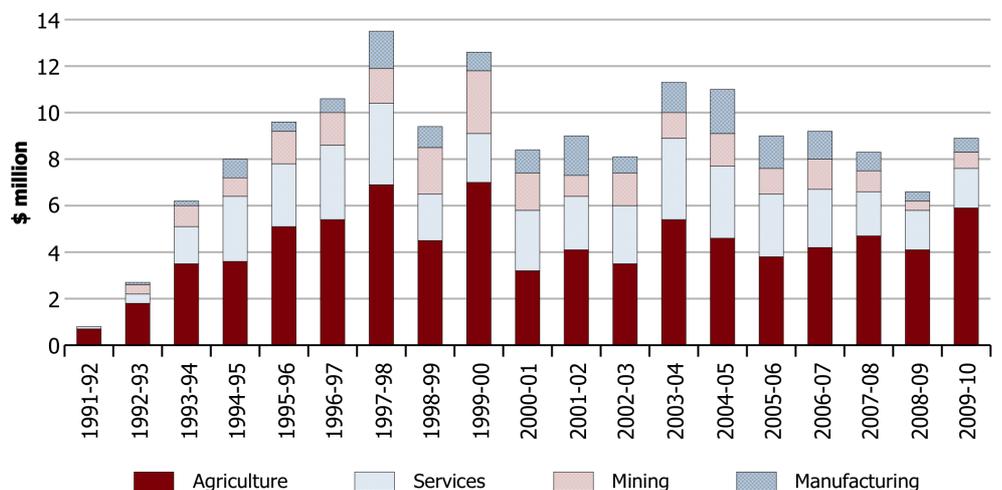
Direct economic impacts have been aggregated in-line with the study’s assessment framework and include Tiers 1, 2 and 3 of outputs. Attribution rates have been applied to outputs where the impact has resulted from the work of a third party as well as a CRC. Outputs, which have been defined as ‘imminent’ are estimated to occur between 2012 and 2017, have also been included in the overall assessment. (Outputs that relate to preparedness, involving forewarning or mitigating risks, have not been included in the reporting of the aggregated direct economic impacts.)

One of the key outputs of any CRC is the number of research postgraduate students that have completed their studies with the support of the CRC. Between 1991-92 and 2009-10, approximately 4,400 doctorate and masters degrees by research were awarded to students who had received industry focussed training as part of their studies with the support of a CRC (DIISRTE 2011c). CRCs involve and support students in a variety of ways such as incorporating postgraduate research in core research activities, supporting students through scholarships, offering targeted career development programs and facilitating industry placements and co-supervision. CRCs work in partnership with higher education providers to provide students with a high level of industry exposure. It should be noted that the above figure is likely to be an underestimate as a number of graduates with CRC exposure. For example, DIISRTE’s student count data excludes students who have been awarded degrees after the CRC’s funding period has ended.

Insight Economics (2006) estimates an output premium of around \$37,000 per annum per research postgraduate in Australia (in \$2012). The cumulative value of education outcomes achieved under the program is \$163 million in total. Figure 3.1 shows how this has been distributed over time. It should be noted that the trend broadly reflects the number of CRCs in operation at any given point in time.

Figure 3.1

VALUE OF CRC SUPPORTED EDUCATION OUTCOMES



Source: Allen Consulting Group analysis based on data provided by DIISRTE.

The CRC program has had the greatest impact in the agriculture sector, with an estimated direct impact of \$6.15 billion. This represents average annual direct economic benefits in the agriculture sector of \$237 million over the life of the CRC program. Approximately 59 per cent of the direct economic impacts in the agriculture sector (CRC products and collaborative impacts) have been realised.

The services sectors has also benefited considerably from the CRC program, with a total of \$5.68 billion of direct economic benefits identified. The CRC program has also impacted significantly on the mining and manufacturing sectors, with direct economic impacts in these industries totalling \$1.55 billion and \$1.07 billion respectively.

The direct economic impacts of the CRC program in each of these industries¹³ are summarised in Table 3.1 and examined in further detail below. The table illustrates the total economic benefits identified by this study in each sector of the economy. Importantly, it is not meant to show the relative performance of CRCs within each sector of the economy, nor is it intended to provide information for a cost benefit analysis. Over the years, the focus of the CRC program has shifted and support for each sector has varied. Considerations about the rationale for funding, particularly public good elements of CRCs, mean comparisons should not be made based on these results.

Table 3.1

DIRECT ECONOMIC BENEFITS OF THE CRC PROGRAM BY SECTOR (\$ MILLION 2012 DOLLARS)

Sector	1991-2012	2013-2017	Average annual	Total current value
Agriculture	3,649	2,501	237	6,150
Services	3,125	2,558	219	5,683
Mining	1,177	372	60	1,549
Manufacturing	628	440	41	1,068
Total	8,580	5,872	556	14,452

Note: It should be noted that in addition to reflecting on the relative performance of CRCs in different sectors, these impacts have also been influenced by changes in program objectives over the years and the availability of data.

Source: Allen Consulting Group analysis.

Impacts in the agriculture sector

In 2010-11 the gross value of total Australian agriculture, forestry and fishing production was \$31.3 billion, directly contributing 2.3 per cent to Australia's GDP. Further, the agriculture sector employed 467,000 people in 2009-10 (ABS 2010).

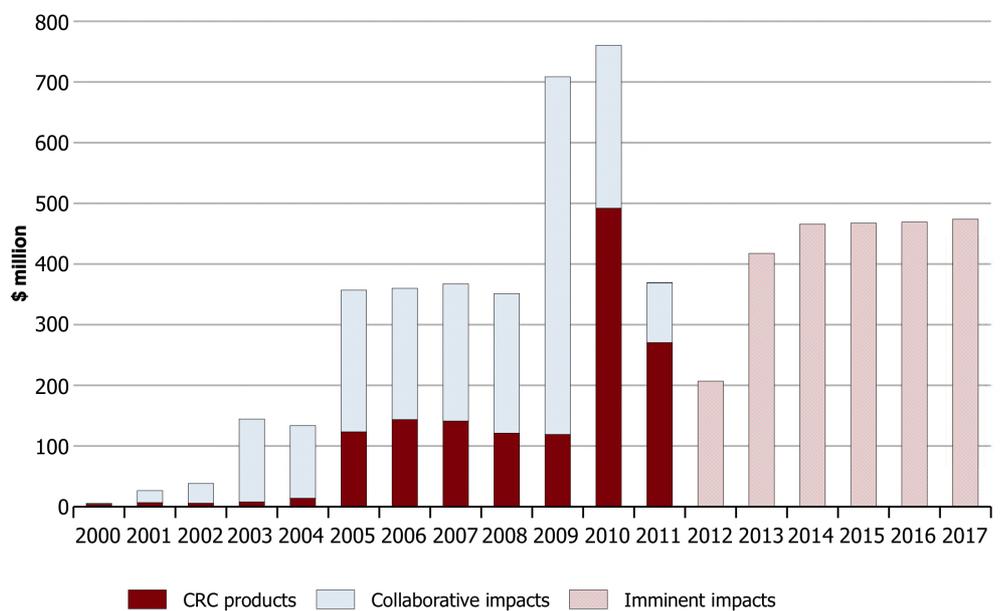
¹³ The sectoral split is based on the ABS Australian and New Zealand Standard Industrial Classification (ANZSIC) system (2006, cat no. 1292.0). The agriculture sector/industry refers to the Agriculture, Forestry and Fishing industry. For the purposes of this report, the services sector/industry encompasses all industries excluding Agriculture, Forestry and Fishing, Mining and Manufacturing.

Over the life of the CRC program, about a quarter of the CRCs have been in the agriculture sector. As noted, the greatest amount of direct economic impacts as a result of the CRC program, have been identified in the agriculture sector. The current cumulative value of the CRC program, between 1991 and 2017, to the agriculture sector is \$6.15 billion dollars. Of this some \$3.65 billion dollars has already been realised, with the remaining \$2.50 billion dollars predicted to occur between now and 2016-17.

As seen in Figure 3.2, this study identified impacts to the agriculture sector from 2000 to 2017. It is noted that this does not mean impacts have not occurred outside of this timeframe. Rather the study has only been able to identify impacts during this time. This also applies to the other sectors.

Figure 3.2

ANNUAL IMPACTS OF THE CRC PROGRAM IN THE AGRICULTURE SECTOR



Note: Where, **CRC products** are those outputs which have been delivered, and have been quantified; **Collaborative impacts** are those outputs where part of an outcome is attributable to the CRC program, with an appropriate attribution rate applied; and **Imminent impacts** — those outputs which are anticipated to occur over the next five years (out to 2016-17), where technology or output has been “proved-up” and the route to market is clear. Limited impacts were recorded prior to 2000.
 Source: Allen Consulting Group analysis

The figure shows that the value of CRC products, directly attributable to CRCs in the agriculture sector, has increased since 2000. The value of impacts anticipated over the next five years is expected to be just over \$400 million each year.

The figure shows significantly greater impacts occurring in 2009 and 2010. This is due to two separately reported impacts. Firstly, Pork CRC reported significant impacts in 2010 (discussed in Box 3.1 below). Secondly, Beef CRC reported the cumulative impacts of BREEDPLAN, which has significantly increased the rates of genetic gain in Australian seedstock and commercial cattle herds. This was reported as a total current value and due to difficulties in attributing it across specific years, it has been reported in 2009.¹⁴

The CRC program has had a variety of economic impacts across the agriculture sector. These include cost savings associated with outputs that have reduced the impact of invasive animals, increased income derived from improved water use efficiency, increased revenue associated with the better management of insects in the cotton industry and developed the Meat Standards Australia grading system.

Appendix C outlines the direct economic impacts identified by CRCs in the agriculture sector. These impacts include:

- cost savings of approximately \$40 million dollars from lower feed usage and greater flock uniformity attributable to the Poultry CRC;
- increased sales revenue of \$86.7 million dollars annually for cotton growers through the management of insects and water savings as a result of work undertaken by the Cotton Catchment Communities CRC;
- cost savings associated with the translocation of lobsters from low to high productivity areas of ocean in the order of \$206.8 million as a result of work undertaken by the Australian Seafood CRC;
- reduced health costs, reduced livestock losses and export income associated with the eradication of equine influenza, totalling \$134 million by the Australian Biosecurity CRC; and
- genetic gains for commercial dairy cows and increased capital value of elite breeding stock of \$31 million attributed to the Dairy Futures CRC.

In addition, between 1991-92 and 2009-10, an estimated 2,200 research postgraduate degrees were supported through CRCs in the agriculture sector (DIISRTE 2011c).¹⁵ The value of education outcomes achieved is \$89 million in total.

The CRC for High Integrity Australian Pork has had significant economic impacts in the agriculture industry. The impacts of this CRC, as well as a brief overview of the CRC are examined in Box 3.1. The discussion also outlines how the unique nature of the CRC has contributed to its success.

¹⁴ Supported by information provided by the CRC for Beef Genetic Technologies, based on R Banks, pers comm. 2012.

¹⁵ This excludes graduations that may have occurred after the CRC funding period had ended.

Box 3.1

CRC FOR HIGH INTEGRITY AUSTRALIAN PORK

The CRC for an Internationally Competitive Pork Industry (Pork CRC) was established in 2005 with initial CRC program funding of \$25.75 million. In 2011, a further \$20 million was announced to establish the CRC for High Integrity Australian Pork. The challenge for the Pork CRC was to enhance the efficiency and cost competitiveness of the Australian pork industry so that Australian producers can compete globally and ensure a sustainable and profitable future. This involves reducing feed costs through the development of better grains and innovative grain processing methods, the development of better pigs and systems to enhance the efficiency of production and better pork to increase the demand for Australian pork in domestic and international markets.

Core participants included Australian Pork Farms Group Ltd, Australian Pork Limited, CHM Alliance Pty Ltd, Murdoch University, New Zealand Pork Industry Board, the SA Research and Development Institute (SARDI) and the University of Adelaide. The Pork CRC has reinvigorated research in the pork industry, with the impacts and participant/producer interest achieved highlighting the benefits of the CRC model to deliver science based outcomes to industry. The CRC program stimulated industry participants to undertake collaborative research, and in numerous cases, join the CRC as partners.

Dr Brian Luxford from Rivalea (Australia's largest pork production company) explains the value of the Pork CRC in the following quote taken from Pork CRC's exit report

"The CRC with its emphasis on collaboration has provided significant opportunities for interaction with both other producers and scientific groups. The benchmarking program established by the CRC is one example. This program provides a forum where producers can jointly seek solutions to improve productivity. The development of the base funding model has brought additional researchers utilizing Rivalea's facilities. This has provided additional opportunities for exchange of ideas".

The Pork CRC conducted research and commercialisation activities in three programs.

1. Research and commercialisation activities in program 1 have resulted in the release of two new grain varieties and three new pea varieties developed specifically for pigs and to be grown in pork producing areas of Australia. Research in Program 1 has also established and commercialised (through AusScan) NIRS calibrations for the rapid assessment of the energy and other nutrient values of grains. The technology and new information developed by scientists at the University of Queensland showed that it is the larger particles (>1.0 mm) in ground grain that affects the availability of starch in the small intestine. In animal experiments removing and/or reducing the percentage of large particles in ground barley and sorghum improved overall feed efficiency in growing pigs by 8-12 per cent and in weaner pigs by 15-20 per cent. Program 1 work, as reported by the Pork CRC, had a total value of \$90 million projected over 15 years and the value will increase as the new grains developed by the Pork CRC become more widely available and grown.
2. The outcomes from Program 2 have had a marked effect on changing processes involved in commercial production and in the use of new technologies to enhance the efficiency of production, to reduce overhead costs and increase revenue. The value of the technologies and new information developed by the Pork CRC within Program 2 when combined is reported by the Pork CRC to be worth 35 cents/kg carcass weight, or \$116 million across the Australian industry. The technologies and information generated by the Pork CRC exceeded expectations and enabled producers to select technologies relevant to their situations/issues.
3. The major outcomes from Program 3 have been the discovery that selenium enhanced pork reduces the incidence of colon cancer in a rat model, and the establishment of the human health attributes of Australian pork. The outcomes from Program 3 have markedly enhanced consumer and human health experts' knowledge on the health attributes of pork. The outcomes of Program 3 work, as reported by the Pork CRC, have had a total value of \$101 million, when projected over 15 years.

Note: The economic impacts identified by the Pork CRC in the above case study are based on industry feedback in relation to the adoption of research and its impact. Source: Consultation with the CRC for High Integrity Australian Pork and Allen Consulting Group analysis, including Pork CRC annual reports, Pork CRC website, CRCs over time document 2011, Pork CRC exit report and impact tool

Impacts in the services sector

The services sector¹⁶ is the largest sector in the Australian economy. In 2010-11 the services sector generated approximately \$1.1 trillion for the Australian economy. In those industries where CRCs are most active the relative contribution to GDP was around \$273 billion. This includes:

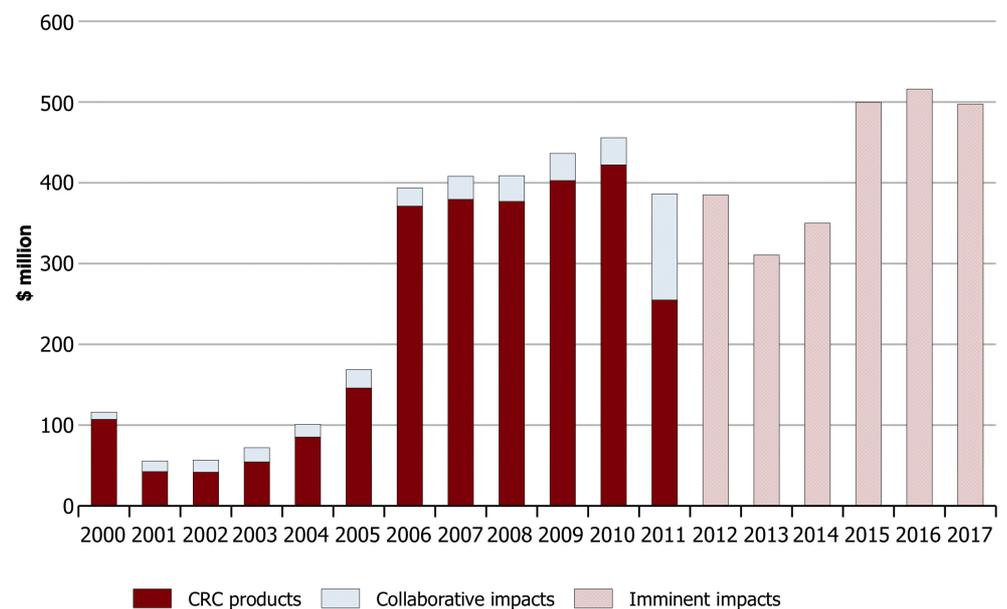
- transport — \$68 billion;
- information media and telecommunications — \$42 billion;
- professional, scientific and technical services — \$89 billion; and
- health — \$74 billion.

The greatest number of CRCs have operated in the services sector. Over the life of the CRC program, just over half of all CRCs have been part of the services sector. Respondents to this study have identified a total of \$5.68 billion of direct economic benefits to the services sector between 1991 and 2017. This includes \$3.12 billion of delivered benefits and \$2.56 billion of benefits predicted to occur before 2017.

The impacts identified by CRCs in the services sector began in 2000, as seen in Figure 3.3. Approximately 55 per cent of the direct economic impacts in the services sector have been realised (CRC products and collaborative impacts). The remaining impacts are anticipated to occur before 2017.

Figure 3.3

ANNUAL IMPACTS OF THE CRC PROGRAM IN THE SERVICES SECTOR



Note: Where, **CRC products** are those outputs which have been delivered, and have been quantified; **Collaborative impacts** are those outputs where part of an outcome is attributable to the CRC program, with an appropriate attribution rate applied; and **Imminent impacts** — those outputs which are anticipated to occur over the next five years (out to 2016-17), where technology or output has been “proved-up” and the route to market is clear. Limited impacts were recorded prior to 2000.

Source: Allen Consulting Group analysis

¹⁶ For the purposes of this report, the services sector includes all industries except agriculture, mining and manufacturing.

Figure 3.3 shows that the value of CRC products, directly attributable to CRCs in the services sector, has steadily increased since 2001. The figure shows a large number of collaborative impacts in 2011. The Oral Health, Vision and HEARing CRCs all reported highly valued outputs, coming to fruition in 2011, with which they collaborated with other organisations. The value of impacts anticipated over the next five years is expected to be peak at just over \$500 million in 2016.

The impacts include contract income and revenue, the value of royalties from the sale of patents, cost savings, increased output, the value of spinoff companies and improved return on investment through improved governance and management of asset portfolios.

The CRC for Rail Innovation, which operates in the services sector, identified a significant quantity of imminent benefits in response to the study's survey. Box 3.2 explores these economic impacts, as well as how the CRC program has facilitated these impacts.

Appendix C outlines all of the direct economic impacts of the CRC program to the services sector. Impacts identified include:

- royalties generated from the sale of patents by the Vision CRC totalling \$90 million;
- license agreements to allow companies to develop and market a drug with a total value of over \$16 million as a result of work undertaken by the CRC for Cancer Therapeutics;
- the value of licenses granted and the value of a spin-off company formed by the CRC for Biomarker Translation of \$120 million¹⁷;
- Capital markets CRC's sale of software to SMARTs Pty Ltd valued at \$9.4 million in 2010; and
- increased revenue of \$99 million associated with the outputs of the Smart Services CRC.

In addition, between 1991-92 and 2009-10, an estimated 1,200 research postgraduate degrees were supported by CRCs in the services sector (DIISRTE 2011c).¹⁸ The value of education outcomes achieved is \$43 million in total.

¹⁷ The estimated impacts are based on the potential outcomes of research and appropriate agreements, and is contingent on these events occurring.

¹⁸ This excludes graduations that may have occurred after the CRC funding period had ended.

Box 3.2

THE CRC FOR RAIL INNOVATION

Following the conclusion of the CRC for Railway Engineering and Technologies in Rockhampton in 2007, the CRC for Rail Innovation commenced operations as the new CRC for the rail industry. With a combined resource total of \$100 million, the CRC for Rail Innovation has been, and continues to be, a significant asset to the Australian rail industry; linking the substantial skills and resources of the industry with the research and development skills of several of Australia's leading universities.

The CRC for Rail Innovation aims to address key challenges common to the rail industry through collaborative research. This enables a small contribution from individual rail companies to be leveraged in order to solve serious problems common to several participants such as social, environmental and economic responsibilities by improving performance and reducing costs, integrating human factors of safety management systems into operational, engineering and management practices and reducing environmental impacts.

In order to address the growth needs of the rail industry, six key research themes have been identified: Climate Change and the Environment, Performance, Safety and Security, Workforce Development, Smart Technology and Urban Rail Access. Large amounts of research within these themes are coming to maturity and the focus is shifting heavily towards adoption and commercialisation.

As of 30 June 2011 there were 56 research projects underway or approved to progress and 45 projects completed. 136 assorted research reports/ outputs have been completed, many of which have been made available on the CRC for Rail Innovation website.

The unique structure and nature of the CRC program has enabled the CRC for Rail Innovation to achieve high standards of quantitative and qualitative research outputs for the Australian rail industry.

The CRC for Rail Innovation, in their response to the study's survey identified a variety of imminent economic impacts. These include the following:

- the development of fatigue software which will reduce fatigue related injuries in the rail industry and improve driver performance. The impact is anticipated to begin occurring in 2014, with annual savings attributable to the CRC of \$10.2 million;
- a reduction in railway level crossing accident numbers through the implementation of safer level crossing research outputs. The impact is anticipated to begin occurring in 2015, with annual savings attributable to the CRC of \$33.3 million;
- improving knowledge of best learning practice for drivers and developing new and effective delivery methods which will increase the speed of entry of new drivers to the workforce, improve safety, reduce training times and associated salary costs. This will be achieved through the use of simulators to accelerate driver training and improving route knowledge acquisition and promote the case for driver-only operations with an emphasis on safety. The impact is anticipated to begin occurring in 2013, with annual savings attributable to the CRC of \$35.6 million;
- improved industry productivity by streamlining the way noise issues are managed, improving effectiveness and reducing construction of noise barriers, maintenance costs and noise monitoring insulation costs and greatly reduced expenditure on noise mitigation infrastructure. The impact is anticipated to begin occurring in 2015, with annual savings attributable to the CRC of \$30 million;
- the development of new insulated rail joints (IRJ) which are used in large quantities industry-wide. Project will potentially increase IRJ life by 50%. The impact is anticipated to begin occurring in 2015, with annual savings attributable to the CRC of \$335 million; and
- the development of the Rail Grinding Best Practice automated decision tool which will save \$25 million per annum in maintenance costs across the industry and is anticipated to begin in 2015.

