Economic Impact Study of the CRC Programme

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EXECUTIVE SUMMARY

Study objectives

The Cooperative Research Centres (CRC) Programme was established in 1990 to improve the effectiveness of Australia's research and development effort. It links researchers with industry to focus R&D efforts on progress towards utilisation and commercialisation.

Since the commencement of the CRC Programme, there have been nine CRC selection rounds, resulting in the establishment of 158 CRCs over the life of the Programme (100 new CRCs and 58 new from existing CRCs). In total all stakeholders have committed $11.1 billion (cash and in-kind) to CRCs. This includes $2.7 billion from the CRC Programme, $2.9 billion from universities, $2.1 billion from industry, $1.3 billion from States, $1.2 billion from CSIRO and $0.8 billion from other sources. There are currently 57 CRCs operating across six sectors.

This study, commissioned by the Australian Government Department of Education, Science and Training (DEST), considers, and where possible quantifies, the wide range of economic, environmental and social impacts from the CRC Programme. It builds upon the work undertaken in the 2005 CRC Impact Assessment Study commissioned by the CRC Association.

In addition to demonstrating the "value" being generated through the commitment of taxpayer funding to the CRC Programme, through consideration of the ways that CRCs deliver benefits, lessons can be drawn that may be useful in informing future Programme design and evaluation methods.

Types of benefits delivered by the CRC Programme

If the only effects on economic performance of the CRC Programme were simple expenditure effects, clearly the overall impact of the CRC Programme on economic wellbeing in Australia would be negative (due to the economic loss involved in collecting and then spending taxation revenues). However, expenditure on CRCs is

quite unlike items of government expenditure such as pensions and unemployment benefits, which are transfer payments. Unlike transfer payments, expenditure on CRCs would be expected to lead to positive economic outcomes beyond simple expenditure effects. The knowledge developed in CRCs would be expected to generate improved productivity in existing industries, help the development of new industries, lead to improved environmental and health outcomes (that do have an economic value) and so on. Each of these impacts would act to boost GDP and in turn boost real consumption. In this way expenditure on CRCs generates effects that are in the nature of "investment" effects in addition to the simple expenditure effects on the economy that are associated with any form of government expenditure.

The channels by which the CRC Programme delivers "investment" effect benefits for Australia have been categorised in this study as:

- **The application of CRC generated knowledge/intellectual property**. This includes specific benefit channels such as:
  - benefits through commercialisation of new or improved products or processes based on CRC R&D via spin-off companies or licensing of IP to existing companies; and
  - economic, environmental, health and social benefits through the application by industry or public sector end users (including capital and operating cost savings delivered in the public sector) of new or improved products or processes enabled by CRC generated IP.
- **Access to international knowledge networks**. This includes specific benefit channels such as:
  - international researchers coming to work in Australia on CRC research projects, bringing with them valuable skills, where the cost of the skills development has been borne overseas;
  - participation by CRCs in international technical standards setting bodies that results in technical standards suited to Australian market needs;
  - Australia in effect "buying" access to the total value of the research being conducted within international research partnerships in which CRC researchers participate; and
  - international industry partnerships or trade relationships that have been facilitated by CRC researchers participating in international projects or conferences.
- **Enhanced skills formation**. This includes specific benefits such as:
  - benefits through the development of highly skilled post-graduates that build a critical mass of skills in a region that either attracts multinational companies to invest in the location or helps retain existing business activity levels;

- benefits through the development of highly skilled post-graduates who then work in industry and allow industry to be smart adopters and adapters of internationally generated technology/knowledge; and

- benefits through industry and academic researchers interacting and increasing their skills, and hence their future productivity, via this interaction. Collaboration across sectors and disciplines encourages researchers to develop understanding of both research provider and end user perspectives, maintaining focus on the active planning for and management of pathways to application.

While not all of the benefits that have been delivered through these channels by the CRC Programme are able to be discretely identified and quantified, within the time and information availability constraints that exist, in this study an attempt has been made to identify and quantify as many of these benefits from the Programme as possible. The inability to capture and measure all benefits means that the economic impact analysis conducted in this report must be viewed as a partial rather than complete accounting of the economic benefits of the CRC Programme.

Approach to quantification of CRC Programme impacts

In order to quantify the economic impact of the CRC Programme since its inception, we must consider how economic outcomes in Australia would have been different in the absence of the CRC Programme and its activities. In effect, the "additionality" of the CRC Programme is being assessed.

To create such a "without CRC Programme" scenario for economic performance, it is firstly necessary to reallocate the Government funding that has gone into CRC Programme to some other use – in this study it is assumed that the money would instead have been used to reduce taxation. In this way the "expenditure" effects of the CRC Programme can be accounted for. The net expenditure effects of the Programme represent the true initial cost of the CRC Programme to taxpayers.

Once expenditure effects are accounted for, it is then necessary to identify any discrete measurable economic outcomes that are attributable to the application of Government funds within the CRC Programme and to remove these impacts from the economy in the "without CRC Programme" scenario for economic performance. In this way the "investment" effects[1] of applying resources to the CRC Programme can be accounted for.

By adopting the above approach, this study aims to measure both the simple "expenditure" effects of the CRC Programme and the more complex "investment" effects associated with CRCs' activities. Through removal of these impacts from the "without CRC Programme" scenario within the Centre of Policy Studies' MONASH MMRF model of the Australian economy, it is then possible to establish whether the Australian community is actually better off (in terms of key economic indicators such

[1] Note that the term "investment" effects is not used here to denote the effect of the Programme on the Investment variable within the National Accounts. Rather it is used only to signal a type of impact resulting from the Programme.

as GDP, Consumption and Investment) under the "with CRC Programme" scenario than they would have been under the "without CRC Programme" scenario.