Source: Consultation with the CRC for Rail Innovation and Allen Consulting Group analysis, including CRC for Rail Innovation annual report, CRC for Rail Innovation website, CRCs over time document 2011, CRC for Rail Innovation impact study survey response 2012.

Impacts on the mining sector

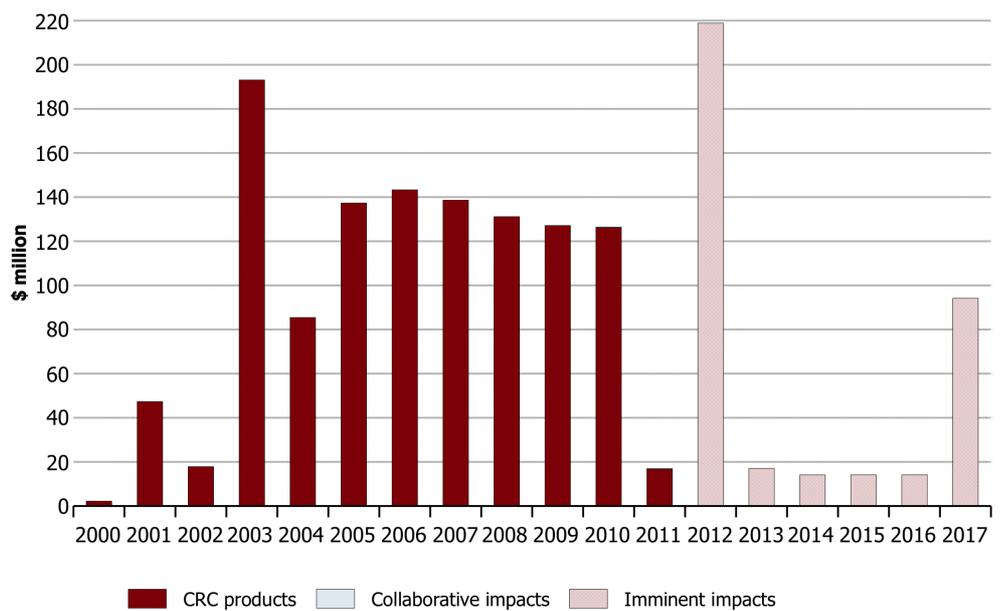
For 2010-11 the gross value of total mining production in Australia was \$95.5 billion, underpinning approximately 7.4 per cent of Australian GDP (ABS 2011). Employment in the mining sector grew to around 144,000 in 2009-10 (ABS 2010).

The mining sector has had the lowest number of CRCs operating within it of the sectors examined. Only 11 per cent of new and extended CRCs have been involved in the mining sector. However, the CRC program has had a significant impact on the mining sector. In total the cumulative impacts of the program on the sector total \$1.17 billion. In addition, a further \$372 million of impacts are anticipated to occur between now and 2016-17. The total current value of impacts on the mining sector therefore amounts to just under \$1.55 billion.

The impacts identified in the mining sector began in 2000, as seen in Figure 3.4. Figure 3.4 also demonstrates that within the mining sector, impacts resulting from CRC products and imminent outputs have been most prominent, with only a limited number of collaborative outputs identified. Additionally, within the mining sector 75 per cent of the identified impacts have already occurred. This is significantly more than the average (59 per cent) of the sectors examined.

Figure 3.4

ANNUAL IMPACTS OF THE CRC PROGRAM TO THE MINING SECTOR



Note: Where, **CRC products** are those outputs which have been delivered, and have been quantified; **Collaborative impacts** are those outputs where part of an outcome is attributable to the CRC program, with an appropriate attribution rate applied; and **Imminent impacts** — those outputs which are anticipated to occur over the next five years (out to 2016-17), where technology or output has been “proved-up” and the route to market is clear. Limited impacts were recorded prior to 2000.

Source: Allen Consulting Group analysis

The figure shows spikes in impact in 2003 and 2012. As reported in the previous study (Insight Economics 2006), Parker CRC for Integrated Hydrometallurgy (Parker CRC) identified highly valued outputs in 2003. In the current survey, the Parker CRC also reported activities that will lead to a large cumulative impact in 2012.¹⁹ This was reported as a total net present value and, due to difficulties in attributing it across past years, the impact has been allocated to 2012. In addition, the cumulative benefits of outputs from CRCMining activities have been allocated to 2012.

Figure 3.4 shows that the value of CRC products, directly attributable to CRCs in the mining sector, has increased consistently over the years 2005 to 2010. Whilst, impacts were relatively low in 2011, it is expected that projects will come to fruition in 2012.

The impacts identified in the mining sector include royalty revenue, increased revenue for mining companies, the formation of spin-off companies and cost savings in relation to reduced truck maintenance costs and efficiency gains. Appendix C outlines a complete list of the direct economic impacts of the CRC program to the mining sector, these include:

- \$34 million of contract income for CRCMining between 2005 and 2012;
- increased revenue for mining companies through the development of computer based monitoring and management systems, and the development of other cost saving technology, with a current value of \$80 million as a result of work undertaken by CRCMining;
- a current value of CRCMining spin-off companies of \$41 million; and
- annual costs savings through productivity increases of \$8 million per year as a result of work undertaken by CRCMining.

In addition, between 1991-92 and 2009-10, an estimated 590 research postgraduate degrees were supported by CRCs in the mining sector (DIISRTE 2011c).²⁰ The value of education outcomes achieved is \$22 million in total.

Impacts on the manufacturing sector

The gross value of manufacturing production in Australia was \$107.8 billion for 2010-11, which accounted for approximately 8 per cent of GDP (ABS 2011). In 2009-10 the manufacturing sector employed 955,000 people (ABS 2010).

Approximately 13 per cent (by number) of new and extended CRCs have operated in the manufacturing sector. Within the manufacturing sector, CRC program outputs have ranged from increases in sales revenue for Australian manufacturing companies to increased competitiveness for manufacturing companies through reducing costs, new high-tech products, improving efficiency and reducing waste.

Since 1991 the CRC program has a \$628 million dollar impact on the manufacturing sector. In addition, just over \$440 million of impacts are anticipated to accrue to this sector between now and 2017. In total, the manufacturing sector has therefore enjoyed a mix of cost savings and increased output to a total current value of just over \$1.07 billion as a result of the CRC program.

¹⁹ Parker reported a number of impacts as commercialise in confidence and therefore cannot be listed separately in this report (see Appendix C).

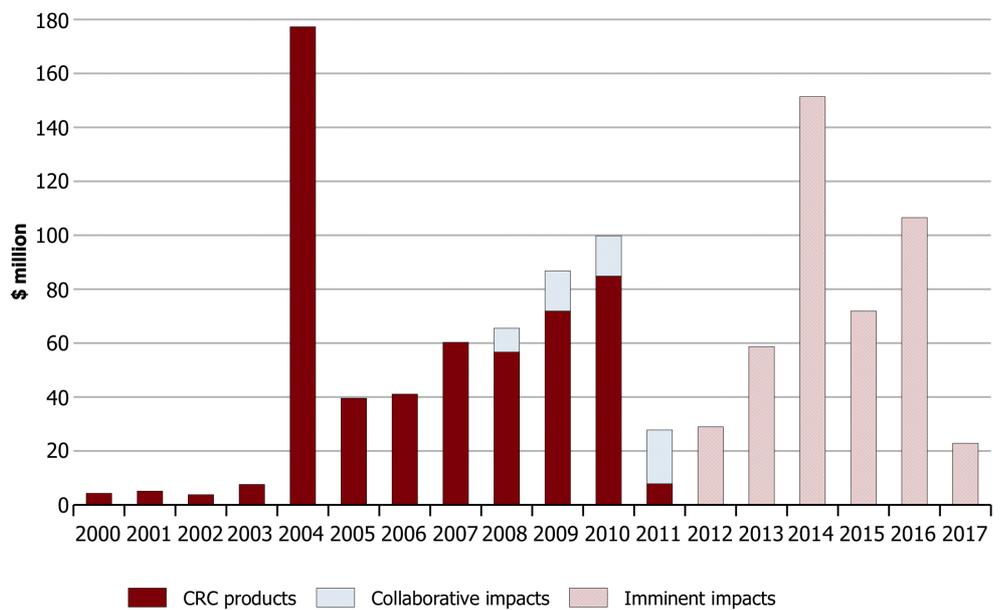
²⁰ This excludes graduations that may have occurred after the CRC funding period had ended.

Figure 3.5 shows the impacts identified by CRCs in the manufacturing sector over time. Approximately 59 per cent of the realised economic impacts in the manufacturing sector (CRC products and collaborative impacts) have been realised.

The figure shows a significant increase in impacts between 2003 and 2004. In 2004, as identified in the Insight Economics report (2006), outputs of CRC Welded Structures allowed a saving of \$120 million in costs. The figure also shows a decrease in impacts between 2010 and 2011. However, the CRC for Polymers and Advanced Manufacturing CRC expect increased commercial sales over the next few years, resulting in a large impact in 2014.

Figure 3.5

ANNUAL IMPACTS OF THE CRC PROGRAM TO THE MANUFACTURING SECTOR



Note: Where, **CRC products** are those outputs which have been delivered, and have been quantified; **Collaborative impacts** are those outputs where part of an outcome is attributable to the CRC program, with an appropriate attribution rate applied; and **Imminent impacts** — those outputs which are anticipated to occur over the next five years (out to 2016-17), where technology or output has been “proved-up” and the route to market is clear.
 Source: Allen Consulting Group analysis.

Figure 3.5 shows that CRCs in the manufacturing sector have identified impacts since 2000. The value of CRC products, directly attributable to CRCs in the manufacturing sector, has, on average, been steadily increasing. Whilst, impacts were relatively low in 2011, it is expected that projects will come to fruition in over the next five years, with the resultant impacts expected to exceed \$140 million in 2014.

Appendix C outlines all of the direct economic impacts identified by CRCs as a result of the CRC program in the manufacturing sector. Specific examples of impacts include:

- the work of the CRC for Polymers, which lead to sales of products manufactured in Australia using CRC technology to the value of \$25 million;

- productivity gains, reduced capital and operating costs of processing infrastructure and cost savings by implementing CAST CRC technology of over \$20 million;
- increased sales revenue related to sales of newly developed alloys, other new products and enhanced margins worth \$33 million between 2009 and 2012 due to work undertaken by CAST CRC;
- an estimated \$15 million licensing deal through the CRC for Asthma and Airways for the production of antibody target in the pharmaceutical sector;²¹ and
- increased commercial sales, of hardening plant and algal products for example, as a result of Advanced Manufacturing CRC outputs of \$50.4 million.

In addition, between 1991-92 and 2009-10, there were approximately 450 research postgraduate degrees supported by CRCs in the manufacturing sector (DIISRTE 2011c).²² The estimated value of education outcomes achieved is \$16 million in total.

The CRC for Advanced Composite Structures has had significant economic impacts in the manufacturing sector since its establishment in 1991. They are explored in detail in Box 3.3.

²¹ This is an example of where a services CRC has produced an impact on the manufacturing sector.

²² This excludes graduations that may have occurred after the CRC funding period had ended.

Box 3.3

CRC FOR ADVANCED COMPOSITE STRUCTURES

Established in 1991 as the CRC for Aerospace Structures, the CRC for Advanced Composite Structures (CRC-ACS) has continued operation with further funding received in 1996, 2003 and 2010. In 2010, the CRC received \$14 million of CRC program funding in support of a new \$65 million five-year extension program. CRC-ACS brings together 28 international and Australian research providers and composites businesses to provide competitive technology for Australian industry and its partners. Since its inception in 1991, it has grown to become one of the world's leading composites research organisations. The partnership includes leading composites businesses, government research laboratories and Australia's foremost universities in composites research. CRC-ACS aims to address the major challenge of embedding Australian composites industry small and medium enterprises (SMEs) into global supply chains. It aims to achieve this through international engagement with multi-national businesses, to undertake collaborative research with Australian researchers and enterprises, thereby building reliance on Australia's proven capability for major technological advancement.

CRC for Advanced Composite Structures technology has enabled Hawker de Havilland (HdH) – now Boeing Aerostructures Australia (BAA) to win an order for Boeing 787 wing-trailing devices. CRC-ACS R&D enabled HdH to propose designs for the 787 that reduce labour costs, material costs and wastage in comparison to current aircraft designs. HdH was able to meet Boeing's demand for lighter structures for the new aircraft with extended life and be supplied at significantly reduced cost.

The production parts are manufactured at BAA's Melbourne production facilities at Fishermans Bend and shipped to the 787 assembly plant in Everett, Washington, USA. CRC-ACS had a central role in supporting the implementation of this contract, with the majority of the CRC's technology transfer process completed by 2008. The total value of the contract is \$4 billion over 25 years. As the CRC was not wholly responsible for the contract win, this economic impact has been classified as an attributable impact for the economic modelling. It is noted that the CRC's R&D contributed largely to the contract. However, with recognition that technology implementation costs and core competencies form a significant aspect of the winning bid, an attribution rate of 10 per cent has been assumed.

The unique structure and nature of the CRC program contributed to this impact, as all of the necessary research capabilities and infrastructure were only available through the consortium assembled and managed by CRC-ACS staff.

"This win [the Boeing contract] was due in large part to the R&D we have undertaken as part of the CRC-ACS research program since 1991" stated Michael Rufert, former Managing Director, Hawker de Havilland.

Source: Consultation with the CRC for Advanced Composite Structures and Allen Consulting Group analysis, including Advanced Composite Structures exit report, CRC website, CRCs over time document 2011, 2006 impact study report, CRC success stories viewed at: https://www.crc.gov.au/html/documents/Documents/PDF/SuccessStories_Manufacturing_Technology.pdf

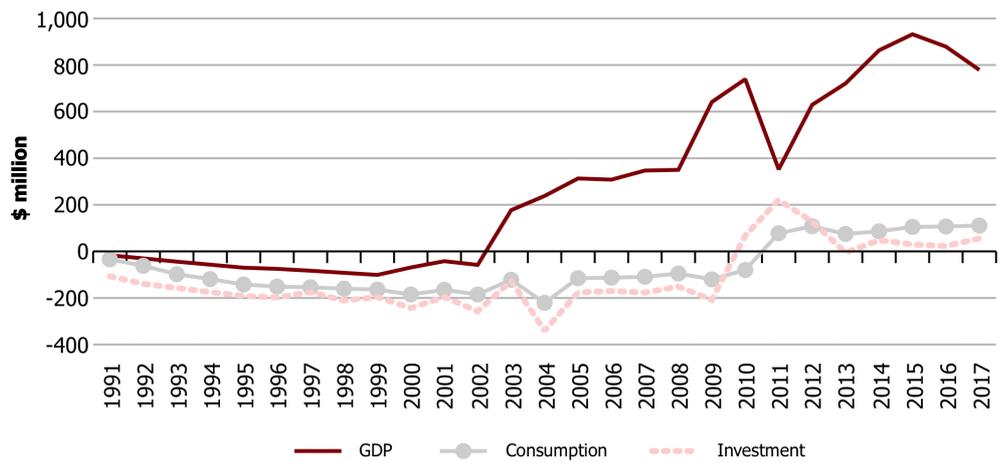
3.2 Indirect economic impacts

As discussed in Chapter 1, the direct impacts of the CRC program are likely to spread throughout the economy in a number of different and unexpected ways. As a diversified economy trading with the rest of the world, the flow through impacts become quite complex. It is also possible that some changes are sufficiently large that they change relative prices in the economy including the price of goods and services, the price of labour and may even change underlying factors such as the exchange rate.

Assessing these impacts and understanding their interconnections requires an economy wide model of the Australian economy. Figure 3.6 and Table 3.2 present the results of the CGE modelling as calculated using the MMRF model. These results can be interpreted as the difference between the current state of the world and the counterfactual — having accounted for both direct and indirect impacts. The modelling is consistent with the assumptions detailed in Table 1.2.

Figure 3.6

ESTIMATED NET IMPACT ON KEY MACRO VARIABLES, 1991-2017



Note: GDP is the sum of income earned from final consumption, government expenditure, investment and net exports. Here, with the exception of funding for the CRC program, government expenditure is assumed constant. The difference in the chart therefore, between the income earned from consumption and investment and total GDP, is the income earned from net exports.

Source: The Allen Consulting Group and COPS.

Figure 3.6 illustrates the net impact of the CRC program on GDP, consumption and investment over time. The dynamics of the CGE results illustrate the lagged nature of the R&D investment.²³ This is consistent with the findings in the Allen Consulting Group’s 2005 study, which observed time lags between commencement of research and realisation of a measurable economic impact of, on average, nine years (Allen Consulting Group 2005).

The CRC program follows a typical investment-like profile for a publically funded R&D program — outlays are incurred in the early years of the program in order to reap future gains. It can be seen in the chart that the CRC program detracted during the “investment” phase, but began to realise positive results from around 2003.

²³ As with the analysis of the direct impacts, the information and data gathering techniques used in this study may have affected the dynamics of the results presented. Impacts achieved in the early years of the CRC Program (up to a decade ago) would be hard to identify and attribute to the CRC Program. Hence, as is seen in the figure, it is unsurprising that the identified indirect economic impacts are concentrated around 2012, whether they have recently occurred or will do so in the near future.

Over the period 1991 to 2017, the net effect of the CRC program was to grow the economy by more than \$7.5 billion. This equates to an average increase in GDP of around 0.03 per percentage points per annum. Consumption (public and private) and investment flows, by and large follow income. As the program began to reap positive rewards, consumption and investment have also begun to increase. Although consumption is on average about \$71 million less than would have otherwise been the case, it has been steadily rising since 2004. The same is true for investment.

It should be noted that the reduction in consumption and investment, in this context, should not necessarily be interpreted as an adverse outcome. Each of these elements, together with net exports, reflects a *source of income* — and, on the whole incomes are rising. The changes in consumption, investment and the trade balance, therefore, simply reflect a change in how and where Australia earns its income.

The modelling reports that the vast majority of GDP growth has accrued through increased export incomes. The modelling estimates that the trade balance has improved by an average of \$480 million per year — a cumulative total of nearly \$12.5 billion. This increase is the result of the CRC program facilitating investments that have allowed the Australian economy to concentrate on areas where a comparative advantage with opportunities for export exists. In particular, a large proportion of CRCs have been based in the more externally focussed sectors of the economy — agriculture, manufacturing and mining. Any increases in the productivity of these sectors might be expected to lead to a net increase in Australia's export capacity.

The cumulative impacts of the CRC program are summarised in Table 3.2. A more detailed discussion of how to interpret the MMRF model results is provided in the box below.

Table 3.2

ESTIMATED NET IMPACT OF THE CRC PROGRAM ON THE AUSTRALIAN ECONOMY, DEVIATION FROM THE COUNTERFACTUAL

Indicator	Average annual impact	Average annual impact	Cumulative impact
	Percentage points	\$ millions	\$ millions
GDP	0.03	278.9	7,530.7
Consumption (private and public)	-0.01	-71.3	-1,924.8
Investment	-0.05	-112.0	-3,025.1
Trade balance	na	480.0	12,479.8

Source: The Allen Consulting Group and COPS.

The spread of this increase in GDP will not be consistent across the above economic variables. This is because of the nature of the CRC program and the differing outputs produced by each CRC. Some of these outputs include investment benefits, such as future cost-saving opportunities, and efficiency gains, while others are more focused on the export market and improving the competitiveness of Australian industry in the face of global competition.

Further, the economic gains associated with each CRC will vary across industries and technologies. Some industries are generally more receptive to the creation and implementation of new technologies, whereas others have reached a stage where new technologies are harder to come by.

Box 3.4

INTERPRETING THE MODELLING RESULTS

The MMRF's modelling of the Australian economy is based conceptually on the following macro economic accounting identity.

- $Y = C + I + G + (X-M)$

Where:

- $Y = GDP$
- $C = consumption$ — adding to the amount of final goods and services that are consumed rather than used in further production;
- $G = government$ spending — providing greater receipts to government and increasing government spending on goods and services in the current period as well as government investments;
- $I = investment$ — increasing the incentive to invest by making certain technologies and industries more attractive to investors that otherwise would not have been; and
- $(X-M) net exports$ — increasing the difference between total exports and total imports, by making Australian industry more productive.

In these simulations the Australian Government's budget balance is fixed. When CRC program funding is removed in the counterfactual, it is returned to the economy as a tax refund. From the accounting identity, this implies that $\Delta Y = \Delta C + \Delta I + \Delta (X-M)$. (Where, the symbol Δ , indicates change.)

It can be expected that most of the change in real income associated with ΔY is consumed by domestic residents. To a reasonable approximation then, the CRC program has no affect on domestic saving and as a consequence, ΔY roughly matches ΔC .

Thus it follows, $\Delta I = \Delta(X-M)$, implying that the key determinate of the change in net volume of trade is the change in investment.

Source: The Allen Consulting Group and COPS.

Communication and knowledge sharing between universities, industry groups, companies and government is an important factor in the efficient transferral of the research results. Collaboration between researchers and industry also varies across industries and this contributes to the variation in benefits associated with individual CRCs. In general terms, the more knowledge sharing there is, the greater the benefits seen from the CRC program.

Relative to the funds committed to the CRC program, benefits to the broader economy generated by the CRC program exceed program costs by a factor of 3.1.²⁴ How this result has been estimated is reported in Table 3.3. Previous studies on the impact of Australian research institutes have demonstrated that they are able to generate significant increases in GDP. A study on research institutes at the University of Queensland for example, estimated that the institutes were able to generate increases in GDP that were as high as 7.1 times the initial outlay (Allen Consulting Group 2011). Comparing the CRC program to those studies however, does not adequately reflect the additional social and environmental impacts inherent to the CRC program, nor its public good nature.