This study includes quantitative assessment of the wide range of benefits from the CRC Programme in Australia out to the year 2009-10 using modelling of the impacts from the Programme in Australia by the Centre of Policy Studies (which conducted the economic modelling in the 2005 CRC Association Economic Impact Study). CRCs funded through Rounds One to Eight of the Programme, as well as new from existing CRCs funded in Round Nine of the Programme are the focus of this study (a change from the 2005 study which focused only on CRCs funded in Rounds One to Seven of the Programme)

A four level hierarchy of economic impacts has been considered within this report. The first three levels have been used as the basis for three economic impact modelling scenarios while the fourth level deals with some of the contingent benefits from the CRC Programme. Contingent benefits are benefits that carry an expected value but where that value will only be actualised if a certain set of conditions/events occur in the future. Contingent benefits are described in qualitative and quantitative terms in this study but have not been included within the economic modelling scenarios due to difficulties associated with ascribing such benefits to a particular year and the fact that the delivery of such benefits is inherently uncertain.

Criteria used for inclusion of quantified benefits within the three levels of economic impact modelling are clearly articulated within the study. It is important to note that in all three impact modelling levels the end user "adoption costs" that have been incurred in relation to the generation of benefits from CRC generated knowledge are explicitly taken into account in this study. It is only the benefits delivered net of such adoption costs that are counted within the impact modelling.

The first level of economic impact modelling is undertaken with a view to providing an incontrovertible minimum quantification of the additional economic impacts of the CRC Programme. It includes only outcomes from the Programme where the outcome occurred as a direct result of CRC Programme funding, the outcome has been delivered and the outcome has been verified and quantified by the end beneficiaries.

The second level of economic impact modelling includes the outcomes from level one and some additional delivered benefits from the Programme where the issue of the extent to which an outcome is attributable to CRC Programme funding (compared to other contributing factors to the eventual outcome) has had to be addressed and an approximate attribution rate applied.

The third level of economic impact modelling includes outcomes from level one and two and some additional benefits from the Programme where the benefit is only now commencing. For a benefit to be included as forthcoming the commencement of the benefit needed to be assessed by end users as "imminent" – i.e. the technology has been "proved-up" and the route to application is clear. This third level of modelling, while still constrained due to the inability to capture and measure all impacts from CRCs, should be seen as representing the "best estimate" of the non-contingent benefits of the CRC Programme over the 1991-2010 period.

Key findings from the economic impact assessment

The inability to capture and measure all benefits (within the time and information constraints of this study) means that the economic impact analysis conducted in this report must be viewed as a partial rather than complete accounting of the economic benefits of the CRC Programme. Notwithstanding this constraint, the outcomes of the level three economic impact modelling scenario undertaken in this study represent the "best estimate" of the non-contingent benefits of the CRC Programme for Australia. Based on the results from the level three economic modelling scenario, the key findings from this study are that:

For each dollar invested in the CRC Programme (rather than left with taxpayers):

- **Australian Gross Domestic Product is cumulatively $1.16 higher than it would otherwise have been.**
- **Total Australian Consumption is $1.24 higher than it would otherwise have been (Private Consumption is $0.10 higher and Public Consumption is $1.14 higher).**
- **Total Investment is $0.19 higher than it would otherwise have been.**

It is important to note that if the same counterfactual had been applied in the 2006 study as was applied in the 2005 study, for each dollar allocated to the CRC Programme the net impact on GDP under scenario three would have been to increase GDP by around $1.36 rather than the $1.16 increase noted above.

Table ES.1 sets out the cumulative impact of the CRC Programme funding between 1991 and 2005 (totalling $2.33 billion in 2005 dollar terms) on Australian economic performance over the 1991-2010 period estimated under the level one, two and three economic modelling scenarios. Results have been converted to 2006 NPV terms with future impacts discounted using a five per cent real discount rate.

TABLE ES.1: NET ECONOMIC IMPACTS OF THE CRC PROGRAMME*

Economic Variable	Level One Finding (2005 dollars)	Level Two Finding (2005 dollars)	Level Three Finding (2005 dollars)
Gross Domestic Product	+$1,157 million	+$2,554 million	**+$2,697 million**
Total Consumption	+$2,264 million	+$2,838 million	**+$2,877 million**
Investment	-$4 million	+$384 million	**+$436 million**

* It is important to note that the findings from the level one impact assessment should not be directly compared with the findings from the 2005 CRCA commissioned impact study. This is because an important methodological change was made between the two studies. In the 2005 study the counterfactual alternative use of CRC Programme funding was that it would have gone to other Government expenditure. In the current study, the counter-factual used was that the CRC Programme funding would have instead gone to tax reductions. If the same methodology had been applied in this study as was applied in the 2005 study, the impact on GDP under each assessment level would have been approximately $450 million higher than the result presented here.

The overall conclusion to be drawn from the three economic impact modelling scenarios is that the CRC Programme, under all scenarios, is delivering very clear net benefits for Australian economic welfare and that, particularly when methodological changes are taken into account, the impact of the Programme is higher than was previously measured in the 2005 CRC Association study.

In relation to contingent benefits considered in level four of the impact assessment, unfortunately, given the generally long running time horizons for the delivery of these benefits and the high levels of uncertainty surrounding when they may be converted from a contingent to an actual benefit, it was not felt that it would be appropriate in this study to quantify such impacts in the same way as other kinds of benefits from CRCs have been quantified. However, difficulties associated with quantification of contingent benefits do not imply that such benefits are either insignificant or unlikely to become actual at some future time. Quite the contrary, contingent benefits considered in this study may in fact be amongst the largest that are provided by the CRC Programme and could result in the Programme delivering benefits considerably in excess of those quantified in the first three economic impact levels.

Lessons learned

When compared to the results of the 2005 CRC Association study, in this study a number of additional delivered benefits have been identified and quantified. In the 2005 study, 25 quantified CRC impacts were identified and included in the impact modelling. In this study, in addition to impacts from the 2005 study, an additional 27 quantified CRC impacts were included across the three economic impact modelling levels. The most dramatic change was in relation to Agriculture & Rural Based Manufacturing CRCs; two impacts from such CRCs were included in 2005 compared to 14 in this study. This change largely reflects the significant effort that a number of Agriculture focused CRCs have made since the 2005 study to gather more end user verification of the impacts of application of the CRCs research.

As a consequence of "capturing" in this study more of the benefits generated by CRCs it has become apparent that the net benefits of the CRC Programme are higher than the lower bound calculation of benefits found in the 2005 study. In particular, when those benefits where "attribution" is an issue are included, the net benefits from the Programme (even without factoring in the impact of the change made in the assumed counterfactual without CRC Programme case) emerge as being twice as high as the level calculated in 2005. Given this result, the *prima facie* case for continuation of the CRC Programme is even stronger than that which emerged from the 2005 study.

While the magnitude of benefits identified in this study have increased considerably when compared to the 2005 study findings, a number of other important points to emerge from the 2005 study have not changed. For instance:

- Benefits delivered through the end user application of research by means other than direct commercialisation processes (spin-offs and licensing) remain the most significant channel of quantified benefits from the CRC Programme.

- Time lags between the formation of a CRC and the generation of measurable end impacts are still significant – time lags between the commencement of a CRC and the delivery of measurable end impacts are generally between five and ten years.

- Challenges in the quantification of impacts, and particularly contingent benefits, remain high and continue to result in an under-accounting of impacts in studies, such as this one, that focus on measuring "delivered" impacts and require end user verification and quantification of impacts.

Two final lessons learnt during this study that may be relevant to future Programme design and evaluation are that:

- Different types of CRCs face very different degrees of difficulty in quantification and verification of their impacts. For some it is as simple as asking one key industry partner to quantify a benefit they have realised, for others it involves complex sampling of end user groups or tracking of final retail outcomes. An example of the type of challenge sometimes involved in quantifying impacts can be seen in the amount of work that was required for the benefits to be calculated of the Beef CRC's contribution to the Meat Standards Australia (MSA) grading system. The benefits could only be calculated because extensive point of sale price information had been collected across Australia that allowed the producer price premium associated with the utilisation of the MSA system to be determined.

- CRCs that are focused on fostering the development of "new" industries or companies face a harder challenge to deliver benefits than do those CRCs that are focused on promoting incremental performance improvement within existing large sectors or companies. In part this is because when attempting to develop new areas of economic activity, a lot of factors (such as state of the venture capital market) beyond the quality and relevance of research come into play. For CRCs that are focused on solving problems of current concern to big existing industries or companies, the equation for success is somewhat simpler, namely: to deliver a benefit it is necessary to solve the problem identified by your industry partners and disseminate the solution to those partners.

Notwithstanding such issues for future consideration, the clear overarching finding from this study is that the CRC Programme is delivering strong net positive economic benefits for Australia.

CHAPTER 1
Introduction

1.1 Project context and objectives

In 2005 the CRC Association commissioned an economic impact study of the CRC Programme. That study, whose focus was limited to clearly quantifiable and delivered benefits attributable to the CRC Programme, demonstrated that the CRC Programme has made a strong positive net contribution to Australia's economic welfare. It highlighted a range of positive economic impacts from the Programme that were achieved as a result of the Programme bringing together researchers and end users and providing for a critical mass of resources to be applied to outcomes-driven research. The study also found that the CRC Programme's performance is improving over time and that the majority of benefits from past investment is still to be delivered.

The 2005 study took an important first step in measuring the economic impacts resulting from the application to date of CRC research outcomes relating to CRCs funded in Selection Rounds One to Seven. This new study, commissioned by the Australian Government Department of Education, Science and Training (DEST), will build on the 2005 economic impact study and attempt to quantify a wider range of economic, environmental and social impacts from the CRC Programme.

In addition to demonstrating the "value" being generated through the commitment of taxpayer funding to the CRC Programme, it is hoped that through consideration of the ways that CRCs deliver benefits, lessons will be learned that may inform future Programme design and evaluation methods.

Over its nine funding rounds, particularly in the two most recent rounds, the CRC Programme has steadily evolved both in terms of how applicants are selected and how outcomes are evaluated. It is clear that in recent funding rounds, successful CRC proposals must be genuinely end user driven, including pathways through which high quality research is going to find application. At the same time there has been a shift in the structure of CRCs – with CRCs now being established as incorporated entities rather than unincorporated joint ventures – to promote better governance arrangements within CRCs and assist in the effective uptake and use of research.

1.2 Overview of project stages

This project involved four core stages, namely:

- Information gathering – All existing CRCs, other than the five entirely new Round Nine CRCs, were sent an information request questionnaire seeking information in relation to CRC impacts in the areas of application of knowledge, skills formation and access to knowledge networks. In addition to questionnaire responses, key information sources included the CRC Management Data Questionnaire administered by DEST, data gathered from former CRCs during the 2005 CRCA study, data gathered from CRC annual reports during the 2005 CRCA study and stakeholder interviews.

- Framework development – The impact framework provides a structure for how impacts from CRCs are described and analysed within the study. It is based on lessons learned from the 2005 CRCA study and from a range of other research impact assessment projects that have been undertaken by the project team.

- Economic impact modelling – Insight Economics has developed three economic modelling scenarios for the impacts of the CRC Programme out to 2009-10. The Centre of Policy Studies modelled these scenarios using the MONASH MMRF computable general equilibrium model of the Australian economy. In addition, a fourth level of Programme impacts, namely contingent benefits from the Programme, are considered (but not modelled due to difficulties in ascribing such inherently uncertain benefits to a particular time period) in this study.

- CRC impact assessment report development – This report sets out and assesses the impacts of the CRC Programme and draws on material developed in the above three project stages.

1.3 Report structure

This report into the impacts of the CRC Programme includes the following sections:

- Executive summary
- Chapter One – Introduction
- Chapter Two – Summary of CRC Programme inputs and outputs
- Chapter Three – Framework for CRC Programme impacts and case studies of CRC impacts
- Chapter Four – Approach to assessment of CRC Programme impact
- Chapter Five – Details of economic modelling scenarios
- Chapter Six – Findings from economic modelling and further implications
- Chapter Seven – Conclusions
- Appendix A – Detailed modelling report

CHAPTER 2
Summary of CRC inputs and outputs

2.1 CRC Programme inputs

The CRC Programme was established in 1990 to improve the effectiveness of Australia's research and development effort. It links researchers with industry to focus R&D efforts on progress towards utilisation and commercialisation.