Table 3.3

NET ECONOMIC BENEFIT FROM COMMONWEALTH FUNDING

Item	Amount
Cumulative Australian Government commitment to the CRC program (for those CRCs included in the study sample) ^A	\$2.42 billion
Cumulative increase in GDP ^B	\$7.53 billion
Benefit to cost ratio	3.1

Notes: These results are based on the impacts identified by this study through the data and information gathering stages, with the majority of impacts self-identified by CRCs. It is noted that this may have underestimated the impacts of the CRC program due to difficulties identifying all impacts from all CRCs, as discussed previously. The increase in GDP reflects the assumptions made about the counterfactual case in Table 1.2.

A — This includes only the funding associated with those CRCs for which benefits were identified.

B — This is based on CGE modelling of the identified impacts and represents the net changes to the Australian economy as a result of the CRC program.

Source: The Allen Consulting Group and COPS.

3.3 Preparedness economic impacts

The data and information gathering stages of this study also asked CRCs to identify outputs that related to preparedness. These outputs involve forewarning or mitigating risks. The economic impacts, which relate to preparedness outputs, have not been included in the modelling or the aggregation of direct economic impacts as they relate to impacts associated with CRCs only in the event that certain circumstances occur. The preparedness outputs range from preparing for the impacts of bushfires to the management of disease in vineyards. Table 3.4 outlines the preparedness economic impacts identified in this study.

²⁴ If the investment was to add no additional growth to the economy (that is to achieve parity) the investment would generate a one for one return for every dollar invested. This simplified explanation does not take account of the cost to the economy of raising a dollar of Australian Government funds. This includes the costs of taxation and costs associated with raising funds through Government bonds and other instruments.

Table 3.4

PREPAREDNESS ECONOMIC IMPACTS

CRC	Sector	Impact	Value
CRC for National Plant Biosecurity	Agriculture	Pest surveillance software and hardware for PDAs provided evidence of absence of key grain pest	Estimated potential savings of \$1.8 billion in wheat exports ²⁵
CRC for National Plant Biosecurity	Agriculture	Protocol to manage incursion of disease and preserve mature premium vines	Estimated total savings of \$3.6 million
CRC for National Plant Biosecurity	Agriculture	Understanding virulence development in Russian Wheat Aphid to underpin plant breeding for resistance	Not estimated
Poultry CRC	Agriculture	Improved and new diagnostic tests using DNA technology to achieve results in hours not days.	Total estimated savings of \$5.5 million
Antarctic Climate and Ecosystems CRC	Services	A reduction in costs associated with the predicted decrease in rainfall and runoff from the Climate Futures models	Estimated cost savings of \$0.5 million per year
Antarctic Climate and Ecosystems CRC	Services	Fundamental climate science research by the ACE CRC has contributed significantly to the world's understanding of the extent and pace of climate change	Total cost savings of \$66 million per annum
Bushfire CRC	Services	Reduction in the marginal cost of service delivery, reduction in loss of life, fire related injuries and community health, reduction of property losses and reduction of community anxiety.	Not estimated
CRC for National Plant Biosecurity	Services	Risk prevention and surveillance activities to reduce probability of entry of plant biosecurity threats	Total estimated benefit of \$26.5 million per year over 20 years

Source: The Allen Consulting Group, drawing on survey responses, annual reports, exit reports, management data questionnaires, consultations and other sources.

Preparedness impacts are perhaps, best demonstrated through case studies. Box 3.5 and Box 3.6 respectively discuss the work of the CRC for National Plant Biosecurity and the Bushfire CRC in greater detail.

²⁵ The Allen Consulting Group is currently consulting with a range of CRCs to verify how estimates of impacts were made. The results of these consultations are currently not available.

Box 3.5

CRC FOR NATIONAL PLANT BIOSECURITY

The CRC for National Plant Biosecurity (CRCNPB) started operating in November 2005 in recognition of the need to strengthen the plant biosecurity scientific capacity of Australia. The CRC provides underpinning biosecurity science on harmful pests and diseases that can impact on food safety and security, trade, market access, market development and, ultimately, the profitability and sustainability of plant industries.

The CRCNPB has a lifespan of seven years, with a finishing date of 30 June 2012. CRC program funding for this period totalled \$13 million. On 22 November 2011 it was announced that the Plant Biosecurity CRC rebid was successful. The core participants of the PBCRC are the Australian Government Department of Agriculture, Fisheries and Forestry, Bio-Protection Research Centre NZ, CABI, Charles Darwin University, Co-operative Bulk Handling Limited; CSIRO Entomology, WA Department of Agriculture and Food, Victorian Department of Primary Industries, GrainCorp Operations Ltd, Grains Research and Development Corporation, Horticulture Australia Ltd, Kansas State University, La Trobe University, Murdoch University, New South Wales Department of Primary Industries, Plant and Food Research New Zealand, Queensland Department of Agriculture, Fisheries and Forestry, Queensland University of Technology, SA Research and Development Institute, University of Adelaide, University of Queensland, University of WA and Viterro Ltd.

Australia is relatively free from many of the plant pests and diseases, which seriously impact on agricultural industries in other countries. Through the absence of many pests and diseases commonly found overseas, Australia's plant industries have a valuable competitive advantage in terms of securing market access and maintaining lower production costs. Surveillance is an important tool for securing market access and exporting countries now need to provide accurate, credible evidence to confirm absence (i.e. known not to occur) for pest freedom status.

The CRC program has allowed the CRCNPB to bring together the key players in the plant biosecurity system, including regulatory authorities, R&D corporations and industry bodies. This has resulted in the priorities of end users being addressed throughout development of projects and has maximised the adoption of the CRC's research.

If certain pests found their way into Australia, the economic viability of Australia's plant industries (which have a farm gate value of over \$18 billion and contribute over \$12 billion to export income) would be directly threatened. Even the perception of pests in Australian produce would have a rapid and negative impact on Australia's reputation as a producer of safe, quality food products.

One of the major impacts of the CRCNPB has been the development of pest surveillance software and hardware for Personal Digital Assistants. These include hazard site pest surveillance, stored grain fumigation monitoring, grain insect resistance testing and fruit fly phenology studies. This approach provides chain of evidence control, increases the volume of data collected as well as its integrity through relational databases and seamless data transfer to corporate systems.

The work of the CRC in this area has the potential to lead to significant economic gains. The pest surveillance software and hardware enables by industry (grain storage managers) and government (primary industry agencies) across Australia to gather evidence as to the absence of key grain pests. For example, if a pest was found to be present, the CRCNPB has estimated that this would result in losses of up to \$1.6 billion in wheat exports over a thirty year period (ABARE. Khapra beetle preliminary response plan. 2007, April. Appendix 2). This economic impact relates to preparedness as it involves mitigating the risk to exports related to the discovery of pests.

Source: Consultation with the Plant Biosecurity CRC and Allen Consulting Group analysis, including CRCNPB Annual report, CRCNPB website, CRCs over time document 2011, CRCNPB impact study survey response 2012, ABARE. Khapra beetle preliminary response plan. 2007, April. Appendix 2.

Box 3.6

BUSHFIRE CRC

The Bushfire CRC commenced in July 2003 and received \$29 million over seven years to June 2010. In the 2009-10 Budget, the government announced a further \$15 million over three years (July 2010 to June 2013) to undertake specific research tasks arising from the 2009 Victorian Bushfires Royal Commission.

The Bushfire CRC undertakes research that addresses understanding the underlying risk to, and exposure of, the community to fire. The CRC research includes a focus on the communication of risk and threat and how warnings and information is best communicated. For example; which media should be used and what tools, methods and techniques can be used by public safety authorities to better ensure the safest behaviour under the types of conditions that occur in major events. Further, the research examines the management of risk and the role of incident coordination; as well as the ability to obtain timely information (situation awareness) consistent with fire prediction and other warnings. Also, the ability to resource threat events effectively and consider the impact of events on important infrastructure and resources.

The key impacts of the research programs are to:

- reduce the marginal cost of service delivery;
- reduce loss of life, fire related injuries and community health;
- reduce property losses; and
- reduce community anxiety and increase community resilience.

The CRC's activities have a very strong end user focus and education and training program that builds engagement, delivers innovation and greater capacity within end user fire management agencies and the community in general.

Stakeholders have indicated substantial uptake of the research outcomes resulting in considerable changes to stakeholder policy, practices and overall industry culture.

The CRC is highly engaged with the peak industry body (Australasian Fire and Emergency Service Authorities Council) and all the major fire management agencies and organisations responsible for emergency management. This partnering underscores the Bushfire CRC's presence as a national research centre and helps to defend against perceptions that it is focussed on the needs or research issues of any single jurisdiction.

Source: Based on consultations with the Bushfire CRC and information provided by DIISRTE.

Key points

Between 1991 and 2017, the data gathering for this study has demonstrated that the CRC program has resulted in a total of \$14.45 billion of direct economic impacts.

Between 1991-92 and 2009-10, around 4,400 research postgraduate degrees receiving CRC support were reported completed, with a value to the economy of \$163 million in total. It is noted that due to data limitations, this is likely to understate the actual number of CRC supported postgraduate degrees completed.

The CRC program has had the greatest impact in the agriculture sector, with an estimated direct impact of \$6.15 billion. The services sector has also benefited considerably from the CRC program, with a total of \$5.68 billion of direct economic benefits identified. The CRC program has also impacted significantly on the mining and manufacturing sectors, with direct economic impacts in these sectors totalling \$1.55 billion and \$1.07 billion respectively.

Over the period 1991 to 2017, the net effect of the CRC program grew the economy by over \$7.5 billion. This equates to an average increase of around 0.03 per percentage points per annum. Relative to the Australian Government's investment over the past 13 years, this equates a benefit cost ratio of 3.1.

Chapter 4

Environmental impacts

Although some kinds of environmental research face difficulty in demonstrating direct links between research and impact, there can be a direct link between environmental research and improved environmental outcomes (Group of Eight 2011). Research can be important, add value and have impact by identifying problems of which we might not otherwise be aware. Research also has a role to play in generating possible solutions to the problems that it has identified.

The environmental impacts of the CRC program are wide-ranging: from reducing greenhouse gas (GHG) emissions and energy consumption to protecting areas of land and endangered species. As with economic outputs, environmental outputs range from those that have been delivered and directly attributable to the CRC, to anticipated outputs and those that relate to preparedness. For some CRCs, their primary objective is to achieve positive environmental impacts. For others, this is secondary to commercial objectives, with impacts occurring as a result of a broader research program. Many of these CRCs focus on public good research.

Some of the positive environmental impacts of the CRC program, listed below, are discussed in this chapter. It should be noted that this list is not exhaustive or definitive given the broad scope of the program.

- Reduced GHG emissions.
- Avoidance of the emission of pollutants.
- Reduced energy consumption.
- Reduced water consumption.
- Reduced environmental costs.
- Protection of areas of environment.
- Protection of endangered species.

These impacts have not been quantified or monetised. They are additional to the economic impacts discussed in Chapter 3.²⁶

4.1 Reduced GHG emissions

Decreasing GHG emissions to the atmosphere is a key environmental issue facing Australia and the world (CO2CRC 2011). Emissions reduction will require a full suite of responses: increased use of renewable energy, greater energy efficiency, fuel switching, and increased sequestration of carbon dioxide away from the atmosphere, particularly capture and geological storage of carbon dioxide, are some of the leading technologies being explored globally.

²⁶ In some instances, benefits here have been quantified. These benefits however, do not appear as economic benefits in the previous chapter.

CRCs have addressed these technology options in reducing GHG emissions. For example, the activities of the CRC for Greenhouse Gas Technologies (CO2CRC) have focused on carbon dioxide capture and geological storage (CCS), or geosequestration, to reduce emissions to the atmosphere of carbon dioxide (CO₂). Through the CRC, more than 100 researchers in Australia and New Zealand are collaborating to develop safe and economical CCS technologies that will make impacts in Australia's GHG emissions.

The International Energy Agency (IEA) states that CCS will contribute 19 per cent of the total global CO₂ emission mitigation needs by 2050 (IEA 2009). In the survey, the CO2CRC reported that it has demonstrated that carbon capture and storage is an effective mitigation strategy and contributes around 5 per cent to the global research effort to reduce GHG emissions. To date, 66 tonnes of CO₂ rich gas has been geologically stored, with work ongoing to achieve the storage of 100 million tonnes of gas per year in geological sites in the longer term. The work of the CO2CRC is discussed in further detail in Box 4.1.

For other CRCs, reducing GHG emissions is a secondary issue. Twenty other CRCs focus on delivering new technology for a cleaner, more sustainable future and many others also support green innovation (CRC 2011e). In the survey, CRCs reported varied contributions to reductions in GHG emissions. Some examples are provided in Table 4.1.

Box 4.1

CRC FOR GREENHOUSE GAS TECHNOLOGIES

Reducing GHG emissions and the impact of climate change is the biggest environmental challenge now facing the world. The CRC for Greenhouse Gas Technologies (CO2CRC) is focused on carbon dioxide capture and geological sequestration (CCS), which is recognised internationally as an essential technology for meeting global GHG emission targets.

Building on the success of the Australian Petroleum CRC (APCRC), which existed between 1991 and 2002, CO2CRC commenced in 2003. While the APCRC was primarily concerned with developing research capability, the focus of CO2CRC has been to apply that capability to address issues of major concern with demonstrating CCS.

CO2CRC is a joint venture comprising 32 participant organisations comprising national and international oil, coal and gas industries, universities and other research bodies from Australia and New Zealand, and Australian, state and international government agencies.

Key research providers currently include Geoscience Australia, CSIRO, Institute of Geological and Nuclear Science in New Zealand, and a number of Australian universities. Industry and government participants include Chevron, Shell, BP, Xstrata Coal and Inpex, and a number of state government departments, such as the Victorian Department of Primary Industries and the WA Department of Mines and Petroleum. There are also key participants in Japan and Korea.

CO2CRC is actively involved in multinational research and policy organisations such as the International Energy Agency GHG research and development program, the Carbon Sequestration Leadership Forum, the Intergovernmental Panel on Climate Change, the Asia-Pacific Partnership on Clean Development and Climate, the Australia-China Joint Coordination Group on Clean Coal Technology and the Global CCS Institute.

Through these collaborations, and also through the global nature of many of the core participants, CO2CRC is widely connected and recognised internationally, and is able to learn from, and contribute to, the global CCS community.

The CO2CRC works in three main research areas.

- Capture of CO₂, through which scientists research, develop and aim to demonstrate technologies that will significantly reduce the costs of capturing CO₂.
- Storage of CO₂, through which researchers are modelling and demonstrating the injection, trapping and monitoring of CO₂ storage, in both the laboratory and at the CO2CRC Otway Project site.
- Facilitating deployment of CCS, through research and activities that cover cross-cutting issues such as economics, risk assessment, education and training, and communicating CCS.

Given our ongoing use of fossil fuels, Australia cannot reach its long term GHG targets without deploying CCS technology. CO2CRC is a leader in developing CCS technology nationally and internationally. By working closely with industry partners, CO2CRC is able to address areas that are critical for commercial scale CCS projects. CO2CRC research programs have led to significant advances in CCS technology at all stages of the value chain, from capture to storage, including several international patents. CO2CRC is a leading source of information on CCS for governments, industry, media and the general public, and has implemented a highly successful community consultation program associated with the CO2CRC Otway Project.

CO2CRC has a commercial arm, CO2CRC Technologies Pty Ltd (CO2TECH), which commercialises carbon dioxide capture and storage technologies developed by CO2CRC, and provides consultancy services in the application of CCS technologies for government and industry in Australia and internationally.

CO2CRC reports that the strength of the CRC program lies in its ability to draw together expertise from many different organisations when needed. Therefore, at each stage of a project, the best skills and knowledge are available to achieve important impacts.

Source: Consultation with the CO2CRC and Allen Consulting Group analysis, including CO2CRC Annual Report 2010-11, CO2CRC overview brochure 2011, CRCs over time document 2011, CO2CRC impact study survey response 2012.

Table 4.1

CRCs REPORTING TO REDUCE GHG EMISSIONS

CRC	Details	GHG reduction
CAST CRC	Research has reduced emissions of Sulfur Hexafluoride (SF6) and improved manufacturing efficiency, reducing energy consumption. Manufacturing companies in Australia and around the world have experienced benefits since 2008, with benefits expected to continue through to 2017 and beyond.	Since 2008, over 61,000 tonnes in CO ₂ equivalent savings have been made, with a further 11,000 tonnes expected to be saved each year to 2017. At a value of \$23 per tonne of carbon, this represents a total saving of approximately \$1.7 million.
CRC for Sheep Industry Innovation	Research conducted has reduced methane production per unit of meat and wool as a result of improved reproductive efficiency. The CRC runs Lifetime Ewe Management and Scanner workshops for producers. The workshops commenced in 2008, with impacts first seen in 2009 and increasing in subsequent years.	Workshops have increased reproductive efficiency by an average of 5 per cent in around 3 million ewes, equating to 1,300 less tonnes of methane per year. Nearly two thirds of the impacts can be attributed to the Sheep CRC.
CRCMining	Tight Radius Drilling (TRD) Program has the potential to significantly reduce methane emission via capture from coal seams, and to enable this gas to be utilised for energy production. This technique is being investigated for both underground and surface mining and has the potential to reduce methane emissions. The impact is expected to occur in 2017, dependent on the success of the commercialisation plan.	If TRD was used to assist in degassing 1 per cent of thermal and metallurgical coal in Australia then in excess of 200,000 tonnes of CO ₂ equivalent gas per annum could be captured and utilised rather than vented to atmosphere. At a value of \$23 per tonne, this represents a saving of \$4.6 million per annum.
Poultry CRC	Conducted research into using 'smart sorbers' to increase carbon sequestration from the use of spent chicken litter as a manure. The impact is expected to commence in 2017.	Over 530,000 tonnes of carbon to be sequestered annually until soil saturation rate is approached. The research has built upon existing university expertise, however 90 per cent can be attributed to the CRC project. At a value of \$23 per tonne, this represents a saving of \$10.9 million per annum attributable to the CRC program.
CRC for Spatial Information	Spatial Information in Regional Australia Project will identify the current adoption of precise positioning and Controlled Traffic Farming. Accelerated use and uptake of Controlled Traffic Farming using precision GNSS machine control will lead to reductions in fuel and chemical usage on farms and associated reduction in carbon emissions.	Up to 33 per cent reduction in chemicals and fuel through farming practices which predominantly use precision GPS. Adopting Control Traffic Farming could reduce GHG emissions by up to 89 kg per hectare relative to conventional non-GNSS tillage techniques.
Advanced Manufacturing CRC	Expect imminent impacts from their work to reduce the amount of CO ₂ emitted by two fossil fuel power stations. Following plant decommissioning in 2012, the impacts are expected to occur between 2014 and 2017.	A reduction of 70,000 tonnes of CO ₂ each year. The research has been supported by the Queensland Government and by private investment, however 50 per cent of the impacts can be attributed to the CRC. At a value of \$23 per tonne, this represents a saving of \$0.8 million per annum attributable to the CRC program.

Source: Allen Consulting Group 2012 – Survey of current CRCs. Note: Other CRCs may have contributed to the reduction in GHG emissions, but did not identify this as an impact.

4.2 Avoidance of the emission of pollutants

Waste management and pollution control is another major issue addressed by the CRC program. Much research has been conducted across many industries. For example, the Poultry CRC has supported the adaptation of existing technology to capture dust emission from tunnel ventilated broiler chicken sheds. The adapted technology will be applied to selected farms from 2015 and will benefit users, including home occupiers, who are located near broiler chicken farms. For a 400,000-bird farm, the technology will aim to capture 3.2 tonnes of total suspended particle dust each year.

The Parker CRC for Integrated Hydrometallurgy Solutions (Parker Centre) reports impacts related to reducing the emission of pollutants. Its work is discussed in Box 4.2 below.

Box 4.2

PARKER CRC FOR INTEGRATED HYDROMETALLURGY SOLUTIONS

The Parker CRC for Integrated Hydrometallurgy Solutions (Parker Centre) commenced in 2005 with \$20 million in funding. However, it previously existed over the 1992 to 1999 and 1999 to 2005 funding rounds as the AJ Parker CRC for Hydrometallurgy. Since 1992, the CRC has grown from a small group of researchers working in different organizations and with limited collaboration, into one of the world's largest and most respected hydrometallurgical research organisations.

Core research participants are the CSIRO, Curtin University, Murdoch University and the University of Queensland. The core industry participants span a number of Australian and international mining companies, such as Alcoa of Australia, BHP Billiton Innovation, Vale and Rio Tinto. Key supporting participants include Barrick Gold of Australia, BASF Australia and Nalco Australia.

The Parker Centre generates research outputs that maximise economic returns from hydrometallurgical processing of minerals and minimise environmental impacts. The Centre also trains the next generation of hydrometallurgists for the global mining industry, public sector research institutions and academia.

Hydrometallurgical processes utilise aqueous solutions to extract metals and metallic compounds such as alumina, gold, nickel, copper, uranium and zinc from minerals. Research in two broad programs – Breakthrough Technologies and Process Fundamentals – focuses on Australia's major markets that utilise hydrometallurgical processes (alumina, base metals, gold and uranium).

Continued development of technically innovative processing options is critical to the continued competitiveness of the Australian and global mining sector. The CRC's activities have many environmental impacts and benefit various companies in the mineral-processing sector, some of which are discussed below.

The CRC is evaluating new science and new technologies for low-emission hydrometallurgical mineral extraction. This includes improved organics management in the Bayer process and advances in processing gold ores. Completion of the Bayer organic project will allow the alumina industry to better manage gaseous emissions resulting from organic constituents in bauxite ores.

Research on non-cyanide pressure leaching of refractory gold ores has significant potential to reduce cyanide discharge from the gold industry. In addition, heap-leaching technologies reduce GHG emissions from leach operations due to lower energy demand. Improved understanding of cyanide destruction technologies potentially improves gold industry tailings water quality.