Since the commencement of the Programme, there have been nine CRC selection rounds, resulting in the establishment of 158 CRCs over the life of the Programme (100 new CRCs and 58 new from existing CRCs).

Since the commencement of the CRC Programme, in total all stakeholders have committed $11.1 billion (cash and in-kind) to CRCs. This includes $2.7 billion from the CRC Programme, $2.9 billion from universities, $2.1 billion from industry, $1.3 billion from States, $1.2 billion from CSIRO and $0.8 billion from other sources.

In terms of Commonwealth Government cash support provided through CRC grants, around $2.3 billion has been provided between 1990-91 and 2005-06[2]. CRC Programme funding now represents around 3.5 per cent of the Australian Government's annual science and innovation funding. This represents a significant commitment of taxpayer funding to the CRC Programme. It is important that the returns on this commitment are assessed, to ensure that taxpayers are receiving value for this investment in the CRC Programme.

[2] A further $400 million has been committed over the period to 2010-11 but has not yet been expended

From July 2006 onwards, there will be 57 CRCs operating across six sectors. Table 2.1 sets out the number of CRCs in each sector by recent funding round.

TABLE 2.1: NUMBER OF CRCs ESTABLISHED BY SECTOR AND FUNDING ROUND

	Manuftg	ICT	Mining & energy	Agriculture & rural based manuftg	Environment	Medical science & technology	*ALL SECTORS*
Rd1	1	2	3	3	3	3	***15***
Rd 2	5	3	2	4	2	3	***19***
Rd 3	2	3	2	5	4	1	***17***
Rd 4	1	0	3	3	3	1	***11***
Rd 5	1	1	3	3	3	5	***16***
Rd 6	6	4	2	4	7	3	***26***
Rd 7	4	2	3	4	4	2	***19***
Rd 8	1	3	3	5	6	3	***21***
Rd 9	3	0	1	5	3	2	***14***
All	24	18	22	36	35	23	***158***

Source: Analysis of *CRC Directory 2006*; *CRC Compendium 2000*; *CRC Compendium 1993*; and Mercer & Stocker (1998), Review *of Greater Commercialisation and Self Funding in the CRC Programme*.

The above table highlights that there was a 33 per cent decline in the number of new CRCs funded through Round Nine of the programme when compared to Round Eight and a 26 per cent decline when compared to Round Seven.

Table 2.2 indicates average (per CRC) CRC Programme funding by sector and by round. It demonstrates that the average CRC Programme funding per CRC has increased from $19.7 million in Round Seven, to $21.9 million in Round Eight and to $28.7 million in Round Nine.

TABLE 2.2: AVERAGE (PER CRC) CRC PROGRAMME FUNDING BY SECTOR AND FUNDING ROUND ($ MILLIONS)

	Manuftg	ICT	Mining & energy	Agriculture & rural based manuftg	Environment	Medical science & technology	*ALL SECTORS*
Rounds 1, 2 & 3 *	11.8	13.8	14.3	13.1	10.8	13.4	***13.0***
Round 4 (1994)	16.7	-	13.1	15.0	14.5	14.7	***14.8***
Round 5 (1996)	21.4	18.6	15.5	16.1	13.5	14.0	***15.4***
Round 6 (1998)	15.4	18.9	16.3	14.2	15.3	13.0	***15.5***
Round 7 (2000)	13.9	18.2	17.6	17.6	20.6	18.9	***19.7***
Round 8 (2002)	14.3	15.0	22.5	24.5	22.6	25.3	***21.9***
Round 9 (2004)	34.6	-	20.0	25.9	33.3	24.0	***28.7***

Source: Analysis of DEST (2006), *CRC Directory 2006*, *CRC Compendium 2000, CRC Compendium 1993*.

* Total resourcing data for all sectors in Rounds 1, 2 and 3 only available in aggregate.

As indicated in Table 2.2, while the number of CRCs funded in Round Nine represents a significant fall compared to previous rounds, the dollar value of Programme funding committed through Round Nine of the programme only declined by 12.9 per cent compared to Round Eight and actually increased by 19.7 per cent compared to Round Seven. This demonstrates that in Round Nine there was a strong shift towards funding fewer CRCs but also to providing them with significantly higher levels of funding. This can perhaps be described as a "fewer, bigger, better" funding strategy.

This shift towards awarding successful applicants larger grants is a Programme response to the rising costs of conducting high quality research and the fact that CRCs are increasing in the scale of their activities. It also recognises that, while it is important to maintain a critical mass in research activity, there are costs involved, including the transaction costs of the CRC application process and the establishment of incorporated CRC entities. In addition, there are non monetary transaction costs associated with the management of CRCs. The time and effort invested in forming and maintaining the "managed relationships" involved with a CRC are costly, but highly valuable. The incubation of such relationships is a core role of the CRC Programme, and is reflected in the decision to allow "new from existing" CRC applications. This acknowledges that, where successful collaborative relationships have been formed, it is important that they be nurtured. Larger grants enable CRCs to participate in international collaborations, and interactions with SMEs. The provision of incentives for individuals to invest time and energy in building relationships furthers these

incubatory Programme objectives. It also ensures that CRC Programme funding does not just serve as a "top up" to existing research, but rather instigates genuinely new projects and partnerships which would otherwise not occur.

Table 2.3 indicates total CRC Programme funding and total CRC resourcing levels (including in-kind contributions from participants) by sector and by round.