The CRC's development of new technologies for characterising and reducing the environmental impacts of residues and emissions from hydrometallurgical processes has focused on removal of caustic from the Bayer process cycle to reduce the amount of salt in red muds. Work from the Centre in collaboration with the Asia Pacific partnership has determined a suite of strategies for the management and rehabilitation of bauxite residues including biological processes and phyto remediation. The behaviour of cyanide and toxic trace elements in hypersaline tailings systems has been determined and an evaluation of technologies for the control of contaminants in tailings streams has been undertaken and recommendations made to industry end users.

The CRC is also evaluating alternative hydrometallurgical processes that have potential to incorporate more environmentally benign reagents. Thiosulfate and halide-based lixiviants are showing promising opportunity to replace cyanide as a gold leach solution under certain ore mineralogy and operating conditions. In addition, development of a new acid leaching technology for nickel laterite processing in partnership with SME Direct Nickel has the potential to fully regenerate acid used in leach process and thus eliminate discharges of spent acid to the environment.

The CRC reports that the way the CRC program brings together researchers and end users is key to delivering outputs that meet the challenges faced by industry. The research agenda is developed to address technological challenges identified by industry end users, which ensures projects deliver relevant outcomes. In addition, the Parker Centre's management and board is independent from both researchers and end users, which assists in the coordination of the CRC's activities and helps the CRC deliver important outputs.

Source: Consultation with the Parker Centre and Allen Consulting Group analysis, including Parker Centre annual report 2010-11, CRCs over time document 2011, Parker Centre impact study survey response 2012.

4.3 Reduced energy consumption

Reducing energy consumption helps protect the environment by reducing GHG emissions, which also reduces costs. Research activities can develop technologies that reduce the consumption of energy in different industries.

Several CRCs have an impact on energy consumption. For example, a primary goal of CRC for Optimising Resource Extraction (CRC ORE) is to facilitate a fundamental transformation of resource extraction and the way it is evaluated, through mine-wide process optimisation that considers the consumption of energy, water and the generation of CO₂ in mining operations.

Another example is the Advanced Manufacturing CRC. A core focus of its research program is developing technologies for the global renewable-energy and electric-vehicle industries. The research on renewable energy will enable the electricity grid to cope with a higher percentage of renewable energy input through the introduction of reactive power control inverters. Following commercialisation of research outputs, the work will benefit electricity grid owners from 2015-16 onwards. The size of the impact is expected to be 2,000 inverters per year supporting approximately 6 million kilowatt hours of renewable energy per year. Some 50 per cent of the benefits can be attributed to the CRC.

The work of the Australian Seafood CRC demonstrates the great variability in CRC activities that affect energy consumption. Stock rebuilding targets from bio-economic analyses of lobster conducted by the Australian Seafood CRC have targeted a 40 per cent increase in stock density, which reduces fuel use from 37.6 to 22.9 mega joules per kilogram of product. The targets have been implemented in Tasmania and WA, with implementation underway in SA and Victoria, however the rebuilding of lobster stock will take several years.

4.4 Reduced water consumption

Total water use is an important indicator of the extent to which human activity draws upon Australia's finite water resources. Given the pressures placed on water systems by society, in particular, the agriculture sector, it is important that methods of reducing water consumption are investigated.

CRCs can have an impact on the amount of water consumed. For example, the development of strategic management practices for dealing with limited water supplies by the Cotton Catchment Communities CRC contributes towards water savings of over 24,000 mega litres per year on Australian cotton farms, in particular growers in the Namoi, Condamine and Fitzroy catchments.

Further, the Australian Seafood CRC has developed microbial floc technology for prawn farms, which has reduced water used from adjacent rivers by 60 per cent. This research also reduces nutrient outflow by 90 per cent. Therefore, the research project concurrently assists reductions in water consumption and the amount of waste produced. Further impacts of the Australian Seafood CRC are discussed in Box 4.3 below.

Box 4.3

AUSTRALIAN SEAFOOD CRC

The Australian Seafood CRC commenced in 2007 with \$36 million in CRC program funding. The Australian Seafood CRC assists the seafood industry to profitably deliver safe, high-quality, nutritious Australian seafood products to premium markets, domestically and overseas.

The seafood industry is the sixth most valuable of Australia's food-based primary industries, with a gross value of production of \$2 billion in 2006-07. Unfortunately the Australian seafood industry has longstanding "weaknesses" at many places along the value chain, stemming from market and institutional failure. A national approach to 'fixing the gaps' in the value chain was needed. The goal of the CRC is to double the value of the Australian seafood industry to \$4 billion by 2017 to generate a significant number of new jobs in rural and regional areas.

Around 35 companies, industry bodies, research institutions and government agencies are participating in the Australian Seafood CRC. Participants include fishing and growers associations, other research organisations (e.g. SA Research and Development Institute), government departments (e.g. WA Department of Fisheries) and universities (e.g. University of Tasmania).

The CRC stimulates and provides comprehensive seafood related research and development and industry leadership on a national basis. This will help address institutional and market failure in many of the Australian seafood industry's value chains. The CRC will undertake research programs covering value chain profitability and product quality and integrity.

There are three research programs:

- product innovation;
- product and market development; and
- commercialisation and utilisation.

While producing environmental impacts is not a main output of the Australian Seafood CRC, it does have several environmental benefits. The environmental impacts of the CRC include reductions in the amount of waste produced, reduction in water usage, reductions in energy consumption and protection of endangered species. Wider benefits also occur as a result of the CRC's activities. For example, the CRC has enhanced the sustainability of wild commercial fisheries through better fishery management models that contribute to reduced harvesting pressure on wild populations. The impacts occurred for western and southern rock lobsters in 2011, and will occur in 2013 for abalone.

In addition, restoration of coastal ecosystems through recovery of sea cucumber (stock restoration) and lobster populations (lobster translocation) has occurred. Lobster translocation is forming part of the Tasmanian Government's response to rebuilding coastal ecosystems' resilience to climate change. Both sea cucumber and lobster restorations are underway at a small scale and are increasing.

The Australian Seafood CRC reports that the close relationship between research and industry is key to achieving successful outcomes. The end user focus of the CRC program, and the need for industry to endorse each research project before it is conducted, ensures that research is relevant. The seafood industry is highly regulated, therefore it is critical to work with both government authorities and fishermen, otherwise achieving outcomes is significantly impeded.

Source: Consultation with the Australian Seafood CRC and Allen Consulting Group analysis, including the Australian Seafood CRC annual report 2010-11, CRCs over time document 2011, Australian Seafood CRC impact study survey response 2012.

4.5 Protection of areas of environment

With many areas of national environmental significance in Australia, the protection of areas of environment is a key outcome of the research of CRCs. Many CRCs work to protect or conserve large areas of land, particularly those in the agriculture sector.

For example, Cotton Catchment Communities CRC reports that between 2006 and 2011 nearly 100,000 hectares of native vegetation and riparian zones on cotton farms have been actively managed. For example, in the Namoi catchment, 980 hectares of native vegetation on cotton farms has been conserved or revegetated. Approximately 50 per cent of the impact can be attributed to the CRC's partnership with the Catchment Management Authority, with the other 50 per cent attributed to the growers. This impact is ongoing.

In addition, the CRC for National Plant Biosecurity produced outputs that have underpinned processes to protect the environment at Barrow Island in WA while allowing the development of a major infrastructure project to progress. Barrow Island is approximately 20,000 hectares in total. The impacts occurred between 2006-07 and the present. Nearly three quarters of the impacts can be attributed to the CRC, with the CRC undertaking all of the research, and implementation and monitoring activity conducted by the development company.

The Invasive Animals CRC has developed Australia's first carp bio-control agent which will lead to extremely rapid decreases in European carp numbers over approximately 1.5 million square kilometres of the Murray-Darling Basin. Impacts will start to accrue in 2017, and overseas experience indicates that a decrease of over 80 per cent in carp abundance will occur. Murray-Darling Basin and other government waterway managers, recreational fishers and the general public will benefit. The project would not have been funded in the absence of the CRC.

CRCs also protect areas of ocean. In particular, the second generation ecosystem models and position analyses of the Antarctic Climate and Ecosystems CRC are projected to protect ecosystems in the Southern Ocean by informing policy in the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). The CRC's work will assist organisations that participate in the CCAMLR and is expected to protect two billion hectares of Southern Ocean. The CRC is working with the Australian Antarctic Division to achieve this impact.

4.6 Protection of endangered species

The protection of endangered species is of primary concern to some CRCs, while for others it is secondary. For example, the activities of the Invasive Animals CRC have obvious benefits for the protection of endangered species. Through investigating and implementing best practice pest animal management and the development of commercial products, the population of Australia's endangered species can be increased. The new strains of rabbit calicivirus evaluated in the Rabbit Haemorrhagic Disease Boost project will potentially have a positive impact on the population size of most of the 156 Commonwealth listed threatened species through the increased regeneration of native vegetation and habitats. Further details on the work of the Invasive Animals CRC are discussed in box 4.14 below.

Box 4.4

INVASIVE ANIMALS CRC

The Invasive Animals CRC is Australia's largest integrated pest animal RD&E program. Commencing in 2005, the Invasive Animals CRC includes a balanced portfolio of technologies that span from new viral rabbit and carp bio-control agents and a new class of humane toxins for feral pigs, wild dogs and foxes. It was previously funded to focus on one platform technology – virally vectored immuno-contraception – in the 1992 to 1999 period as the CRC for Biological Control of Vertebrate Pest Populations and in 1999 to 2005 as the CRC for the Biological Control of Pest Animals.

The CRC aims to counteract the impact of invasive animals through the development and application of new technologies and by integrating approaches across agencies and jurisdictions. A total of 41 organisations are participating in the Invasive Animals CRC, including Australian government agencies, industry bodies and small-medium enterprises, as well as seven international organisations from New Zealand, Britain and the USA. Key participants include state government departments, the Murray-Darling Basin Authority, Australian Wool Innovation, Meat and Livestock Australia and ABARES.

Outcomes from the CRC's research programs will help solve the prominent and costly impacts of invasive species on agricultural, environmental and social values. The Invasive Animals CRC creates a vertically and horizontally integrated value chain of organisations from end user investors to research providers, commercialisers and finally industry and government agencies to drive adoption.

The environmental impacts of the Invasive Animals CRC are wide-ranging, from protection of threatened species, protecting environmental assets from invasive animal impacts to reducing GHG emissions. Examples of these are discussed below.

The activities of the Invasive Animals CRC have avoided the loss of abundance and extinction risk of up to 76 native species that are at risk of predation if foxes establish in Tasmania. The impacts commenced in 2006 when the Tasmanian Government adopted new CRC DNA fox detection technology as a central plank of their Tasmanian fox eradication program. Evidence shows that fox numbers remain very low. The Government and private land managers responsible for biodiversity conservation benefit from the impact. Direct benefits occur in Tasmania, but given a number of animal species are at risk of global extinction, the benefits have national and international dimensions. Additionally, this now proven technology is transferable to other contexts and could be applied to future potential eradication programs if foxes invaded other high conservation Australian islands that are currently fox free, such as Kangaroo Island, SA.

Through next generation pig bait (HOGGONE) and delivery systems (HOGHOPPER) developed by the CRC, more efficient and effective control of feral pigs is assisting protect high conservation areas, including the Macquarie Marshes and Wet Tropics. The impacts will potentially start from 2013, depending on APVMA regulatory approval of HOGGONE and from 2011 for HOGHOPPER. This system is also now being adopted by the US Department of Agriculture.

The CRC's RHD Boost Project aims to identify new and more effective Rabbit Haemorrhagic Disease Virus (RHDV) strains that are naturally occurring overseas. If successful, a reduction in rabbit numbers is expected to lead to a set of benefits that includes increased biosequestration of GHG through increased native vegetation regeneration that will reduce GHG emissions from 2014. Additional carbon sequestered in southern pastoral zone after removal of 85 per cent of rabbits is expected to save 0.14 tonnes of carbon per hectare in the southern pastoral zone. An area of 1.5 million square kilometres will have additional carbon sequestration due to removal of rabbits. Additionally, reduced rabbit impacts will benefit 156 nationally listed threatened species, and assist the protection and recovery of many high conservation areas that are currently affected by growing rabbit numbers and consequent impacts. The impact will benefit private landowners and government agencies. The RHD Boost project would not have been developed and funded in the absence of the Invasive Animals CRC.

The Invasive Animals CRC reports that projects wouldn't have occurred without the investment provided by the CRC program. The funding allows discrete projects to be established quickly between collaborative organisations, and the technology rapidly developed to deal with problems that pose increasingly high threats to the environment.

Source: Consultation with the Invasive Animals CRC and Allen Consulting Group analysis, including Invasive Animals CRC annual report 2010-11, CRCs over time document 2011, Invasive Animals CRC impact study survey response 2012.

The Australian Seafood CRC is an example of a CRC whose protection of endangered species is a secondary objective. Lobster pots cause occasional entanglements with Australian sea lions, leatherback turtles, loggerhead turtles and whales. The Australian Seafood CRC has researched the effect of reduced pot sets to reduce entanglement risk. Effort reductions at maximum economic yield are around 40 per cent, which implies a 40 per cent reduction on existing entanglements.

4.7 Other environmental impacts

The activities of many industries incur costs attempting to mitigate their environmental impact in terms of GHG emissions, energy consumption and water consumption for example. Therefore, it is important to find innovative ways to reduce the costs associated with environmentally-friendly operation.

The work of many CRCs reduces environmental costs. The examples below demonstrate the range of activities that CRCs undertake to mitigate costs associated with a variety of environmental issues.

- The CRC for Greenhouse Gas Technologies has tested a range of monitoring equipment that has the potential to reduce the impact of any leaked CO₂ from carbon capture and storage sites. While the investment of \$20 million has already been made by the CRC, it is anticipated that this will save at least \$100 million to a large-scale commercial project, which could be wholly attributed to the CRC.
- The CRC for Infrastructure and Engineering Asset Management reports that from 2012 its creation of a sustainability-rating model will lead to improvements in asset performance, with particular benefits to the Australian Green Infrastructure Council and its members who are applying the model and taking remedial steps according to the outcomes. The risk adjusted net present value of future impacts scaled from eight years to three years is approximately \$5 million.
- The Antarctic Climate and Ecosystems CRC provide data for input into global and regional climate change models, which enables more effective and timely mitigation and adaptation actions. The research helps Commonwealth, state/territory and local government to set climate change policies. The CRC estimates that their contribution to savings is valued at \$66 million per annum.
- The CRC for Spatial Information has improved decision support tools for environmental management. The work undertaken will have indirect impacts on environmental services through the ability to improve environmental management and monitoring. Improved environmental management supports environmental goods and services productivity. Farmers will feel the impacts over the next five years.

Key points

The environmental impacts of the CRC program are wide-ranging. For some CRCs, the primary objective is to achieve positive environmental impacts. For others, this is secondary to other objectives, with environmental impacts occurring as a result of a broader research program.

Reducing GHG emissions is a common impact of CRCs across all sectors. Reducing energy and water consumption, and protecting areas of environment and threatened species are also common.

These environmental impacts have not been quantified or monetised. They are additional to the economic impacts.

Chapter 5

Social impacts

Many areas of research have social impacts. Research can provide knowledge and understanding that can help inform policy development or which can lead to the improved efficiency and effectiveness of public service program delivery and development (Group of Eight 2011). However, a problem with measuring social impact is that the routes through which research can influence individual behaviour or inform social policy are often very diffuse.

The CRC program affects a wide range of social outcomes: from the establishment of international collaborations and increasing local business diversity, to improving health and wellbeing and increasing participation in community services. For some CRCs, their primary objective is to achieve public good impacts. For others, this is a secondary objective, with impacts occurring as a result of a broader research program. This chapter discusses some of the social impacts of the CRC program, listed below.

- Improved health and wellbeing.
- Establishment of international collaborations.
- Provision of education and training.
- Labour force participation.
- Business diversity.
- Participation in community services.
- Change in character of local communities.
- Improved safety.
- Social costs saved or avoided.

As with the environmental impacts, the social impacts of the CRC program have not been quantified or monetised, and are additional to the economic benefits.²⁷

5.1 Improved health and wellbeing

CRCs deliver world-leading health and medical research. These innovations range from developing new radiopharmaceuticals targeting specific diseases such as melanoma, epilepsy and brain tumours to advancing the cochlear implant. Eleven CRCs have a direct focus on healthcare innovation (CRC 2011f). Many other CRCs deliver innovations that improve health outcomes.

²⁷ In some instances, benefits here have been quantified. These benefits however, do not appear as economic benefits in the previous chapters.

Some CRCs have an obvious link to health and wellbeing outcomes. For example, the HEARing CRC's development of the Hybrid-L electrode array, and the Hybrid system, has provided the opportunity for a 10 per cent improvement in speech perception scores, and possibly an increase in the number of patients taking up cochlear implants. The CRC estimates that this equates to an increase in productivity valued at \$70 million, of which 40 per cent can be attributed to the developments of the CRC.

The CRC for Asthma and Airways' (Asthma CRC) activities have improved asthmatics' quality of life, which is associated with savings in government expenditure on healthcare. Since 2010, healthcare costs have reduced as a result of enhanced treatment, better diagnosis and improved understanding of air pollution effects. Impacts have started occurring due to the publication of the results of a large number of clinical and pollution studies, and are expected to continue until 2025. The activities of the Asthma CRC clearly relate to the achievement of social outcomes. The CRC's work and its impacts are discussed in detail in box 5.15 below.

Other CRCs have less obvious, but important, benefits to health and wellbeing. For example, the Australian Seafood CRC developed nutritionally modelled seafood diets to delay the onset of diabetes and cardiovascular disease (CVD) in high-risk patients. These research projects on the relationship between seafood and health have resulted in pilots in 30 medical practices with 109 general practitioners (GPs) in 2011. The benefits are anticipated to occur in future years.

Improved health and wellbeing can be measured by the increase in the number of quality adjusted life years (QALYs) attributable to the CRC program. The Australian Seafood CRC estimates that its research into nutritionally modelled seafood diets for diabetes will increase QALYs by between 0.09 and 0.41 per person per year, equating to an overall gain of 12.3 years per person, based on existing GP led nutrition interventions. Based on international and Australian research, the Office of Best Practice Regulation (OBPR), estimates the value of a statistical life year is \$151 000 (in 2007 dollars) (OBPR 2007). Thus a gain of 12.3 years per person is valued at just over \$2.1 million. Box 5.1 discusses this issue further.

With respect to CVD, based on a Mediterranean diet high in seafood developed as part of a CRC project, the Australian Seafood CRC estimates between 0.09 to 0.77 QALYs will be gained per person per year. Nearly two thirds of the impacts can be attributed to the CRC, with non-government organisations providing assistance. Using estimates from OBPR, these gains are estimated to have a value of between \$15,000 and \$132,000.

The CRC for Spatial Information developed and deployed a Health Management Tool, which will aid in the early detection of target cancers. Early detection allows early intervention and better life expectancies. This can be measured in saved disability adjusted life years (DALYs) for populations. The use of spatial information, modelling and resource allocations would lead to savings of 17,823 DALYs nationally over the period 2013 to 2017, of which 40 per cent can be attributed to the CRC.

Box 5.1

CRC FOR ASTHMA AND AIRWAYS

The CRC for Asthma and Airways (Asthma CRC) commenced in 2005 with funding of \$26 million. It developed from the CRC for Asthma, which was funded between 1999 and 2005. The Asthma CRC aims to combine world-class science with leading pharmaceutical companies to address a major health priority; discover and develop novel therapeutic and diagnostic products for the benefit of all asthmatics and the Australian economy and; improve indoor, urban and regional air quality standards to reduce the risk of exposure to the triggers of chronic airway conditions.

The Asthma CRC is a joint venture between two medical research institutes (Woolcock Institute of Medical Research and Garvan Institute of Medical Research), four universities (Sydney, Monash, Newcastle and WA) and two pharmaceutical companies (GlaxoSmithKline and Pharmaxis). The supporting members are Bird Healthcare, the NSW and WA Departments of Health and the WA Department of Environment.

The Asthma CRC's outputs will generate both health and economic outcomes and will include the development of superior treatments, advanced diagnostic tools and enhanced air quality standards. Achieving these goals will require a multifaceted approach integrating a range of diverse fields. The Asthma CRC has assembled a team of world-class researchers with expertise in genetics, cell biology, immunology, physiology, pharmacology and epidemiology to achieve these outcomes. This team has access to state of the art research infrastructure at a number of leading Australian academic and research institutions. These resources have been deployed in a synergistic fashion to achieve the Asthma CRC's aims.

The Asthma CRC's impacts have started to accrue due to the completion and publication of the results of a number of clinical and pollution studies.

A number of important contributions have been made by the air pollution programs and the outputs of this research have been provided to state government partners. The clinical outputs generated by the diagnostics and education programs have been published and presented at national and regional conferences. These outputs will improve clinical practice and enhance the standard of care of patients with asthma.

The therapeutics research program has produced a number of unique drug targets, which the Asthma CRC is offering to pharmaceutical companies. The biomarker intellectual property generated by the diagnostics program is now entering the commercialisation phase.

Through the development and adoption of improved therapeutics, advanced diagnostic techniques, air pollution guidelines and clinical algorithms, Asthma CRC activities improved patients' daily quality of life by lessening the debilitating effects of asthma and other airway diseases and increasing the freedom of these people to engage in active lifestyles. It is estimated that the activities of the Asthma CRC result in a reduction of 1,177 asthma-related DALYs, corresponding to a potential annual cost saving in asthma-related healthcare expenditure of \$17 million.

The Asthma CRC reports that the CRC program brings together users and researchers in a formalised way, which is key to the achievement of impacts. Further, the CRC program establishes long term relationships with research and public good organisations, which assists in the delivery of important social impacts.

Source: Consultation with the Asthma CRC and Allen Consulting Group analysis, including the Asthma CRC annual report 2010-11, CRCs over time document 2011, Asthma CRC impact study survey response 2012.

Box 5.2

THE VALUE OF A STATISTICAL LIFE AND STATISTICAL LIFE YEAR

The concept of the value of a statistical life (VSL) is used when there is a need to calculate the benefits of a regulation or policy. VSL is based on the willingness to pay for a reduction in the risk of physical harm, and therefore places an estimate on the financial value society places on reducing the average number of deaths by one. A related concept is the value of statistical life year, which estimates the value society places on reducing the risk of premature death, expressed in terms of saving a statistical life year.

Various methods can be used to measure society's willingness to pay to reduce the risk of death. These include surveying individuals on what they would pay to save or prolong life; observing how much consumers pay for products that reduce the risk of death or injury (e.g. safety equipment for a car); and observing how much workers are willing to pay for an improvement in workplace safety.

A review of empirical studies relevant to Australia noted that the VSL is estimated to range from \$3 million to \$15 million, and it was concluded that the most credible VSL estimate is \$3.5 million for VSL and \$151,000 for the value for statistical life year (in 2007 dollars) (Abelson 2007).

It is important to note, however, that estimates can vary according to the characteristics of the people affected and the nature of the risk or hazard. For instance, the VSL is like to be higher if it is based on younger people with longer to live and particularly painful deaths are likely to attract a higher willingness to pay to avoid.

Consistent with the advice of international regulatory agencies, the Office of Best Practice Regulation (OBPR) advises that regulation impact statements use a VSL that is derived from previous studies. In particular the Abelson (2007) estimate of VSL, which is based on recent empirical evidence and is assessed to ensure that it is comprehensive and rigorous, is recommended to be used by the OBPR.

Source: The Allen Consulting Group and the OBPR (2007).

5.2 Establishment of international collaborations

Participants in the CRC program include private industry, industry associations, universities, federal and state government agencies, public research organisations, non-government organisations and regional development corporations, as well as international partners. In 2009-10, 545 international alliances were operating under the CRC program. To date, nearly 7,500 international collaborations in 112 countries have been established by CRCs between 1991 and 2010.

For example, the CRC for Infrastructure and Engineering Asset Management has steadily increased the number of international collaborations since 2003. Over the period, the CRC has established 18 international collaborations. Its collaborations have been established with international asset management research organisations located in Asia, Europe, North America and Africa.

The HEARing CRC is another example of a CRC that has collaborated effectively to achieve social impacts. Important developments in hearing aids and cochlear implants can be attributed to the CRC, as they have occurred through working with other organisations. The work of the HEARing CRC is described in box 5.17 below.

Box 5.3

HEARING CRC

The HEARing CRC commenced in 2007. It had two predecessors, the CRC for Cochlear Implant, Speech and Hearing Research (1992-1999), and the CRC for Cochlear Implant and Hearing Aid Innovation (1999-2007).

The HEARing CRC is focused on the twin challenges of more effective prevention and improved remediation of hearing loss. Hearing loss currently affects one in six Australians, with an estimated direct financial cost of around \$23 billion per annum (economic impact established by CRC research and published in 2007 in Listen Hear!). Through research and its utilisation, the HEARing CRC aims to reduce the impact of hearing loss by: maximising lifelong hearing retention; reducing loss of productivity due to hearing loss; increasing uptake and use of hearing technology; and providing postgraduate and professional education and training.

The core participants of the HEARing CRC are Australian Hearing Services, Cochlear, Macquarie University, Siemens Hearing Instruments and the University of Melbourne. There are a further 21 support members who provide expert support to one or more projects. International partnerships include the University of Freiburg, New York University Medical Centre, the Chinese University of Hong Kong, the University of Toronto, the University of Auckland, the University of Wisconsin (Madison) and Washington University. International collaborations such as these provide specific expertise and access to patient groups critical to conducting clinical trials.

The HEARing CRC is a member or supporter of a number of collaborative organisations, which include AusBiotech, Research Australia, the Australasian Speech Science and Technology Association and the First Voice Alliance.

The HEARing CRC's multidisciplinary collaboration has led to achievements such as the development of the Hybrid-L cochlear implant electrode array released by Cochlear Ltd as a core component of the commercial Cochlear™ Hybrid™ System. Recently recognized by a CRC Association Award for Excellence, the new technology has the potential to significantly expand cochlear implant candidature, opening opportunities to individuals who have lost high frequency hearing but retain the capacity to hear low frequency sound. Just under half of the impacts that are being achieved can be attributed to the CRC collaboration.

Other commercial outcomes from HEARing CRC research include: NAL-NL2 nonlinear hearing aid prescription fitting software, first released by Siemens AG and later licenced to all other major hearing aid and audiological testing equipment manufacturers, is one of two world-wide industry standards and is currently used to fit over half the world's hearing aids; a user-trainable hearing aid released by Siemens; and HEARLab® with its associated Automatic Cortical Assessment (ACA) software test module (released by US-based licensee Frye Electronics Inc.) which enables audiological assessment and fitting of hearing aids and cochlear implants to infants and young children.

These achievements underline the HEARing CRC's focus on development of technology that meets industry and clinical-service needs, ultimately create benefit for end users and economic impact for Australia both in terms of royalties paid, and in improved cost-benefit for clinical service delivery.

The HEARing CRC is also focused on hearing health service-delivery, and is collaborating with rural, remote and Indigenous health and community groups to develop training modules that will enable both remote service delivery, and also training and mentoring of rural-based health professionals. To support this, the CRC is developing new hearing aid technology that can be fitted using internet-based or fully automated processes.

The HEARing CRC reports that the unique value of the CRC program lies in its ability to create large multidisciplinary and multi-institution research teams that can address significant problems over longer timeframes. The funding provided by the program and the focus on outcomes-driven research, underpinned by the infrastructure created by program funding, encourages groups, particularly industry, to collaborate and invest at a much greater level than has been achieved through other research funding models.

Source: Consultation with the HEARing and Allen Consulting Group analysis, including HEARing CRC annual report 2010-11 and 2009-10, CRCs over time document 2011, HEARing CRC impact study survey response 2012.

5.3 Provision of education and training

A core feature of the CRC program is industry contribution to CRC education programs to produce industry-ready graduates. Research students working in CRCs gain direct experience of working in an environment that is outcome-oriented. Such students are highly valued by CRC industry partners, who tend to recruit from these graduates. Over the period 1991-92 to 2009-10, 1,331 masters degrees and 3082 doctorates were awarded to students with CRC exposure (DIISRTE 2011c).

A number of current CRCs surveyed for this study reported an increase in education and training as a result of the CRC program. They reported supporting a number of masters and doctorate students, as well as vocational education and training (VET) outcomes. The period of impact ranged from 2003 to the present, with most CRCs reporting that they expected further impacts over the next few years.

For example, the CRC for Biomarker Translation reports that between 2012 and 2017, a further 70 students will graduate with a doctorate and 10 students will graduate with a masters degree as a result of the CRC's operations. These impacts can be wholly attributed to the CRC and will benefit scientific-based employers, as the applicants will be more highly educated and better attuned to the needs of industry.

With respect to VET outcomes, the activities of the Poultry CRC will lead to 10 industry personnel being trained via a formal VET system in nutrition and environmental management systems, which can be wholly attributed to the CRC. A further 40 industry personnel will be trained via a formal VET system in on-farm food safety assessment of egg quality and safety, of which 80 per cent of the impacts can be attributed to the Poultry CRC.

5.4 Labour force participation

CRCs provide employment opportunities directly and indirectly. Direct opportunities are provided through employment with the CRC itself. Indirect opportunities are provided through the activities made possible through CRC funding. The CRC program has proved to be a successful training ground for R&D managers, some of whom have subsequently been appointed to leadership positions in major research institutes. The provision of postgraduate education associated with CRCs also leads to increased labour force participation, with 205 students taking up industry employment in 2009-10.

It follows that all CRCs affect employment outcomes by creating positions within the organisation, but many CRCs affect labour force participation in other ways. An example of a CRC contributing labour force participation in several different ways is the Cotton Catchment Communities CRC (Cotton CRC). The Cotton CRC reported that there were 9.7 FTE staff members who are employed directly by the CRC. In addition, 49 new FTEs were provided by the CRC's activities. Therefore, 100 per cent of the impacts can be attributed directly to Cotton CRC. The CRC's activities provided opportunities for people in regional NSW and Queensland, and led to an increase in the labour force participation of 10 people of Aboriginal and Torres Strait Islander descent. Benefits have been seen over the past seven years and are anticipated to occur beyond the life of the CRC.

5.5 Business diversity

The CRC program can have an impact on business diversity, with new and distinct businesses resulting from CRC activities. Diversifying the industry base of local communities provides greater stability and resilience in times of economic uncertainty. The establishment of new businesses provides employment opportunities that would otherwise not have existed.

For example, the Australian Seafood CRC has assisted in the establishment of five end user owned organisations, with four in full operation. These organisations are helping the seafood industry grow and diversify. The Australian Seafood CRC established four of the organisations exclusively, with the fifth, a trade forum, established jointly.

Other examples include CRCMining who provided greater access for original equipment manufacturers and mining companies to new innovative products, with the creation of 56 new businesses between 2006 and 2011. In addition, work conducted by the CRC for Infrastructure and Engineering Asset Management has accelerated the activities of three small to medium sized enterprises in 2009-10. Further, the CRC for Spatial Information has created three additional businesses, leading to 64 positions.

5.6 Participation in community activities

CRCs can contribute to increased participation in community services. Increased participation in community services can lead to greater educational and employment outcomes in local regions.

For example, the Antarctic Climate and Ecosystems CRC established the Climate Conversations education and outreach program. Climate Conversations is an interactive panel discussion session with scientists from the Australian Antarctic Division and the CRC speaking directly to the community about its research. It commenced in late 2010, with 650 members of the public and 500 school students participating across NSW and Tasmania in 2011. The program is ongoing.

The outputs of other CRCs have increased participation in community services. The Cotton Catchment Community CRC's Community Program builds mutually beneficial interactions between industry and regional communities. It has resulted in greater school and regional community participation by approximately 3,000 people each year. Nearly all participants were located in regional NSW and Queensland and were given access to resources and information previously not seen in these regional locations. These events are expected to continue for at least the next five years, with 100 per cent of the impacts attributable to the CRC.

The CRC for Greenhouse Gas Technologies' Otway Project has become a prototype for community consultations within the CRC. The project has been conducted since 2005 and involves on- and off-site public forums and information sessions. The project contributes revenue and employment to the local community, with the impacts expected to continue, of which 100 per cent can be attributed to the CRC.

5.7 Change in character of local communities

Local communities can be influenced in a variety of ways by the work of CRCs. The activities of the Dairy Futures CRC have influenced the outlook of the dairy farming industry. Dairy farmers and related service businesses in local communities have a more positive perception of the future prosperity of the industry and have embraced the role of new technology.

The Smart Services CRC has improved social connectedness by making museum and other historical artefacts available to youth in disadvantaged communities. By connecting individuals with their families, elderly relatives and culture in this way, the CRC is enabling inclusion and communication in local communities. It is anticipated that this will lead to lower crime rates and decreased youth vagrancy and increased educational outcomes and workforce participation over the years 2013 to 2018. Further details of the activities of the Smart Services CRC and the associated impacts are provided in Box 5.4.

Box 5.4

SMART SERVICES CRC

The Smart Services CRC commenced in 2007 with funding of \$31 million. It developed from the CRC for Smart Internet Technology (2001 to 2008). The CRC research projects address challenges across the areas of customer service needs, ecosystems for service delivery and services of the future.

The CRC creates new and improved services for industry to enable customers to receive, affordably and easily, personalised, continuous service from businesses irrespective of their world-wide location and which instantly adjusts for any mobile or fixed device they use. The challenge is to provide customers with a richer, more intuitive, responsive and individually tailored experience during their consumption of a service.

Smart Services CRC Service Innovation Foundry fast tracks development and testing of new services, quickly creates robust proof-of-concept demonstrators and shows economic viability for partners delivering services for local and international markets from Australia. The Innovation Foundry is an essential component in the path to the adoption of Smart Services innovations by industry participants and other commercial, industrial and government organisations.

There are 14 core participants in the Smart Services CRC, including Fairfax, InfoSys, Queensland University of Technology, Swinburne University, RACQ, NSW Government, Queensland Government, UNSW, University of Sydney, University of Wollongong, RMIT University, AARNet, Austin Health, Sirca and Suncorp.

In addition, Smart Services CRC engages in both ICT forums and service sector agendas, and seeks to collaborate with other organisations via third party engagements in research and commercialisation / utilisation projects where it is of clear advantage to do so. An example of this approach is in the area of e-health where Smart Services CRC is collaborating with National E-Health Transition Authority (NEHTA), IBM and SME group CSN Technology Pty Ltd, to test how research outcomes can be utilised by the e-health industry to meet the emerging standards to be set by the Australian Government in the use of e-health patient records.

NEHTA, IBM and a Smart Services CRC spin-off, CSN Technology, used the Innovation Foundry to test new e-health inter-operability and conformance concepts for broader industry adoption

Smart Services CRC has worked with Austin Health in providing IT systems that data mine patient data (on presentation / emergency and intensive wards) and provide predictive advice regarding likelihood and danger signals regarding possible adverse medical events, the work is expected to improve health outcomes for aged, infirmed and at-risk patients. By reducing avoidable deaths, this will reduce societal trauma and loss of productivity for both families and health workers involved.

The activities of the Smart Services CRC also improve social inclusion in Indigenous and migrant communities through an improved connectedness with their cultural heritage. New online and communication services provided by the CRC will have social and cultural benefits, especially for school children in isolated regions. The impacts started occurring in 2011 and will continue to 2018.

The Smart Services CRC reports that the CRC program facilitates and fosters strong collaboration with end user companies. As a result of this, research is focused on the needs of end users and the CRC's ability to achieve meaningful social impacts is improved. This is important in the services sector when dealing with problems at the individual level. The long term and collaborative nature of research conducted in the CRC program allows the CRC to take on projects with a higher risk profile that lead to significant breakthroughs that would not otherwise occur.

Source: Consultation with the Smart Services CRC and Allen Consulting Group analysis, including Smart Services CRC annual report 2010-11 and 2009-10, CRCs over time document 2011, Smart Services CRC impact study survey response 2012.

5.8 Improved safety

CRCs have improved the safety of Australians through their research. Those that focus on the manufacturing, construction and mining sectors can improve the design of machinery and systems to improve workplace health and safety in those industries. For example, CRCMining has designed collision avoidance technologies and fatigue monitoring devices that are likely to prevent mine site accidents and therefore reduce injury.

The current CRC for Advanced Automotive Technology has a research theme devoted to safety and intelligent vehicle systems. This focuses its efforts on improving vehicle safety and injury prevention through pedestrian impact protection, far-side impact protection, human machine interface optimisation and child safety.

5.9 Social costs saved or avoided

The research conducted by CRCs can avoid social costs associated with a variety of issues. The responses to the survey demonstrate the wide-ranging impacts of the CRC program. Although the work of some CRCs is targeted towards reducing environmental impacts, they have associated social impacts. For example, although the practice of sheep mulesing is associated with the environment, it creates intense attention as an animal welfare issue, which leads to social pressures on the sheep farming industry. The CRC for Sheep Industry Innovation took the lead in establishing training and resource material to assist producers to manage the risk of flystrike without mulesing, with its Flyboss Program and Flystrike Management Workshops, which commenced in 2009. This has benefitted the 1500 individual producers who took the courses through premium prices for non-mulesed wool. It has also helped the industry as a whole, as it was seen to respond to public scrutiny and relieve the social pressure on the producers.

Some of the impacts of the CRC program are felt with respect to forewarning or mitigating risk. The Antarctic Climate and Ecosystems CRC manages the Climate Futures for Tasmania project, which provides the first fine-scale climate information for Tasmania by downscaling six global climate models with two emission scenarios to generate climate information from 1961 to 2100. In providing detailed climate predictions, the project is expected to avoid social costs by enabling farmers, communities and local governments in Tasmania to adapt in readiness for climate change. More details on the social impacts of the Antarctic Climate and Ecosystems CRC are provided in Box 5.5.

Box 5.5

ANTARCTIC CLIMATE AND ECOSYSTEMS CRC

The current Antarctic Climate and Ecosystems (ACE) CRC began in 2010 with \$20 million in funding. It was extended from the CRC for Antarctic Climate and Ecosystems (2003 to 2010), CRC for Antarctica and the Southern Ocean (1997 to 2003) and the CRC for the Antarctic and Southern Ocean Environment (1991 to 1997).

Antarctica and the Southern Ocean influence both the regional and global climate in profound ways. These vast areas will experience significant change as the world warms, and in turn those changes will impact on the global climate. The ACE CRC is investigating the critical scientific uncertainties, highlighted by the Intergovernmental Panel on Climate Change, that limit Australia's and the global community's ability to respond effectively to climate change. It is a multidisciplinary partnership of 23 national and international organisations, which provides science, knowledge and understanding to help Australia meet the challenges of climate change.

Essential participants of the CRC are the Australian Antarctic Division, CSIRO, University of Tasmania, the Department of Climate Change and Energy Efficiency, the Alfred Wegener Institute for Polar and Marine Research and the National Institute of Water and Atmospheric Research. The Department of Climate Change and Energy Efficiency is also the major end user of the CRC's research, which it uses to inform policy. There are a further 17 supporting partners. Five of the supporting partners in ACE are commercial. These commercial collaborations underline the increasing recognition of the potential commercial impacts of climate change.

The ACE CRC also has many social impacts in fulfilling its role of investigating the critical scientific uncertainties that limit the way Australia and the global community can respond to climate change. In addition to increasing participation in community services and savings on social costs mentioned elsewhere in this report, its social impacts include provision of education and training, labour force participation, international collaborations and tourism development. These are discussed below.

- Education: between 2003 and 2011, 73 students involved with the CRC were awarded PhD or masters degrees. Research institutes in Australia and abroad benefit, especially those in the climate and Antarctic science sector. The CRC collaborated with the University of Tasmania to achieve this impact.
- Training: in 2009 the CRC provided vocational training in the latest sea-level rise science to planners, engineers, consultants and climate change officers in local and state governments. Over 900 participants attended the training.
- Labour force participation: the CRC will create employment opportunities for 25 people each year between 2010 and 2014.
- International collaborations: as mentioned above, the CRC has established many formal international research collaborations. In 2012 it is involved in 55 international collaborations. All parties benefit by sharing resources and expertise to tackle climate change questions that require a multidisciplinary approach.
- Tourism development: the ACE CRC attracts international visitors, which benefits Hobart's local economy and the broader Tasmanian economy. The impact has been occurring since 1991.

The ACE CRC reports that the CRC program facilitates collaboration between multidisciplinary teams that wouldn't occur as easily or efficiently without the structure of the program. The funding provided by the Australian Government draws partners together, and provides access to people with a diverse range of skills. Further, the program's focus on end users is central to the translation of research into meaningful outcomes.

Source: Consultation with the ACE CRC and Allen Consulting Group analysis, including ACE CRC annual report 2010-11 and 2009-10, CRCs over time document 2011, ACE CRC impact study survey response 2012.

Key points

The CRC program affects a wide range of social outcomes. For some CRCs, the primary objective is to achieve public good impacts. For others, this is a secondary objective, with impacts occurring as a result of a broader research program.

Improving health and wellbeing is an impact of many CRCs, including those with and without an explicit focus on achieving health outcomes. All CRCs provide education and training and offer employment opportunities.

As with the environmental impacts, the social impacts of the CRC program have not been quantified or monetised, and are additional to the economic benefits.

Chapter 6

The overall impacts of the CRC program

The CRC program differs significantly from other R&D support measures. The program's long term funding, scale, and engagement with end users of the research make the program a unique mechanism to promote targeted research activities throughout the economy.

This unique structure has a significant influence on the program's impacts.

- Medium and long term commitments made by CRC partners, as required by the program, provide the CRCs with the capacity to tackle ambitious projects that require more time and resources than normally available.
- Competition for CRC funding and the rigorous application process results in only the most prospective proposals receiving support.
- The experience of researchers and staff working with industry in the CRC program provides education and training that produces graduates that are attractive to industry.

As a result of R&D undertaken by CRCs, a variety of impacts have occurred. These have accrued to CRCs themselves in the form of additional revenues and direct payments, to industry participants in the form of cost savings and increases in revenue and profitability and across industries in the form of efficiency gains, the development of new technology and productivity improvements.

This study has considered the contributions made by some 117 CRCs over the period 1991-2017. Over this period, the study has identified direct economic impacts totalling \$14.45 billion — including some \$8.58 billion of impacts already materialised and a further \$5.87 billion of imminent impacts estimated to occur between 2012 and 2017.

As noted throughout the study, this figure underestimates the direct benefits of the CRC program for a number of reasons. First, this number reflects only about three fifths of the CRCs that have participated in the program. It was not possible to identify the impacts of all the CRCs that have existed since the program began.

Second, this figure does not include the indirect impacts on the Australian economy or impacts that occur internationally. The CRC program's investment in Australian R&D has widespread consequences for the community, affecting every industry and sector. These impacts have been assessed using a CGE model, which estimates a *net* benefit to the economy of \$7.5 billion over the period assessed — a contribution of around 0.03 percentage points to GDP growth per annum.

The benefits to the broader economy generated by the CRC program exceed the Australian Government's investment by a factor of 3.1. How this result has been estimated is reported in the table below. This means that for every dollar invested in the CRC program by the Australian Government, GDP has increased by a factor of 3.1.²⁸

²⁸ An alternative measure that might be considered, but not employed here, is the Internal Rate of Return (IRR). The IRR is a rate of return used in capital budgeting to measure and compare the profitability of investments. The IRR on an investment or project is the "annualised effective compounded return rate" that makes the net

Previous studies on the impact of Australian research institutes have demonstrated that they are able to generate significant increases in GDP. A study on research institutes at the University of Queensland for example, estimated that the institutes were able to generate increases in GDP that were as high as 7.1 times the initial outlay (Allen Consulting Group 2011). Comparing the CRC program to those studies however, does not adequately reflect the additional social and environmental impacts inherent to the CRC program, nor its public good nature.

Table 6.1

NET ECONOMIC BENEFIT FROM AUSTRALIAN GOVERNMENT FUNDING

Item	Amount
Cumulative Australian Government commitment to the CRC program (for those CRCs included in the study sample) ^A	\$2.42 billion
Cumulative increase in GDP ^B	\$7.53 billion
Benefit to cost ratio	3.1

Notes: These results are based on the impacts identified by this study through the data and information gathering stages, with the majority of impacts self-identified by CRCs. It is noted that this may underestimated the impacts of the CRC program due to difficulties identifying all impacts as discussed previously. The return on investment is based on the assumption that the CRC program has induced participants to spend 50 per cent more on R&D than they would have in the absence of the program. A — This includes only the funding associated with those CRCs for which benefits were identified. B — This is based on CGE modelling of the identified impacts and represents the net changes to the Australian economy as a result of the CRC program. Source: The Allen Consulting Group and COPS.