TABLE 2.3: CRC PROGRAMME FUNDING AND TOTAL CRC RESOURCING BY SECTOR AND FUNDING ROUND

		Manuftg	ICT	Mining & energy	Agriculture & rural based manuftg	Environment	Medical science & tech.	ALL
Rds 1, 2 & 3* 1991-93	CRC	94.7m	110.3m	100.3m	157.6m	97.5m	94.0m	**666.4m**
	Total	283.0m	360.0m	330.0m	585.0m	405.0m	290.0m	**2353.0m**
	CRC%	27.4%	33.3&	30.3%	28.2%	30.9%	32.8%	**30.2%**
Rd 4 1994	CRC	16.7m	-	39.2m	29.9m	57.9m	14.7m	**379.6m**
	Total	48.4m	-	180.5m	127.0m	207.0m	40.7m	**1260.0m**
	CRC%	34.6%	-	21.7%	23.5%	28.0%	36.1%	**30%**
Rd 5 1996	CRC	21.4m	18.6m	46.5m	48.4m	40.5m	70.2m	**245.6m**
	Total	61.2m	58.0m	241.4m	189.1m	198.5m	309.7m	**1057.9m**
	CRC%	35%	32.1%	19.3%	25.6%	20.4%	22.7%	**23.2%**
Rd 6 1998	CRC	92.2m	75.4m	32.6m	56.9m	107.3m	39.1m	**403.5m**
	Total	434.5m	479.7m	157.3m	293.9m	458.7m	145.0m	**1969.1m**
	CRC%	21.2%	15.7%	20.7%	19.4%	23.4%	27.0%	**20.5%**
Rd 7 2000	CRC	55.5m	36.3m	52.7m	70.5m	82.3m	37.8m	**335.1m**
	Total	261.7m	152.0m	290.8m	377.3m	421.2m	242.2m	**1745.2m**
	CRC%	20.%	24.%	18%	19%	20%	16%	**19%**
Rd 8 2002	CRC	14.3m	44.9m	67.6m	122.6m	135.3m	76.0m	**460.7m**
	Total	64.9m	269.4m	344.2m	474.6m	628.6m	637.7m**	**2419.4m**
	CRC%	22%	17%	20%	26%	22%	12%	**19%**
Rd 9 2004	CRC	103.9m	-	20.0m	129.4m	99.9m	47.9m	**401.1m**
	Total	299.2m	-	75.7m	497.7m	332.3m	131.6m	**1336.5m**
	CRC%	35%	-	26%	26%	30%	36%	**30%**
Rds 1- 9	**CRC**	**398.7m**	**285.5m**	**358.9m**	**615.3m**	**620.7m**	**379.7m**	**2648.8m**
	Total	**1452.9m**	**1319.1m**	**1619.9m**	**2176.3m**	**2651.3m**	**1796.9m**	**11016.4m**
	CRC%	**27.4%**	**21.6%**	**22.2%**	**28.3%**	**23.4%**	**21.1%**	**24.0%**

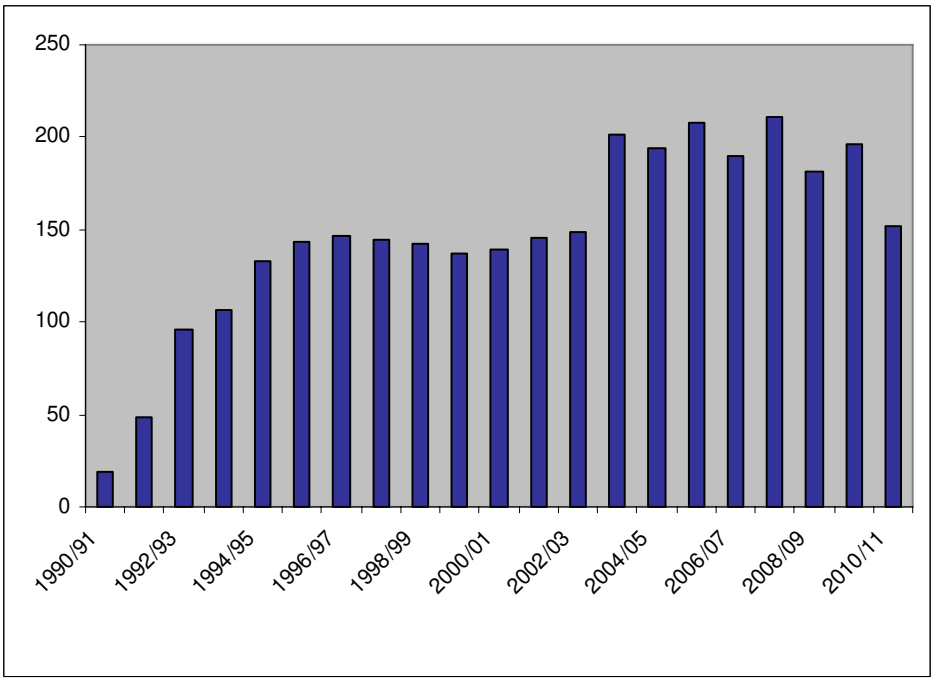
Source: Analysis of DEST (2006), *CRC Directory 2006, CRC Compendium 2000, CRC Compendium 1993.*

* Total resourcing data for all sectors in Rounds 1, 2 and 3 only available in aggregate

** This result is dominated by the Vision CRC, which reports $32 million in CRC Programme funding against overall resources of $387.7 million.

It should be noted that it is expected that the non-CRC Programme share of the Round Nine CRCs will grow somewhat in coming years as further resources are secured from participants as the recently established CRC operations become fully established. For instance, non Programme resources reported for Round Eight CRCs increased by $181 million between 2004 and 2006. However, such an outcome would not be expected to lower the CRC Programme share of total Round Nine CRC resources more than a couple of percentage points.

FIGURE 2.1: TOTAL CRC PROGRAMME EXPENDITURE (ACTUAL DOLLARS) 1990-2011



Source: DEST data

Aggregated expenditure (in nominal terms) on the CRC Programme, after remaining fairly constant from 1995 through to 2003, has increased significantly in recent funding rounds. This higher level is projected to continue through to 2009-10 before declining to 2002-03 levels in 2010-11.

2.2 CRC Programme outputs

Two key outcome areas from the CRC Programme that are amenable to whole of programme measurement are commercialisation performance and student training outcomes. In both these areas, which are briefly considered below, the Programme is playing an important role within the Australian innovation system.

In addition to these readily quantifiable performance areas, however, the CRC Programme has also been playing a role in the generation of new knowledge that is then applied by end users, and in engendering cultural change in the way that public sector researchers and private sector research end users interact. Outcomes of the CRC Programme in these areas are a key focus of the remaining Chapters of this study.