Note that it is difficult to compare this figure with previous studies for various methodological reasons. The differences between this study and the Insight Economics report are further explained in Box 6.1.

Third, whereas previous studies have focused on just the economic impacts (such as those above), this study has demonstrated that the program also generates significant environmental and social impacts. Indeed, for some CRCs, producing environmental and social benefits is the main objective. In addition, this does not include the value of collaboration and networks, the increase in research capability or the high quality nature of the research as a result of the CRC program. The estimates of both the direct and indirect impacts above do not account for the substantial difference the CRC program has made to Australia through environmental and social benefits.

The environmental impacts achieved by the CRC program are diverse and reflect the broad scope of research activities undertaken across the CRCs. They include the reduction of GHG emissions to the protection of threatened species. The environmental impacts discussed in this report show that although a CRC can target a particular environmental impact, other impacts are also achieved indirectly.

present value of all cash flows (both positive and negative) from a particular investment equal to zero. This metric was not employed here as it fails to adequately capture the public good nature of the CRC Program, nor the extent of its spillovers. Furthermore, the Australian Government does not fund the CRC Program to get a ‘return’ in any sense to which return normally refers. Its prime motivation is to encourage collaborative R&D between universities, publically funded research agencies and end-users that would not otherwise occur; and results in an overall improvement in welfare. The purpose of an impact assessment is to assess the effectiveness of the CRC Program, that is, to what extent the program induces additional R&D and improves welfare (noting that this particular assessment assumes a level of additional R&D). Reducing the impact of the CRC Program to a simple financial measure such as the IRR would diminish the nature of its impacts.

Similarly, the range of social impacts achieved by CRCs varies significantly as well. Given the CRC program’s focus on producing industry-ready graduates, all CRCs have provided education and training and increase labour force participation. With other social impacts ranging from direct benefits for health and wellbeing, to increased community participation resulting from broader research activities, it is clear that the CRC program serves an important role in Australia’s R&D effort.

Box 6.1

INTERPRETING THE RESULTS OF THIS STUDY

The results reported in this study differ from those reported in the Insight Economics report due to the treatment of two key inputs.

The first is the treatment of industry and university direct and in-kind funding. In the Insight Economics report, it was assumed that private sector CRC participants spent no monies on R&D in the absence of the CRC program. In other words, Insight Economics assumed that the CRC program was responsible for inducing 100 per cent of participant direct and in-kind support. By contrast, this study has taken a moderate position and assumed that the CRC program has induced industry and university participants to spend 50 per cent more on R&D than they would have in the absence of the program.

The second is the treatment of government spending. Of the 190 CRCs funded to date, the survey and other data gathering undertaken for this study identified impacts from 117 CRCs. The results reported in this study therefore, reflect only the impacts made by some 62 per cent of CRCs in the program. The CGE modelling has been adjusted in this study to reflect this by including only the resources dedicated to the CRCs included in this study. (Insight Economics however, did not adjust Australian Government funding to take into consideration those CRCs from which impacts had not been identified.)

As a result, in relation to the benefit cost ratio, both the numerator and denominator for this study represent different calculations to those used in the Insight Economics report. In order for the figures to be comparable adjustments to take account of the differing methodologies are necessary. The table below shows how the benefit cost ratio might be adjusted taking account of these differences.

It is important to note that these estimates have been calculated by simply scaling the expected impacts — they have not been re-estimated using the CGE model. As such these figures only give an indicative comparison between the two reports and should not be interpreted as definitively comparable.

Item	Insight Economics	Adjusted measures used in this study
Cumulative Australian Government commitment to the CRC program (\$ billion)	2.3	3.4 ^A
Cumulative increase in GDP (\$ billion)	2.7	8.6 ^B
Benefit cost ratio	1.16	2.52

^A This figure reflects the total cumulative Australian Government commitment to the CRC program, not just that included in the sample.

^B This figure is based on the sensitivity analysis in Appendix E.

Source: The Allen Consulting Group.

Finally, the study has also identified a number of impacts relating to preparedness. These impacts involve forewarning or mitigating risks and relate to outputs associated with CRCs only in the event that certain circumstances occur. The preparedness impacts range from preparing for the impacts of bushfires to the management of disease in vineyards.

This study has demonstrated that the CRC program is highly important within Australia. By linking researchers with domestic and international end users, significant economic, environmental and social impacts have been produced.

*Appendix A***Consultations**

Data gathered for this study in relation to the impacts of the CRC program was primarily based on a survey of current CRCs. The survey was undertaken between December 2011 and February 2012. Survey respondents were provided with the details of our evaluation framework to assist with the classification of impacts. While annual reports, data management questionnaires, exit reports and consultations supplemented the survey, the data and information identified through the survey has been very important for this study. We would therefore like to thank the following CRCs for providing a survey response.

In addition to the survey of current CRCs, during the course of the study, a number of individual consultations with CRC representatives and external stakeholders were undertaken. In particular, Professor Tony Peacock (CEO, CRC Association), Dr Geoffrey Vaughan AO (Director, Advanced Manufacturing CRC) and Mr Peter Laver AM (Vice President, Australian Academy of Technological Sciences and Engineering) were consulted. The Allen Consulting Group project team would like to express our appreciation for the thoughtful insights and comments that were so willingly provided. Table A.1 outlines the consultations with CRCs undertaken for this study, as well as the CRCs consulted in previous studies.

Table A.1

CONSULTATION

Cooperative Research Centre	Method
Antarctic Climate and Ecosystems CRC	Survey response and consultation
CRC for Asthma and Airways	Survey response and consultation
Australian Biosecurity CRC	Survey response
CRC for Beef Genetic Technologies	Survey response
CRC for Cancer Therapeutics	Survey response
Capital Markets CRC	Survey response
CAST CRC	Survey response
Cotton Catchment Communities CRC	Survey response
CRC Advanced Composite Structures	Survey response and consultation
CRC for Advanced Automotive Technology	Survey response
CRC for Biomarker Translation	Survey response
CRC for Greenhouse Gas Technologies	Survey response and consultation
Advanced Manufacturing CRC	Survey response
CRC for Infrastructure and Engineering Asset Management	Survey response
CRC for Mental Health	Survey response
CRC for Polymers	Survey response
CRC for Rail Innovation	Survey response and consultation
CRCMining	Survey response
CRC for National Plant Biosecurity	Survey response and consultation
Dairy Futures CRC	Survey response
Deep Exploration Technologies CRC Ltd	Survey response
Energy Pipelines CRC	Survey response
eWater CRC	Survey response
Invasive Animals CRC	Survey response and consultation
Parker CRC for Integrated Hydrometallurgy Solutions	Survey response and consultation
CRC for High Integrity Australian Pork	Survey response and consultation
Poultry CRC	Survey response
CRC for Remote Economic Participation	Survey response
Australia Seafood CRC	Survey response and consultation
CRC for Sheep Industry Innovation	Survey response
Smart Services CRC	Survey response and consultation
The HEARing CRC	Survey response and consultation

Cooperative Research Centre	Method
The Vision CRC	Survey response
CRC for Spatial Information	Survey response
Oral Health CRC	Survey response
CRC for Optimising Resource Extraction	Survey response
CRC for Bioproducts	Insight (2006)
CRC Welded Structures	Insight (2006)
CRC for CAST Metals Manufacturing	Insight (2006)
AJ Parker CRC for Hydrometallurgy	Insight (2006)
Australian Photonics CRC	Insight (2006)
CRC for Cattle and Meat Quality	Insight (2006)
CRC for Sensor Signals and Information Processing	Insight (2006)
CRC for Technology Enabled Capital Markets	Insight (2006)
CRC for International Food Manufacture and Packaging Services	Insight (2006)
CRC for Cardiac Technology	Insight (2006)
CRC for Broadband Telecommunications Networking	Insight (2006)
CRC for Water Quality and Treatment	Insight (2006)
CRC for Sustainable Agriculture and Finfish	Insight (2006)
CRC for Clean Power from Lignite	Insight (2006)
CRC for Vaccine Technology	Insight (2006)
CRC for Environmental Biotechnology	Insight (2006)
CRC for Australian Poultry Industries	Insight (2006)
Predictive Minerals Discovery CRC	Insight (2006)
Australian Sheep Industry CRC	Insight (2006)
CRC for Viticulture	Insight (2006)
CRC for Cochlear Implant and Hearing Aid Innovation	ACG (2005)
CRC for Landscape Environments and Mineral Exploration	ACG (2005)
CRC for Tissue Growth and Repair	ACG (2005)
CRC for Sustainable Rice Production	ACG (2005)
CRC for Aquaculture	ACG (2005)
CRC for Soil and Land Management	ACG (2005)
CRC for Sustainable Production Forestry	ACG (2005)
CRC for Innovative Dairy Products	ACG (2005)
Value Added Wheat CRC	ACG (2005)
CRC for Railway Engineering and Technologies	ACG (2005)

Note: A number of the CRCs listed have been extended. Previous iterations of these CRCs have been included in the impact study.

Source: The Allen Consulting Group

*Appendix B***Indicators used in the study**

The survey undertaken for this study asked CRCs to identify the economic, social and environmental outputs of their CRC. This was conducted in line with the study's evaluation framework. In order to assist respondents and the analysis, indicators were used for each type of output. These indicators are outlined in the tables below.

Table B.1

ECONOMIC INDICATORS

Indicator	Description
Economic benefit to CRC	
Licenses granted	The dollar value of licenses granted as a result of CRC research.
Contract income	The dollar value of contract income earned (either individually or through partnerships with other organisations).
Value of patents sold	The dollar value of patents sold associated with CRC research.
Value of spin-off companies	The dollar value of spin-off companies generated as a result of CRC research.
Other revenues	The dollar value of other revenues, such as payments for services provided, generated from CRC research.
Funding/ in-kind benefits	The dollar value of funding or in-kind benefits generated, attributable to CRC research.
Other	The dollar value of any other economic benefits generated by CRCs from CRC research.
Economic benefit to users (e.g. industry, businesses, government)	
Costs saved or avoided	The dollar value of costs saved or avoided through research conducted under the CRC program.
Potential costs saved/avoided	The dollar value of potential costs that would be saved or avoided if an event was to occur, as a result of CRC research.
Increased sales/revenue	The dollar value of increases sales or revenue to users of CRC research.
Increased capital value of CRC partners	The estimated dollar value increase in capital for CRC partners arising from CRC research.
Other	The dollar value of other economic benefits to users of or associated with CRC research.

Source: The Allen Consulting Group

Table B.2

ENVIRONMENTAL INDICATORS

Indicator	Description
Reductions in environmental costs	The value of any reductions in environmental costs arising from CRC research. In this instance environmental costs may refer to the costs associated with addressing negative impacts on the environment.
Savings on government expenditure	The value of savings achieved on government expenditure as a result of CRC research. This refers to the value of government expenditure that would have been used for activities such as conservation or regeneration works.
Number of endangered species saved	The type and number of endangered species saved resulting from CRC research.
Reduced GHG emissions	The nature and number of tonnes of emissions reduced associated with CRC research.
Emission of pollutants avoided	The nature and number of tonnes of emission pollutants avoided due to CRC research.
Water consumption reduced	The reduction, in mega litres, of water consumed as a result of CRC research.
Reduction in use of natural resources	The type of natural resource and the amount by which its use is reduced arising from CRC research.
Reduction in the amount of waste produced	The reduction in the amount of waste produced as a result of CRC research (measured in kilograms / litres / tonnes).
Reduction in energy consumption	The reduction in energy consumption as a result of CRC research, measured in mega-joules saved.
Reduction in usage of transport and commuting	The amount of transport and/or commuting time or distance reduced as a result of CRC research. The amount of transport and/or commuting reduced measured by the dollar value of savings.
Reduction in contamination of natural resources, including soil, water, air etc.	The amount of contaminated natural resources, including soil, water, air, etc. reduced as a result of CRC research. The amount can be measures through kilograms / litres / tonnes.
Area of environment protected	The area of protected environment arising from CRC research. The area is measured in the amount of hectares protected or conserved.
Other	The value, number or amount of any other environmental impacts associated with CRC research.

Source: The Allen Consulting Group

Table B.3

SOCIAL INDICATORS

Indicator	Description
Social benefit to individuals, businesses or industry	
Education and training provided	The increase in education and training as a result of CRC research. This refers to the number of new postgraduate degrees (i.e. Masters, PhD) generated through the CRC program.
International collaborations	The number of new collaborations established with organisations outside Australia resulting from the CRC program.
Labour force participation	The increase in labour force participation attributable to the CRC program. This is any increase in the number of individuals willing and able to work associated with the CRC program.
Business diversity	The number of new and distinct businesses resulting from the CRC program. This refers to an increase in the variety of business operating in a particular community.
Business success	The number of successful businesses as a result of the CRC program. Business success refers to the number of start-up businesses whose success can be attributed to the CRC program.
Tourism development	An increase in visitors to an established tourism destination attributable to the CRC program. This refers to the number of new visitors to a tourism destination.
Other	The number or value of other social benefits not mentioned above to individuals, businesses or industry associated with the CRC program.
Social benefit to the community	
Improved health and wellbeing	An increase in the number of quality adjusted life years (QALYs) attributable to the CRC program.
Improved safety	An increase in the number of disability adjusted life years (DALYs) resulting from CRC research.
Expected social costs avoided	The value of expected social costs that are circumvented as a result of the CRC program. If no value can be provided, outline an explanation of the type of social costs avoided.
Savings on government expenditure	The value of savings on government expenditure attributable to the CRC program. This refers to any government savings associated with a reduction in expenditure on social issues such as health and welfare.
Participation in community activities	The number of new community activities and the number of people in attendance at said activities resulting from the CRC program. This refers to any additional activities and increased participation in community activities such as community art competitions.
Change in character of local community (positive and negative), maintenance of heritage, cultural development events or change in crime patterns	A description of any changes that have emerged in a local community as a result of the CRC program. This refers to any positive or negative changes, such as increased participation in community activities or increased vandalism respectively.
Other	A description of any other social benefits to a community arising from the CRC program.

Source: The Allen Consulting Group

Appendix C

Identified economic outputs and impacts

In addition to the impacts identified in the 2005 and 2006 impact studies, the tables below outline the cost savings or increases in output identified by this study. The identified impacts have been grouped according to the assessment framework tiers and in-line with the manner in which they have been inputted into the CGE Modelling.

The impacts have been self-identified by CRCs and, to the extent possible, verified by the study team and the CRC Association. The following tables outline the identified impacts according to the robustness of their measurement.

The Allen Consulting Group has verified all economic outputs and impacts identified in this study over the value of \$100 million. This process has involved consultation with CRCs, the review of independent assessments, citing of supporting documents and discussing the basis for calculations made. A footnote explaining the verification undertaken for each impact over \$100 million has been included within this Appendix.

Table C.1

CRC PRODUCTS — ECONOMIC OUTPUTS AND IMPACTS

CRC	Sector ²⁹	Output	Impact value
Cotton Catchment Communities CRC	Agriculture	Revenue created from the sale of products to by a commercial partner	\$0.9 million between 2005 and 2012
CRC for National Plant Biosecurity	Agriculture	Research contract to develop biosecurity risk management plans	Over \$2.2 million in revenue between 2006 and 2012
Poultry CRC	Agriculture	Cost savings from lower feed usage and greater flock uniformity for processing	Savings of \$40 million in 2006-07
Poultry CRC	Agriculture	Cost savings for a vaccine company — commercial in confidence	Cost savings of \$1.9 million between 2006 and 2010
CRC for Sheep Industry Innovation	Agriculture	CRC advice provided on the management of ewe flock for improved reproduction	Value of over \$1.6 million from 2009 to 2011
CRC for Sheep Industry Innovation	Agriculture	Cost savings from improved flystrike management programs	Value of approximately \$5 million from 2009 to 2011
Australian Biosecurity CRC	Agriculture	The containment of equine influenza, which lead to eradication. Benefits included reduced health costs, export income, reduced livestock losses and market protection	Value of \$134 million in total in 2007 ³⁰
eWater CRC	Agriculture	Value of research contracts	Value of \$3.36 million in 2010-11
Invasive Animals CRC	Agriculture	Reducing the impact of foxes, wild dogs, feral pigs and rodents	Value of \$52 million in 2010-11
CRC for Irrigation Futures	Agriculture	Decreased water use and increased efficiency of water due to the use of the IrriSatSMS tool, a low-cost irrigation scheduling system that can be used by all growers, regardless of the scale of their operation. It combines satellite remote sensing, weather stations and SMS messaging.	\$2.05 million in 2010
CRC for Irrigation Futures	Agriculture	Reduced water purchase and application costs by growers as a result of improvements in application efficiency	\$3 million per annum from 2010
CRC for High Integrity Australian Pork	Agriculture	Cost savings through advances in grain technology and feed efficiency	\$14 million annually since 2010 ³¹
CRC for High Integrity Australian Pork	Agriculture	The development of new feeding devices, an image analysis system for estimating pig weight, reproductive technologies for increasing fertility and litter size in sows and a new diagnostic tool for swine dysentery.	Total value of \$116 million ¹⁸
CRC for High Integrity Australian Pork	Agriculture	A new grain processing technology was investigated and established in the Pork CRC to remove the larger particles in both barley and sorghum, improving feed efficiency in the pork industry	Total value of \$90.7 million ¹⁸
CRC for High Integrity Australian Pork	Agriculture	Enhanced consumer and human health experts' knowledge on the health attributes of pork	Total value of \$101 million ¹⁸
Cotton Catchment Communities CRC	Agriculture	Additional income, derived from either water sales or its use in increasing output due to improved water use efficiency	Annual cost savings of \$57-\$108 million per year from 2011 ³²

²⁹ Sector refers to classification of CRC rather than impact.

³⁰ Based on independent economic analysis of AB-CRC projects by Agrtrans Research.

³¹ Discussed further in section 3.1

³² Based on an economic assessment of CRC water research and development by Deloitte Access Economics.

CRC for Polymers	Manufacturing	Revenue received from licensing technologies	Approximately \$2.3 million between 2005 and 2012
CRC for Polymers	Manufacturing	Sales of products manufactured in Australia using CRC technology	Increase in sales revenue of over \$25 million.
CRC for Advanced Composite Structures	Manufacturing	Research contract revenue	\$1.7 million in 2010, up to 3.6 in 2014
CRC for Advanced Composite Structures	Manufacturing	Commercial sales from spin-off company Australian Composites Pty Ltd relating to products such as ballistics-grade S2 glass prepregs for bullet proof vest inserts, as well as prepregs for oil and gas pipe repair, materials for wind turbine blades and their repair, and a variety of other industrial parts.	\$1 million per annum from 2006
CRC for Advanced Composite Structures	Manufacturing	Revenue received by spin-off company	\$2 million per year from 2010-2014
CRCMining	Mining	The current value of spin-off companies	Current value of approximately \$41 million
CRCMining	Mining	Royalties payable to CRC Mining	Approximately \$4 million between 2004 and 2012
CRCMining	Mining	Annual cost savings due to productivity increases	Cost savings of \$8 million per year
CRCMining	Mining	Annual cost savings due to reduced truck maintenance costs	Cost savings of \$2.4 million per year
CRCMining	Mining	Annual cost savings due to efficiency gains	Cost savings of \$3 million per year
CRCMining	Mining	Income derived from contract research	Over \$34 million between 2005 and 2012
Parker CRC for Integrated Hydrometallurgy Solutions	Mining	Commercial in confidence	A total value of \$160 million ³³
Antarctic Climate and Ecosystems CRC	Services	Web-based tool that enables infrastructure owners to assess the future likelihood of flooding resulting from sea-level rise.	Costs savings of \$0.4 million per year
Antarctic Climate and Ecosystems CRC	Services	Contract income and revenue through consultancy services and research in relation to climate change	Increased output of 5 million dollars between 2003 and 2011
Capital markets CRC	Services	Sale of software to SMARTs Pty Ltd	\$9.4 million in 2010
Capital markets CRC	Services	Value of spinoff company, EWS, Market quality report and consulting	\$1 million in 2012
Vision CRC	Services	Royalties generated from the sale of patents	Approximately \$90 million from 2005 to 2011
HEARing CRC	Services	The value of licenses granted	Approximately \$14.3 million from 2005 to 2012
CRC for Spatial Information	Services	Income derived from contract research	\$8.1 million between 2007 and 2011

³³ Cannot be verified due to commercial in confidence nature

CRC for Spatial Information	Services	The development of a web mapping application for the WA Department of Health leading to improved information for decision-making, productivity increases and cost savings on the generation of reports.	\$2.5 million in 2012
CRC for Spatial Information	Services	Development of software to produce the Australian Georeference Image	Avoided cost of \$14.5 million
CRC for Spatial Information	Services	Supplier contracts to non CRC participants for the supply of information and services related to the National Digital Elevation Program	\$7 million between 2008 and 2011
Oral Health CRC	Services	Reduction in cost of manufacturing Recaldent	\$0.5 million per annum since 2010
Oral Health CRC	Services	Increased sales revenue as a result of the development of enhanced Tooth Mousse Plus	\$17.2 million per year from 2005
Oral Health CRC	Services	Increased sales revenue as a result of the development of Chewing Gum products	\$200 million per year from 2005 ³⁴

Note: These impacts have been incorporated into the economic modelling as detailed in the evaluation framework. Source: The Allen Consulting Group, drawing on survey responses, annual reports, exit reports, management data questionnaires, consultations and other sources.