Commercialisation performance

Based on data from the 2001-02 National Survey of Research Commercialisation, the CRCA Productivity Commission submission (2006) suggested that commercialisation outcomes from the CRCs in 2002 compared very favourably with those from university research more broadly. For every million dollars of Commonwealth research expenditure, the CRCs as a group produced at least twice as many inventions, patents and licences as the overall university sector.

While these measures of direct commercialisation do not capture the majority of CRC outcomes, which mostly arise from the application of CRC knowledge to improve end users' existing products and processes, they do suggest that the CRC Programme has particular advantages in encouraging research with a strong focus on commercial outcomes.

TABLE 2.4: COMMERCIALISATION OUTCOMES FROM UNIVERSITIES AND THE CRCs IN 2002 (UNITS PER $ MILLION OF COMMONWEALTH GOVERNMENT RESEARCH FUNDING)

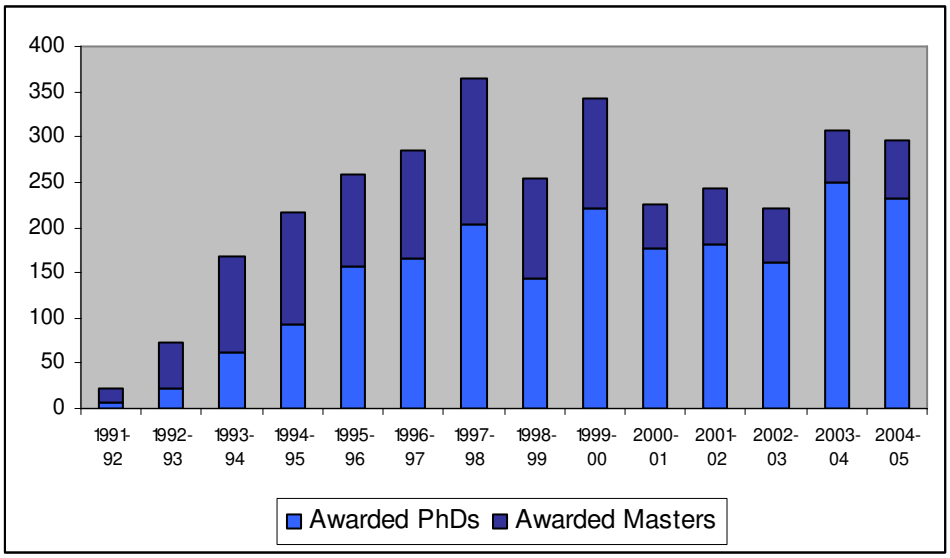
Commercialisation activity	Universities	CRCs
Inventions disclosed	0.26	0.50
Patent applications filed	0.23	0.51
Patents issued	0.06	0.17
Licences executed	0.11	0.32

Source: Commercialisation performance data from DEST (2004) *National Survey of Research Commercialisation*; Commonwealth expenditure data from DEST (2004), *Australian Science and Technology at a Glance*, Chart 36.

Student training

From initially low levels at the Programme's start-up, there have been relatively steady numbers of higher degrees awarded to students researching at CRCs – on average, around 280 a year from 1995-2004. In total, 2081 PhD and 1207 Masters level degrees have been awarded through the CRC Programme's lifetime.

FIGURE 2.2: AWARDED DEGREES AT CRCs 1991-92 TO 2004-05



Source: MDQ data, Department of Education, Science and Training

In addition to the numbers of degrees, important qualitative benefits arise from the CRC postgraduate programme. The CRC training environment is contributing to the development of industry-focused and industry-ready researchers.

BOX 2.1: CRCs: DEVELOPING INDUSTRY-FOCUSED RESEARCHERS

Dr Rachel Ashley, who completed her PhD thesis on *Improving the sustainability of wine grape quality in warm region irrigated vineyards* at the CRC for Viticulture in 2003, is currently working as the Victorian Regional Viticulturist for Fosters Wine Estates in Gippsland, Victoria. Of her experience at the Centre, Dr Ashley said,

"I really appreciated the opportunity the CRCV gave us to interact with both the scientific community and industry…I think the program really taught us how to transfer knowledge effectively to industry, without compromising the science"

Charline Gauthier was appointed Executive Vice President and Chief Operating Officer of the Californian IntraLase Corp, with worldwide responsibility for manufacturing, engineering, supply chain management and facilities management. IntraLase produces lasers which are used in the LASIK eye correction procedure, a refractive operation performed approximately 3.2 million times a year around the world. IntraLase proprietary technology is one of the most popular lasers used in this procedure.

Ms Gauthier completed her PhD thesis on the "*Effect of photorefractive keratectomy on the human corneal epithelium*" at CRCERT (later Vision CRC) in 1996. She was subsequently the Chief Operating Officer of Summit Autonomous, a US manufacturer of eximer lasers, before moving to IntraLase in 2003.

The CRC for the Australian Poultry Industries provides research to poultry meat and egg producers. CRC PhD candidate Anthony Keyburn has recently demonstrated that alpha-toxin is not the main causal factor for necrotic enteritis – the most common and costly disease affecting broiler chicken flocks. This is a breakthrough step in understanding about this bacterium, a significant issue for the poultry industry. Anthony commented that working at the CRC,

"brings focus to my work in a way that a university or CSIRO alone could not do"

Source: CRC for Viticulture (CRCV); Vision CRC; Australian Poultry CRC

CHAPTER 3
Framework for CRC impacts

3.1 CRC Programme benefit channels

If the only effects on economic performance of the CRC Programme were simple expenditure effects, clearly the overall impact of the CRC Programme on economic wellbeing in Australia would be negative (due to the economic loss involved in collecting and then spending taxation revenues). However, expenditure on CRCs is quite unlike items of government expenditure such as pensions and unemployment benefits, which are transfer payments. Unlike transfer payments, expenditure on CRCs would be expected to generate positive economic outcomes beyond simple expenditure effects. The knowledge that CRCs generate would be expected to generate improved productivity in existing industries, help the development of new industries, lead to improved environmental and health outcomes (that do have an economic value) and so on. Each of these impacts would act to boost GDP and in turn boost real consumption. In this way expenditure on CRCs generates effects that are in the nature of "investment" effects in addition to the simple expenditure effects on the economy that are associated with any form of government expenditure[3].