³⁴ Based on actual royalties received by the University of Melbourne

Table C.2

COLLABORATIVE PRODUCTS — ECONOMIC OUTPUTS AND IMPACTS

CRC	Industry	Output	Impact value
CRC for Beef Genetic Technologies	Agriculture	The development of the Meat Standards Australia voluntary meat grading system which was aimed primarily at providing an accurate prediction of beef eating quality for the domestic market.	Total cumulative economic benefit of \$523 million ³⁵
CRC for Beef Genetic Technologies	Agriculture	Through the Beef CRC, scanned and actual carcass and beef quality, feed efficiency and reproductive performance traits and data have been added to BREEDPLAN to significantly increase the rates of genetic gain in Australian seedstock and commercial cattle herds.	Total cumulative economic benefit of \$336 million ³⁶
CRC for Beef Genetic Technologies	Agriculture	Beef CRC commercialised two vaccines to control Bovine Respiratory Disease (BRD) and reproductive losses resulting from Pestivirus. Key end users are the feedlot sector across Australia which routinely uses the vaccines to control BRD and commercial beef producers who use Pestigard™ to improve the reproductive performance of their breeding herds	Total product sales of the CRC vaccines since commercial release to June 2010 were \$20 million
CRC for Beef Genetic Technologies	Agriculture	Beef CRC results show that 'pre-boosting' feeder steers around weaning minimises sickness during feedlot finishing and is a highly effective strategy to improve herd productivity	Total benefits to the industry by 2001 estimated to be \$8 million
CRC for Beef Genetic Technologies	Agriculture	CRC results relating to combinations of growth path, transport and genetic effects on beef eating quality have been used to increase compliance of cattle to premium beef market specifications	Total benefits of \$9 million per annum
Cotton Catchment Communities CRC	Agriculture	Increased sales revenue for cotton growers through management of insects	Increased sales of \$55 million annually
Cotton Catchment Communities CRC	Agriculture	Increased sales revenue for cotton growers through additional crop grown with additional water saved through CRC activities	Increased sales of \$32.6 million annually
Australian Seafood CRC	Agriculture	Regaining access to the EU market for Australian abalone	Net value approximately \$2.4 million per annum
CRC for Sheep industry Innovation	Agriculture	Cost savings associated with reduced labour costs in data collection and sheep management and reduced chemical use and sheep deaths. Work undertaken with Victorian DPI and AWI.	Benefits of over \$4.1 million between 2007 and 2010
CRC for Sheep industry Innovation	Agriculture	Increased revenues for sheep producers through increased reproductive efficiency in sheep flock and better access to improved genetic parameters for ram breeders	Benefits of over \$5.3 million between 2007 and 2010
CAST CRC	Manufacturing	Productivity gains, reduced capital and operating costs of processing infrastructure and cost savings by implementing CRC Technology	Value of over \$20 million from 2009 to 2012.
CAST CRC	Manufacturing	Increased sales revenue related to sales of newly developed alloys, other new products and enhanced margins	Value of over \$33 million from 2009 to 2012.

³⁵ Based on calculations by Garry Griffith, Adjunct Professor, School of Business, Economics and Public Policy, University of New England, Armidale; and Project Leader, CRC for Beef Genetic Technologies, Armidale, in his paper - *The Aggregate Economic Benefits to the Australian Beef Industry from the Adoption of Meat Standards Australia: updated to 2010/11*

³⁶ Supported by information provided by the CRC for Beef Genetic Technologies, based on R Banks, pers comm. 2012.

CRC for Greenhouse Gas Technologies	Manufacturing	Increased revenues associated with a decrease in carbon dioxide used in bottling processes	Increased earnings of \$0.5 million
CRC for Greenhouse Gas Technologies	Manufacturing	Revenue generated through research contracts with external funding bodies, examining carbon dioxide storage	\$8 million in 2008-09 and \$4 million 2011-12
Advanced Manufacturing CRC	Manufacturing	Increased revenue from maintenance contracts	Increased revenue of \$4 million per annum
CRCMining	Mining	Royalties payable to CRC Mining in conjunction with other partners related to implementation of rock cutting technology	Approximately \$1 million between 2010 and 2012
CRC for Spatial Information	Services	Value of spin-off companies, Scanalyse and iintegrate	Value of \$3.15 million between 2006 and 2012
The HEARing CRC	Services	Use of CRC technology by Cochlear	Attributed value of approximately \$120 million to date ³⁷
Oral Health CRC	Services	Agreement to take an option to the periodontal disease technology and pay an access royalty	\$0.114 million per year from 2009-2011
Oral Health CRC	Services	Value of an option to use CRC technology and sales royalty	Total value of \$8.93 million in 2009 and 2010

Note: These impacts have been incorporated into the economic modelling as detailed in the evaluation framework. Source: The Allen Consulting Group, drawing on survey responses, annual reports, exit reports, management data questionnaires, consultations and other sources.

³⁷ Based on sales revenue as presented in Cochlear's annual report and information about attribution rates which is commercial in confidence.

Table C.3

IMMINENT ECONOMIC OUTPUTS AND IMPACTS

CRC	Industry	Output	Impact value
CRC for National Plant Biosecurity	Agriculture	Management of insect pests in stored grain in export and domestic wheat	Total impact of \$3 million dollars
Dairy Futures CRC	Agriculture	Genetic gains for commercial dairy cows and increased capital value of elite breeding stock	Total value of over \$31 million
Poultry CRC	Agriculture	Research supporting registration studies for Fowl Cholera vaccine. Vaccine to reduce Fowl Cholera mortality by 2%, creating savings from reduced mortality.	Predicted to lead to cost savings of approximately \$3.5 million
Australian Seafood CRC	Agriculture	Cost savings associated with the translocation of lobsters from low to high productivity areas of ocean is introduced into the Southern rock lobster fishery,	Cost savings of \$45 million per year
Australian Seafood CRC	Agriculture	Cost savings associated with improved genetics on prawn farms results in increased productivity and genetic improvement in oysters	Cost savings of \$27 million
Australian Seafood CRC	Agriculture	Increased sales revenue associated with sea cucumbers able to be produced as juveniles in land based hatcheries and released into estuaries to grow for subsequent harvesting, the development of new crab products and an increase in yellowtailed Kingfish aquaculture production	Increased revenue of over \$34.2 million
CRC for Beef Genetic Technologies	Agriculture	Increased genetic gain through crossbreeding and development of composites in northern Australia	Annual benefit beginning in 2013 of \$207 million ³⁸
CRC for Asthma and Airways	Services	Licensing deal for the production of antibody target in the pharmaceutical sector	Approximately \$15 million between 2009 and 2017
CRC for Polymers	Manufacturing	Anticipated increases in sales through the utilisation of technologies licensed to CRC participants	Total current value of \$32.6 million
CRC for Polymers	Manufacturing	Predicted cost saved through productivity improvements arising from the potential use of products developed by the CRC.	Total savings of \$65.3 million
CRC for Polymers	Manufacturing	Revenue associated with licensing technologies to participants	Revenue totalling approximately \$1.6 million between 2012 and 2017
Advanced Manufacturing CRC	Manufacturing	Increased commercial sales as a result of CRC outputs	Increased commercial sales valued at over \$50.4 million
CRCMining	Mining	Increase in revenue for mining companies	Predicted increase in revenues by \$80 million in 2017
Australian Seafood CRC	Services	Reduced hospital costs for heart disease due to increased consumption of seafood	Value of \$0.5 in 2012 rising to \$1 million by 2016-17
CRC for Cancer Therapeutics	Services	Contract income in relation to research collaborations with pharmaceutical companies to develop a cancer drug	Total value of approximately \$3 million from 2012 to 2017
CRC for Cancer Therapeutics	Services	The value of license agreements to allow companies to develop and market a drug	Total value of over \$16 million from 2012 to 2017

³⁸ Based on the paper *Economic value of crossbreeding and grain-finishing tropically adapted cattle*, written by H.M. Burrow, G.R. Griffith, S.A. Barwick and W.E. Holmes

CRC	Industry	Output	Impact value
CRC for Infrastructure and Engineering Asset Management	Services	The value of licenses granted as a result of CRC research	Total current value of \$15 million
CRC for Infrastructure and Engineering Asset Management	Services	Improved return on investment in large assets through multi-criteria decision support and improved governance and management of asset portfolio by asset-intensive industries through the Asset Management Capability Maturity Model and other tools.	Total value of cost savings of \$10 million
CRC for Biomarker Translation	Services	Value of spin off company Value of licenses granted	Total current value of \$20 million ³⁹
CRC for Biomarker Translation	Services	Income from monies received from licenses granted flowing to CRC participants	Total current value of \$100 million ⁴⁰
Smart Services CRC	Services	Increased revenue associated with a variety of projects with outputs used to speed up reporting breaking news, toolkits to support cost-effective transition of paper-based and manual services to web-based service delivery.	Current value of \$63 million
Smart Services CRC	Services	Increased revenue associated with two projects with outputs resulting in a new service broker platform to catalogue and manage services at an enterprise level, a new network for secure sharing of health information and improved employment opportunities for students in the services sector.	Current value of \$36 million
CRC for Spatial Information	Services	Cost savings as a result of improved software, which is able to more efficiently and effectively generate information from acquired data, through the use of asset inspection technology, utilisation of the National Positioning Infrastructure, avoided duplication of data sets, better management of farms through spatial information and decision support software, cost savings due to better health planning tools and the ability of Government agencies to use a single authoritative and corrected digital evaluation model for planning purposes.	Total overall value of costs savings in the order of \$72 million between 2012 and 2017.
CRC for Spatial Information	Services	CRCSI developed technology has enabled low cost data capture, analysis and sharing of electrical infrastructure captured from airplanes at a scale and level of detail not previously possible. This has fundamentally changed the way in which spatial information is used and shared within the electricity sector.	Total overall value of costs savings in the order of \$76 million between 2012 and 2017 ⁴¹
CRC for Spatial Information	Services	Supplier contracts to non CRC participants for the supply of information and services	Total value of \$14.3 million between 2012 and 2017
CRC for Asthma and Airways	Services	Licensing revenue associated with patented drug targets	Licensing revenue total \$31 million from 2012-2017
Oral Health CRC	Services	Increased sales revenue to users of the CRC program through the development of dental varnish, a dry mouth treatment, salivary diagnostic to determine the presence of bacteria that can cause periodontal disease and glass ionomer cement with Recaldent	Total value of \$10.7 million between 2012 and 2017

³⁹ The estimated impacts are based on the potential outcomes of research and appropriate agreements, and is contingent on these events occurring.

⁴⁰ The estimated impacts are based on the potential outcomes of research and appropriate agreements, and is contingent on these events occurring.

⁴¹ Based on information provided by CRC end-user (commercial in confidence).

Oral Health CRC	Services	Increased sales revenue as a result of the development of Enhanced Performance Tooth Mousse	\$0.5 million per year from 2012
CRC for Rail Innovation	Services	The development of fatigue software which will reduce fatigue related injuries in the rail industry and improve driver performance.	Annual savings attributable to the CRC of \$10.2 million from 2014.
CRC for Rail Innovation	Services	A reduction in railway level crossing accident numbers through the implementation of safer level crossing research outputs.	Annual savings attributable to the CRC of \$33.3 million from 2015
CRC for Rail Innovation	Services	Improving knowledge of best learning practice for drivers and developing new and effective delivery methods which will increase the speed of entry of new drivers to the workforce, improve safety, reduce training times and associated salary costs. This will be achieved through the use of simulators to accelerate driver training and improving route knowledge acquisition and promote the case for driver-only operations with an emphasis on safety.	Annual savings attributable to the CRC of \$35.6 million from 2013
CRC for Rail Innovation	Services	Improved industry productivity by streamlining the way noise issues are managed, improving effectiveness and reducing construction of noise barriers, maintenance costs and noise monitoring insulation costs and greatly reduced expenditure on noise mitigation infrastructure.	Annual savings attributable to the CRC of \$30 million from 2015
CRC for Rail Innovation	Services	The development of new insulated rail joints (IRJ) which are used in large quantities industry-wide. Project will potentially increase IRJ life by 50%.	Annual savings attributable to the CRC of \$35 million from 2015
CRC for Rail Innovation	Services	The development of the Rail Grinding Best Practice automated decision tool which will reduce maintenance costs across the industry	Savings of \$25 million per annum from 2015.
CRC for Rail Innovation	Services	Implementation of a new Human Factors Analytical Tool. Cost savings to industry will flow in the form of: <ul style="list-style-type: none"> reduction in wasted investment by understanding human factors; and ensured use of new technology leading to increased industry productivity. 	Savings of \$50 million per annum from 2014.
CRC for Infrastructure and Engineering Asset Management	Services	Combat aircraft and steel bridges instrumented to warn of impending failures due to corrosion. Extended life and increased availability of assets. Reduced risk of catastrophic failure	Current value of impact attributable to CRC is \$6.8 million
CRC for Infrastructure and Engineering Asset Management	Services	Asset Health Management technology leading to extended life and availability of asset, and to reduced maintenance costs.	Current value of costs saved of \$10 million
CRC for Rail Innovation	Services	A reduction in railway level crossing accident numbers through the implementation of safer level crossing research outputs.	Annual savings attributable to the CRC of \$33.3 million from 2015

Note: These impacts have been incorporated into the economic modelling as detailed in the evaluation framework. Source: The Allen Consulting Group, drawing on survey responses, annual reports, exit reports, management data questionnaires, consultations and other sources.

Appendix D

The MMRF model

The Monash Multi-Regional Forecasting (MMRF) model is a Computable General Equilibrium (CGE) model of Australia's regional economies developed by the Centre of Policy Studies (CoPS) at Monash University (CoPS 2008). It is a model of the entire Australian economy and it captures the interactions between different regions and sectors. For a detailed description of the theoretical structure of the model see Peter et. al., 1996.

The MMRF model is used for a wide range of policy studies, including the analysis of state tax reforms and the potential benefits of the National Reform Agenda. More recently, the Department of the Treasury and the *Garnaut Climate Change Review* applied the MMRF model to the national climate change modelling to assess the impacts of the proposed CPRS on the Australian economy.

D.1 Introduction to the MMRF model

The MMRF is a dynamic model of the Australian economy that models the behaviour of economic agents within each of Australia's eight states and territories. Each region is modelled as an economy in its own right, with region-specific commodities, prices and industries. The model contains explicit representations of intra-regional, inter-regional and international trade flows.

Each sector produces capital that is specific to the region in which it is located. In each region, there is a single representative household and a regional government. At the national level, the Australian Government is also represented. Finally, the rest of the world is represented as a single agent, whose behaviour is driven by regional international exports and imports. The regions are linked through inter-regional trade, labour and capital mobility, and the taxing and spending of the federal government.

D.2 The database

There are many versions of the MMRF model. The version of MMRF used for this project provides a representation of the Australian economy as it was in 2005-06.

The model allows for joint production — where one industry can produce a number of different commodities. Specifically, the model contains 58 industrial sectors, which produce 63 commodities. The industries and their related commodities are detailed in Table D.1 and Table D.2 respectively.

Table D.1

MMRF: INDUSTRIES

Industry	
Agriculture, Forestry and fishing	30. Motor vehicles and parts
1. Sheep and beef cattle (high emissions)	31. Other manufacturing
2. Dairy cattle	Utilities
3. Other livestock (low emissions)	32. Electricity generation: Coal
4. Broadacre agriculture except for animal	33. Electricity generation: Gas
5. Other agriculture	34. Electricity generation: Oil products
6. Agricultural services and fishing	35. Electricity generation: Nuclear
7. Forestry	36. Electricity generation: Hydro
Mining	37. Electricity generation: Other
8. Coal mining	38. Electricity supply
9. Oil mining	39. Gas supply
10. Gas mining	40. Water supply
11. Iron ore mining	Services
12. Non-ferrous ore mining	41. Construction services
13. Other mining	42. Trade services
Manufacturing	51. Financial services
14. Meat and meat products	52. Business services
15. Other food, beverages and tobacco	53. Dwelling services
16. Textiles, clothing and footwear	54. Public services
17. Wood products	50. Communication services
18. Paper products	43. Accommodation, hotels and cafes
19. Printing and publishing	55. Other services
20. Petroleum and coal products	56. Private transport services
21. Chemicals	57. Private electricity equipment services
22. Rubber and plastic products	58. Private heating services
23. Non-metal construction products	Transport
24. Cement	44. Road passenger transport
25. Iron and steel	45. Road freight transport
26. Alumina	46. Rail passenger transport
27. Aluminium	47. Rail freight transport
28. Other non-ferrous metals	48. Water, pipeline and transport services
29. Metal products	49. Air transport

Source: CoPS, MMRF database.

Table D.2

MMRF: COMMODITIES

Commodities	
1. Sheep and beef cattle (high emissions)	33. Other non-ferrous metals
2. Dairy cattle	34. Metal products
3. Other livestock (low emissions)	35. Motor vehicles and parts
4. Broadacre agriculture except for animal	36. Other manufacturing
5. Bio fuel	37. Electricity generation: Coal
6. Other agriculture	38. Electricity generation: Gas
7. Agricultural services and fishing	39. Electricity generation: Oil products
8. Forestry	40. Electricity generation: Nuclear
9. Coal mining	41. Electricity generation: Hydro
10. Oil mining	42. Electricity generation: Other
11. Gas mining	43. Electricity supply
12. Iron ore mining	44. Gas supply
13. Non-ferrous ore mining	45. Water supply
14. Other mining	46. Construction services
15. Meat and meat products	47. Trade services
16. Other food, beverages and tobacco	48. Accommodation, hotels and cafes
17. Textiles, clothing and footwear	49. Road passenger transport
18. Wood products	50. Road freight transport
19. Paper products	51. Rail passenger transport
20. Printing and publishing	52. Rail freight transport
21. Petrol	53. Water, pipeline and transport services
22. Diesel	54. Air transport
23. LPG	55. Communication services
24. Aviation fuel	56. Financial services
25. Petroleum and coal products nec	57. Business services
26. Chemicals	58. Dwelling services
27. Rubber and plastic products	59. Public services
28. Non-metal construction products	60. Other services
29. Cement	61. Private transport services
30. Iron and steel	62. Private electricity equipment services
31. Alumina	63. Private heating services
32. Aluminium	—

Source: CoPS, MMRF database.

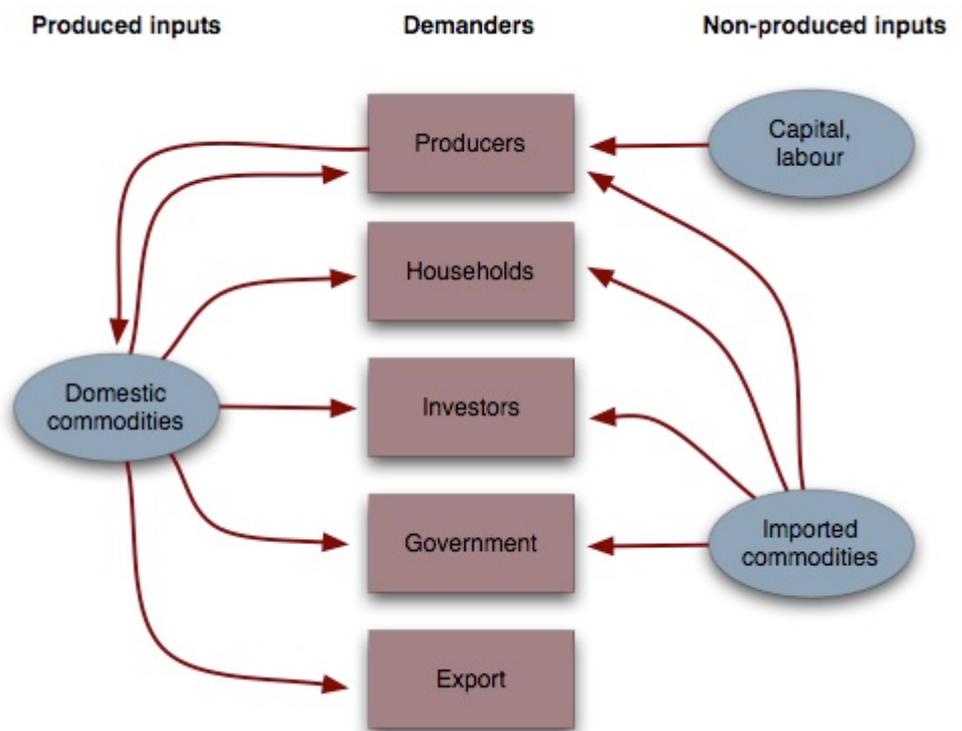
The MMRF database is comprised of detailed input-output tables for each state and territory as well as a set of government fiscal accounts. Each of the eight input-output tables details the core cost structure of each region specific industry and how each industry in each state economy is linked to other industries within that state and other states. Further, they show the flow of goods through the economy and the final demands of the principal economic agents.

D.3 Structure of the model

The core structure of the MMRF model is illustrated in Figure D.1. Producers use primary factors (labour, land and capital), region specific intermediate goods, and imports to produce domestic commodities. Domestic commodities and imported commodities flow to households, investors, and governments. In addition a proportion of domestic commodities flow to foreigners as exports. As well as demand schedules, the MMRF model has a detailed government budget and a set of regional labour markets.

Figure D.1

STRUCTURE OF THE MMRF MODEL



Source: Allen Consulting Group analysis, 2010, adapted from Monash.

The MMRF model is built on the core assumptions of neoclassical economics. Consumers aim to maximise utility within a fixed budget constraint, while firms select the mix of inputs that minimises costs for their level of output. This optimising behaviour determines the regional supplies and demands of commodities and the demand for primary factors within the model. Labour supply at the national level is governed by demographic factors and national capital supply is determined by rates of return. Both labour and capital can cross regional borders such that each region's stock of productive resources reflects relative employment opportunities and relative rates of return.

Assumptions regarding the economic behaviour of agents together with detailed input-output tables for each of the eight regions are linked by mathematical equations. This allows for second round impacts or feedback responses to be accounted for in the modelling framework. For instance, it allows for price response adjustments across all industries and factors. In this way, the results detail the actual effect of a change on the entire economy, not just within the region or industry that is directly affected. This allows a more sophisticated insight into policy analysis than is possible from partial equilibrium analysis or input-output analysis.

The model is driven by the assumption of competitive markets. That is, all markets clear and there exists equality between the producer's price and marginal cost for each sector in each region (all markets clear with the exception of the labour market). The purchaser's price and producer's price differs by the size of any government taxes and associated margins. All government taxes are levied as ad valorem sales taxes on commodities. Margins are additional costs associated with transport or retail trade required for market transactions.

Aggregate demand

Demand for goods from households, investors, governments and foreigners together comprise aggregate demand as represented in the equation below.

$$Y = C + I + G + (X - M)$$

Where:

- Y is aggregate demand;
- C is household consumption;
- I is investment;
- G is government spending;
- X is exports; and
- M is imports.

The components of aggregated demand and how they are represented within the model are discussed below.

Household demand

There exists a utility maximising representative household in each of the eight regions. Households consume bundles of goods from either domestically produced or imported commodities. Domestically consumed goods are a combination of goods from the eight regions. Total household demand is disaggregated into essential goods and luxury goods, as represented in the equation below.

$$X_i = X_i^{Sub} + X_i^{Lux}$$

Where:

- X_i is total household demand;
- X_i^{Sub} is essential consumption; and
- X_i^{Lux} is luxury consumption.

In MMRF it is assumed that a household will first purchase all essential goods before purchasing any luxury goods such that disposable income for luxury goods is a function of total income and the summed value of essential consumption.

$$Y^{Lux} = Y - \sum P_i X_i^{Sub}$$

Where:

- Y^{Lux} is income for luxury goods;
- Y is total disposable income
- P_i is price of good i ; and
- X_i^{Sub} is quantity of essential good X .

MMRF assumes a non-homothetic utility function (MMRF applies a Klein-Rubin utility function), which allows both income and relative prices to affect consumption.

Capital creation

Investors in each regional sector combine inputs to generate capital. Investors are limited to the technology set that is available for production in that regional sector. Rates of return are used as a signal for capital investment or disinvestment.

Government demands

There are nine governments represented in MMRF — the eight regional governments and a federal government — each demanding commodities. Government demands are either imposed on the model or determined endogenously by setting government expenditure rules. For example, government expenditure could be linked to aggregate consumption.

Foreign demand

Most exports can be categorised as either traditional exports, non-traditional exports or tourism exports. Demand for traditional exports is characterised by a downward sloping demand curve and associated assumptions regarding foreigners' preferences for Australian goods. Each regional sector has an associated export market, which faces a downward sloping foreign demand curve. It is assumed that the foreign demand schedules are specific to the regional sector; as such movement in world prices can differ across different regions.

The demand for non-traditional export goods is driven by the average price of the collective non-traditional export bundle. In the MMRF database, non-traditional exports account for two per cent of total national exports and include: electricity generation, gas and water, construction, trade services, rail transport and dwellings.

Within MMRF, it is assumed that the tourism sectors — hotels and cafes, road transport, air transport and other services — do not face their own individual demand schedules. Rather, foreigners purchase a holiday bundle, the quantity of which is determined by the average price of the tourism goods.

Demands for inputs used in production

Producers in each region utilise primary factors — land, labour and capital — intermediate goods and imported goods to produce domestic commodities. Producers are assumed to choose the mix of inputs that minimises costs for a given level of production. The MMRF model assumes a multi-stage nested structure of production. At the first stage the optimal combination of region specific intermediate goods and the optimal combination of occupational specific labour is selected. At the second stage, producers make decisions regarding the optimal combination of the three primary factors and the combination of imported and domestically sourced goods. Finally, producers combine primary inputs and intermediate goods to produce a level of output at minimum cost.

D.4 Government finances

MMRF contains a set of equations detailing government revenues and government expenditures for each government. Government revenues are comprised of income taxes, sales taxes, excise taxes, taxes on interregional trade and receipts from government assets. Government expenditures include — as detailed above — expenditure on commodities as well as transfer payments to households. In addition, for the Federal government there is a set of equations describing fiscal transfers to the states.

D.5 MMRF dynamics

There are two main types of inter-temporal links incorporated into MMRF: physical capital accumulation and lagged adjustment processes.

Physical capital accumulation

It is assumed that investment undertaken in year t becomes operational at the start of year $t+1$. Thus, given a starting point value for capital in $t=0$, and with a mechanism for explaining investment through time, the model can be used to trace out the time paths of industry capital stocks.

Capital stock in industry i in state/territory s in year $t+1$ is determined by the equation below.

$$K_{i,s}(t+1) = (1 - DEP_{i,s}) * K_{i,s}(t) + INV_{i,s}(t)$$

Where:

- $K_{i,s}(t)$ is the quantity of capital available in industry i located in state/territory s at the start of year t ;
- $INV_{i,s}(t)$ is the quantity of new capital created through investment for industry i in state/territory s during year t ; and
- $DEP_{i,s}$ is the rate of capital depreciation in industry i , treated as a fixed parameter.

Investment in industry i in state/territory s in year t is explained via a mechanism that relates investment to expected rates of return. The expected rate of return in year t can be specified in a variety of ways. In MMRF two possibilities are allowed: static expectations and forward-looking model-consistent expectations. Under static expectations, it is assumed that investors take account only of current rentals and asset prices when forming current expectations about rates of return. Under rational expectations the expected rate of return is set equal to the present value in year t of investing \$1 in industry i in state/territory s , taking account of both the rental earnings and depreciated asset value of this investment in year $t+1$ as calculated in the model.

Lagged adjustment processes

One lagged adjustment process is included in MMRF. This relates to the operation of the labour market in year-to-year simulations.

In comparative static analysis, one of the following two assumptions is made about the national real wage rate and national employment:

- the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or
- the national real wage rate is unaffected by the shock and employment adjusts.

MMRF's treatment of the labour market allows for a third, intermediate position, in which real wages can be sticky in the short-run but flexible in the long-run and employment can be flexible in the short-run but sticky in the long-run. For year-to-year simulations, it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in aggregate employment from its baseline-forecast level. The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years. This is consistent with macroeconomic modelling in which the Non Accelerating Inflation Rate of Unemployment (NAIRU) is exogenous.

D.6 Closure assumptions of MMRF

In MMRF, there are more endogenous variables than the number of equations. For the model to generate a solution, the number of endogenous variables must match the number of equations. Hence, some endogenous variables are set to be exogenous to ensure the number of endogenous variables matches the number of equations.

The desired economic environment/assumption for the policy scenario determines the choice of exogenous variables. These choices are also known as the closure assumptions. The most common closure assumptions are the long-run, short-run economic closure and fiscal closure.

Short-run closure

In the short-run, the economy is less able to respond to policy changes, as prices and wages are sticky (or fixed). Labour market (in terms of employment) is flexible and unemployment rate can be above or under its natural rate. Capital stock is fixed in the short-run, and investment responds to changes in rates of return.

Long-run closure

The key elements of a typical long-run economic environment are:

- At the national level, long-run employment is determined by demographic factors (birth and death rates, the level of international migration, etc.). Additionally, the unemployment rate reverts to its natural rate or NAIRU in the long-run. Therefore, the national employment figure is fixed. However, labour is perfectly mobile across industry and states, thus there can be changes in industry and state employment.
- Labour market adjusts via changes in real wages.
- Capital stock in each industry adjusts to equilibrate its expected and actual rates of return on capital. The baseline expected rates of return are determined by values in the MMRF database. Industries' demands for investment goods are linked by an exogenous investment/capital ratio to changes in their capital stock.
- Nominal household consumption in each region is a constant share of post-tax household disposable income.

Fiscal closure

The role of government also plays a part in determining the impacts of a simulation. A typical fiscal closure will have the following assumptions:

- real government consumption (Commonwealth and States) is fixed; and
- government budget balances (Commonwealth and States) are fixed, via changes in the fiscal item 'Government transfers to households'.

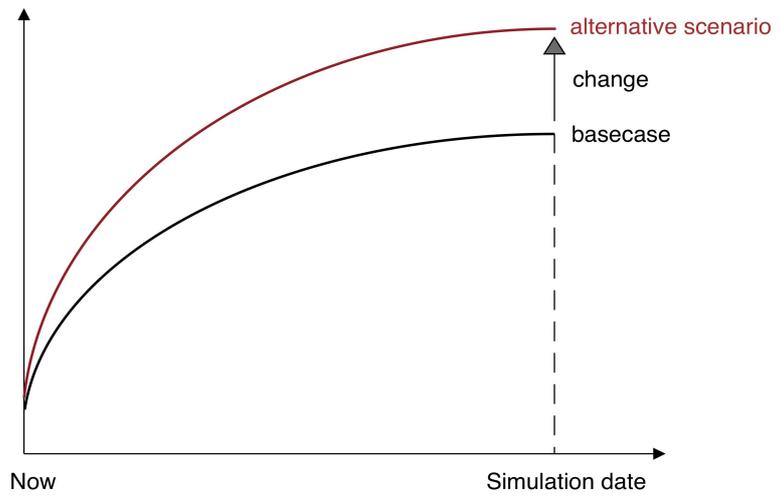
D.7 Interpretation of MMRF simulations

The MMRF can be solved in comparative static or recursive dynamic modes. Comparative static modelling shows the effect of a policy shock only. That is, it answers 'what happens when this happens?' without stating the adjustment process.

A dynamic CGE model would provide answers on the forecast structure of the economy under the baseline and the alternative case. It provides an explicit baseline over time against which the impact of a policy change can be compared. The model could incorporate more up to date data and the timing and policy paths are clear.

Figure D.2

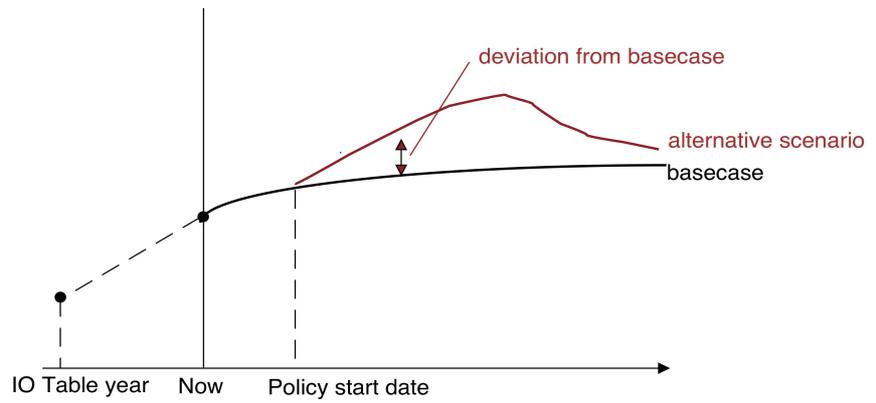
COMPARATIVE STATIC INTERPRETATION OF RESULTS



Source: Allen Consulting Group analysis, 2010.

Figure D.3

DYNAMIC INTERPRETATION OF RESULTS



Source: Allen Consulting Group analysis, 2010.

Appendix E

Sensitivity analysis

This Appendix outlines the sensitivity analysis conducted on key assumptions. It provides:

- an analysis of the results of the CGE modelling according to each tier of output, classified according to the robustness of measurement; and
- a comparison of the results of the CGE modelling using differing assumptions about the level of participant direct and in-kind funding, which would have occurred in the absence of the CRC program.

E.1 Results according to the robustness of their measurement

As discussed in Chapter 1, the evaluation framework used in this study identifies four tiers of outputs. These being:

- Tier 1: CRC products — those outputs which have been delivered, and have been quantified;
- Tier 2: Collaborative outputs — those outputs where part of an outcome is attributable to the CRC program, with an appropriate attribution rate applied;
- Tier 3: Imminent outputs — those outputs which are forthcoming, where technology or output has been “proved-up” and the route to market is clear; and
- Tier 4: Preparedness — those outputs involve forewarning or mitigating risks. They relate to impacts associated with CRCs only in the event that certain circumstances occur.

Over the period 1991 to 2017, the net effect of the CRC program was to grow the economy by over \$7.531 billion. This is reported in Table E.1, along with the expected impacts that would accrue if only CRC products were considered. In this case, the economy would have grown by \$1.13 billion as a result of the program. If both CRC products and collaborative impacts are considered, the CRC program has grown the Australian economy by \$4.94 billion. Figure E.1 shows the impact of the CRC program on the economy overtime according to these measures.

Table E.1

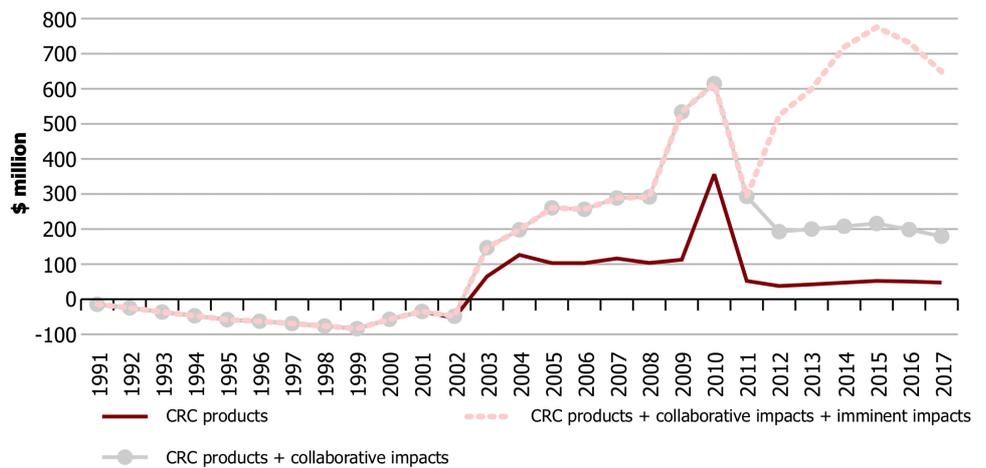
ESTIMATED NET IMPACT OF THE CRC PROGRAM ON THE AUSTRALIAN ECONOMY, DEVIATION FROM THE COUNTERFACTUAL

Item	Amount
Cumulative increase in GDP, \$ millions	
CRC products only	1,127
CRC products and collaborative impacts only	4,937
CRC products, collaborative impacts and imminent impacts (central case)	7,531
Benefit cost ratio	
CRC products only	0.47
CRC products and collaborative impacts only	2.04
CRC products, collaborative impacts and imminent impacts (central case)	3.11

Source: The Allen Consulting Group and COPS.

Figure E.1

ESTIMATED INDIRECT IMPACT ON GDP, 1991-2017, VARIOUS SCENARIOS



Source: The Allen Consulting Group and COPS.

E.2 Level of participant direct and in-kind funding

As noted in Chapter 1, the primary difference between this study and the Insight Economics report is the treatment of participant direct and in-kind funding. In the Insight Economics report, it was assumed that private sector CRC participants spent no monies on R&D in the absence of the CRC program. In other words, Insight Economics assumed that the CRC program was responsible for inducing 100 per cent of participant direct and in-kind support. The PC however, argued that this was unlikely to be the case, adjusting Insight Economics results in a way that suggested the complete opposite - that the CRC program induced no additional expenditure from participants on R&D⁴².

⁴² It is noted that the PC only adjusted Insight Economics' first tier estimates.

Consultations undertaken with CRC participants have indicated that the real story is perhaps, somewhere in between: industry and universities would have spent some monies on R&D, but the CRC program induced some as well.

How much induced spending by the CRC program remains uncertain. Moreover, the amount of spending the program induced is likely to differ for different industries and in accordance with the nature of the CRC. A public good CRC for example, is probably less likely to raise as much participant support in the absence of the program, than is a CRC based around improving manufacturing productivity. In the absence of more informed data, this study has assumed that in the absence of the CRC program, industry and university participants would have spend 50 per cent of CRC funding elsewhere in the economy. It is assumed the remaining 50 per cent of industry and university funding, as well as all of State Government and CSIRO funding, would have been spent on other R&D activities.

This study has taken a deliberately moderate position and assumed that in the absence of the CRC program, industry and university participant expenditure on R&D would only amount to 50 per cent of what was spent on CRC activities.

A second difference relates to the treatment of the Australian Government's support for the program. Despite having data on only a sample of CRC impacts, their analysis was made relative to the full Australian Government commitment. This would have the effect of overstating the program's costs relative to benefits observed.

In light of these uncertainties, as part of the analysis undertaken for this study, the following three scenarios have been modelled to assess the results of changing this assumption:

- Scenario 1 — (the study's central case) the CRC program has induced industry and university participants to spend 50 per cent more on R&D than they would have in the absence of the program.
- Scenario 2 — (Insight Economics' treatment) — the CRC program has induced industry and university participants to spend 100 per cent more on R&D than they would have in the absence of the program.
- Scenario 3 — the CRC program induced no additional spending on R&D. That is, industry and university participants would have spent the same amount of money on R&D if the CRC program did not exist.

Table E.2 outlines the net impact of the CRC program to the Australian economy under each of these scenarios. Notably, had this study used the same treatment of participant direct and in-kind funding as the Insight Economics report, for every dollar of Australian Government funding spent on the program, the program would have grown the economy by a factor of 3.55. (This, figure differs from that reported in Box 6.1 because of the different treatment of Australian Government funding.)

Table E.2

**ESTIMATED NET IMPACT OF THE CRC PROGRAM ON THE AUSTRALIAN ECONOMY,
DEVIATION FROM THE COUNTERFACTUAL**

Item	Amount
Cumulative increase in GDP, \$ millions	
Scenario 1 — Central case, 50 per cent inducement	7,531
Scenario 2 — Insight Economics, 100 per cent inducement	8,590
Scenario 3 — Productivity Commission*, 0 per cent inducement	4,731
Benefit to cost ratio	
Scenario 1 — Central case, 50 per cent inducement	3.11
Scenario 2 — Insight Economics, 100 per cent inducement	3.55 ⁴³
Scenario 3 — Productivity Commission*, 0 per cent inducement	1.94

* It is noted that the PC only adjusted Insight Economics' first tier estimates.
Source: The Allen Consulting Group and COPS.

⁴³ Note this figure differs from that reported in Box 6.1 because of the different treatment of Australian Government funding.

References

Australian Bureau of Statistics (ABS) 2006, *Catalogue number 1292.0 – Australian and New Zealand Standard Industrial Classification (ANZSIC)*, accessed 4 April 2012, available from

<[Australian Bureau of Statistics \(ABS\) 2010, *Catalogue number 8155.0 – Australian Industry 2009-2010*, accessed 27 March 2012, available from](http://www.abs.gov.au/AUSSTATS/abs@.nsf/Latestproducts/1292.0Main%20Features12006%20%28Revision%201.0%29?opendocument&tabname=Summary&prodno=1292.0&issue=2006%20%28Revision%201.0%29&num=&view=></p></div><div data-bbox=)

<[Australian Bureau of Statistics \(ABS\) 2011, *Catalogue number 6401.0 – Consumer Price Index, Australia, Dec 2011*, accessed 11 April 2012, available from](http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/8155.02009-10?OpenDocument></p></div><div data-bbox=)

<[Australian Bureau of Statistics \(ABS\) 2011b, *Catalogue number 5204.0 – Australian System of National Accounts 2010-2011: Table 5 – Gross Value Added \(GVA\) by Industry*, accessed 27 March 2012, available from](http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/938DA570A34A8EDACA2568A900139350?opendocument></p></div><div data-bbox=)

<[Allen Consulting Group 2011, *The University of Queensland research institutes: working together to advance Queensland and Australia*, a report for the University of Queensland.](http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5204.02010-11?OpenDocument></p></div><div data-bbox=)

Allen Consulting Group 2005, *The Economic Impact of Cooperative Research Centres in Australia*.

Beesley L 2003, *Relationships Among Knowledge Creation, Diffusion and Utilisation in the CRC Process*.

CO2CRC 2011, *Research overview page*, <<http://www.co2crc.com.au/research/>>, accessed 6 March 2012.

CRC 2011a, *About CRCs*

<https://www.crc.gov.au/Information/ShowInformation.aspx?Doc=about_CRCs&key=bulletin-board-information-about-crcs&Heading>About%20CRCs>, accessed 6 December 2011.

CRC 2011b, *The program*,

<https://www.crc.gov.au/Information/ShowInformation.aspx?Doc=about_programme&key=bulletin-board-programme&Heading=The%20Program>, accessed 6 December 2011.

CRC 2011c, *14th Selection Round*,
<https://www.crc.gov.au/Information/ShowInformation.aspx?Doc=14th_Selection_rounds&key=bulletin-board-selection-rounds_14&Heading=14th%20CRC%20Selection%20Round>, accessed 22 February 2012.

CRC 2011d, *Selection Round 14 Application Instructions*.

CRC 2011e, *Innovation in climate change and clean technologies fact sheet*,
<<https://www.crc.gov.au/Information/ShowInformation.aspx?Doc=Publications&key=bulletin-board-publications&Heading=Publications>>, accessed 6 March 2012.

CRC 2011f, *Innovation in health research fact sheet*,
<<https://www.crc.gov.au/Information/ShowInformation.aspx?Doc=Publications&key=bulletin-board-publications&Heading=Publications>>, accessed 6 March 2012.

DIISRTE 2008, *Venturous Australia: Building Strength in Innovation*.

DIISRTE 2011a, *Portfolio Budget Statement 2011-12*.

DIISRTE 2011b, *Australian Innovation System Report 2011*.

DIISRTE 2011c, *MDQ DATA – 1991-92 to 2009-10 Education*.

Garrett-Jones S & Turpin T 2002, *Measuring the Outcomes of the CRC Program: A Framework*.

Group of Eight 2011, *Go8 Backgrounder 23: Measuring the impact of research — the context for metric development*.

Harman G 1999, 'Australian Science and Technology Academics and University-Industry Research Links', *Higher Education*, vol. 38, pp. 83-103.

Howard Partners 2003, *Evaluation of the Cooperative Research Centres Program*.

IEA 2009, *CO2 Capture and Storage: A Global Call to Action: NCCSA Briefing*.

Insight Economics 2006, *Economic Impact Study of the CRC Program*.

NHMRC 2011, *About*, <<http://www.nhmrc.gov.au/about>>, accessed 6 December 2011.

OECD 2009, *Science, Technology and Industry Scoreboard 2009*, December 2009

Office of Best Practice Regulation, Australian Government Department of Finance and Deregulation, 2007, *Best Practice Regulation Guidance Note: Value of statistical life*. VSL for 2011

O'Kane M 2008, *Collaborating to a Purpose: Review of the Cooperative Research Centres Program*.

Productivity Commission 2007, *Public Support for Science and Innovation: Research Report*.

Stevens N 2011, *Innovation in Australia: Future Challenges and Opportunities*.