The CRC Programme has played a pioneering role in bringing together public and private sector researchers and research end users to focus on solving real challenges of importance to Australia, encouraging medium to long-term oriented collaboration

[3] Note that the term "investment" effects is not used here to denote the effect of the Programme on the Investment variable within the National Accounts. Rather it is used only to signal a type of impact resulting from the Programme.

between research providers and research users. The wide range of channels through which the Programme delivers benefits for Australia also includes the direct commercialisation of research, the application of research outcomes by industry or public sector users, increasing access to international knowledge networks, and the generation of "industry-ready" postgraduates.

Below, the different channels through which CRCs generate both economic and non-economic impacts are considered. These channels can be broadly categorised as benefits from:

- the application of CRC generated knowledge/intellectual property;
- access to international knowledge networks; and
- enhanced skills formation.

3.2 Benefits from the application of CRC generated knowledge/intellectual property

The category of benefits from the application of CRC generated knowledge includes:

- benefits through commercialisation of new or improved products or processes based on CRC R&D via spin-off companies or licensing of IP to existing companies; and
- economic, environmental, health and social benefits through the application by industry or public sector end users (including capital and operating cost savings delivered in the public sector) of new or improved products or processes enabled by CRC generated IP.

3.2.1 Benefits through commercialisation of products based on CRC generated knowledge/intellectual property

Benefits through this channel include specific impacts such as the:

- current market value of spin-off companies established to commercialise CRC research;
- turnover of spin-off companies established to commercialise CRC research;
- level of employment within spin-off companies established to commercialise CRC research;
- dollar value returned to public research organisations through the sale or licensing of intellectual property generated through CRC research; and
- turnover accrued to company(s) associated with the sale of products that have been developed on the basis of licensed intellectual property generated through CRC research.

Following are some examples of impacts that CRCs have generated via the direct commercialisation of knowledge.

Capital Markets CRC: Capital Markets Surveillance Services

Investor confidence in the integrity of the stock exchange is a necessary condition for markets to grow and thrive. Exchanges invest significant capital in monitoring of trade activity to ensure that trading activity is both legal and ethical, and prosecute cases of fraud. Capital Markets Surveillance Services (CMSS), spawned from the Capital Markets CRC, has commercialised ICT research that helps stock exchanges better mine their data to prevent and identify fraud. The software developed from the ICT research compares trading data from relevant markets with confidential broker data, and alerts the exchange to unusual broker trading activity. Critically, the software (Compliance Explorer) streamlines and speeds up the analysis of broker and market activity so that real time monitoring can be achieved. This lowers the operating costs of the exchange, and improves outcomes for not only the exchange, but also the investor and the market.

CMSS was created from collaboration between SMARTS Pty Limited (a company formed in 1994 that specialised in securities market surveillance and analysis software), SIRCA (a not-for-profit company created to develop new data analysis methods), Computershare, and a number of other firms. SMARTS had begun its ICT development in the 1990s at the University of Sydney, driven in large part by a need among PhD researchers in the finance and economics field for more efficiently accessible data. This led to the assemblage of large data sets, and created the impetus for ICT innovations to better mine this data. SMARTS, since it was formed as a company in 1994, has marketed its surveillance and compliance systems to exchanges and brokerages globally.

Once operational, SMARTS received a number of requests from international broking firms for its products. However, many broking firms ultimately could either not afford the systems or lacked the IT expertise to install and maintain the SMARTS systems. Only the largest brokers were able to afford and support the full on-site market surveillance system offered by SMARTS.

The Capital Markets CRC was created in 2001 to build on the ICT research already completed by SMARTS, and in particular, to expand the applications of this technology into new fields. Other partners in the CRC included ac3, ABN Amro, Computershare, Reuters and The Health Bureau. Within a year the SMARTS technology had been successfully extended into commercial applications for the finance sector. CMSS was formed in the year (2002) following the CRC's establishment and it immediately began to market its anti-stock fraud software, Compliance Explorer, to businesses and regulatory authorities.

Compliance Explorer obtains data directly from data aggregators such as exchanges and information vendors (e.g. Reuters). This reduces IT installation and maintenance costs. This has made the software more affordable for more brokerage houses. This software is now reported to be used by 17 Australian brokerages, and is exported globally. For example, the CRC reported that the Credit Suisse First Boston (CSFB)

equities brokering arm uses the software to monitor all of its trading activities globally.[4]

The impacts of the Capital Markets Surveillance Service product commercialisation are manifest in a number of ways, including increased revenues and profits associated with sale of CMSS products and, much more significantly, from the improved outcomes that are associated with use of CMSS technology in the financial services sector. The use of CMSS products results in reduced levels of insider trading which generates wider benefits for Australia through improved investor confidence and reduced investment risk — Australia ranked 3rd in the world for lack of insider trading.[5] The detail of data monitored by Compliance Explorer has been reported to have greatly increased the ability of brokerage houses, such as CSFB, to deter and to identify suspect trading and market obligation breaches in real time.

CRC for Sensor Signal and Information Processing: GroundProbe

Rock slides in open cut mines can result in fatalities and lost revenue for mining companies world wide. The development of ICT technology that more efficiently and effectively analyses data about rock wall stability can help companies avoid these costly disasters. GroundProbe, the product of public funding at the Cooperative Research Centre for Sensor Signal and Information Processing (CSSIP) and the University of Queensland, has developed and commercialised this technology.

GroundProbe markets Slope Stability Radar and Ground Penetrating Radar services for the global mining and civil infrastructure industries. Its primary product, the Slope Stability Radar, analyses movements in rock walls with the sub-millimetre precision required to provide a precise evaluation of the stability of mining slopes. The aim is to alert mine managers to risks of slope collapse and allow measures to be taken to prevent the collapse of the slope.

GroundProbe has said that it plans to focus on open cut mine markets in the Asia Pacific region, Africa, North and South America. In the future it also intends to scope markets in China, India and Russia. GroundProbe is also working on expanding its technology base, including bringing a unique new ground penetrating radar system to market that can rapidly map the subsurface of runways, railroads and roads in 3-D.

GroundProbe began with a PhD project in CSSIP in the School of Information Technology and Electrical Engineering. David Noon, the Chief Operating Officer of GroundProbe, was a supervisor for the PhD work.[6]

The PhD work formed the basis for a breakthrough technology: a radar system for monitoring rock wall stability. To capture the commercial opportunities of the technology, GroundProbe was formed in 2001 as a spin-off from CSSIP and The University of Queensland. During that year the original R&D projects and associated technical teams were initially funded by a variety of loans and grants, including $200,000 from the Commonwealth and $85,000 from the Queensland Government.

4 Capital Markets CRC Annual Report
5 Capital Markets CRC Annual Report
6 Discussions with GroundProbe staff

The company also received strong support from the Australian Coal Association Research Program (ACARP) and local companies. The company was owned by CSSIP (49 per cent), University of Queensland (18 per cent) and the inventors (33 per cent).[7]

GroundProbe has been the recipient of several awards including the 2003 Engineers Australia Excellence Award for Small Business, the 2004 Premier of Queensland Smart Award (Rising Star category), the Premier of Queensland Emerging Exporter Award in 2005, and the 2005 Queensland Telstra Small Business Award (AMP Business Category).

The direct commercialisation of publicly funded ICT R&D through the formation of GroundProbe is now contributing to Australia's economic performance.

- *Sales of goods and services, including through exports* — GroundProbe has reported that more than 30 devices have been sold since its inception and in FY2005 GroundProbe turned over $12.5 million. It is expected in FY2006 that revenues will double to $26 million, with strong sales both domestically and overseas.

- *Increased employment* — GroundProbe's employment of Australians has increased from only four persons in 2001 to more than 70 today. This increases household income and the welfare of Australians. GroundProbe expects to more than double its current employment levels by 2010. Moreover, GroundProbe estimates that employment by local suppliers of materials is estimated to have increased by 20-30 people to support GroundProbe's growth. Strong growth is projected over the next five years.

CRC for Tropical Plant Protection: developing 'super fodders'

The CRC for Tropical Plant Protection (CRC TPP) has developed new varieties of lucerne, stylo, cowpea and oats which have been labelled "super fodders" for their groundbreaking resistance to disease. The animal feed crop industry is worth around $1 billion per annum in Australia with an estimated US$10 billion market in East Asia. Prospects for Australian companies breaking into this lucrative market will be substantially boosted by increased production of fodder crops, particularly lucerne, following the commercialisation of CRC TPP-generated research. The commercialisation of CRC generated knowledge has been delivered by four different Australian seed production companies, and these disease resistant forages represent around 40 per cent of Australia's proprietary seed market.

The new varieties of disease and drought-resistant lucerne are expected to increase Australian production of this crop by 10 per cent (dryland production) to 30 per cent (for irrigated crops) over the next 5-10 years. The current shortfall of supply in the lucerne market makes this a potentially very valuable expansion. In addition to raising export income, lucerne is recognised to have beneficial environmental effects. In the grain crop industries, lucerne is being increasingly used as a rotation crop, valued for its soil improvement contributions, enhanced nutrition, improved drainage, disease break and erosion control.

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7 Gome, A., 2006, 'Mine of its Own', *BRW*, February 16-22, p.41

3.2.2 Benefits through application by industry or public sector end users of new or improved products or processes enabled by CRC generated knowledge

The application of CRC generated knowledge by means other than direct commercialisation is likely to be the channel whereby the greatest economic, environmental and social impacts from the CRC Programme are delivered. Application based impacts include specific impacts such as the:

- uptake of new knowledge, products or processes developed through CRCs that have improved end users' economic performance. Improved performance may involve things such as cost savings in production processes or increased output from a given level of inputs (i.e. efficiency gains);
- cases where CRC research has allowed risks to be avoided or mitigated against by end users of the research;
- uptake of new knowledge, products or processes developed through CRC research that has reduced pressures on the government budget in areas such as health, social security and defence spending;
- application of CRC research to reduce the environmental impacts associated with industry (including agricultural) production activity; and
- application of CRC research to beneficially impact on human health outcomes.

Following are examples of a number of economic and other impacts from CRCs that have been the result of end user knowledge application that has occurred by means other than direct commercialisation.

CRC for Advanced Composite Structures: maintaining Australia's stake in aerospace

The CRC for Advanced Composite Structure (CRC-ACS) was established in 1991, and is currently in its third round of funding. Significant amounts of CRC-ACS generated knowledge have been used by Hawker de Havilland (HdH), the designers and manufacturers of composites technology for Boeing. The CRC-ACS's expertise in the design of control surface devices was leveraged by HdH in its bid for a major contract to supply components for the Boeing 787 aircraft. The 787 will utilise an unprecedented proportion of composites, by weight, for a civil aircraft, and HdH has won Tier One supplier status for the first time, largely as a result of the CRC-ACS generated knowledge.

CRC-ACS technologies feature heavily in both the design and construction of these components, increasing efficiency and lowering costs. In the pre-production phase of the 787 components contract, HdH is using CRC-ACS expertise in process simulation and testing requirements. In addition, the long term process of knowledge transfer from the CRC to HdH continues. About half of the engineers currently working on the 787 program at HdH were trained at the CRC-ACS, and there is an ongoing program of secondment between the two organisations.

The value of CRC-ACS research, however, does not just accrue to Hawker de Havilland. The CRC-ACS estimates that the 787 project will employ 250 skilled workers in the manufacturing process, once production reaches full rate in 2013, and projects a further flow on of as many as 3300 jobs in the local economy. The aerospace industry is characterised by long lead times, high implementation costs, and a requirement for component supply companies to carry out significant amounts of R&D, which means that the maintenance of high quality, industry focused research is essential in order to keep Australian companies in the running to win major contracts.

Cotton Catchment Communities CRC: managing pests and improving water efficiency

The research outputs from the Cotton Catchment Communities CRC (and its predecessor the Australian Cotton CRC) have contributed to industry cost savings through several channels, including; improved and integrated pest management, development of more productive and disease or herbicide resistant seed stock, and more efficient water management methods.

The CRC's research into integrated pest management has yielded both economic and ecological benefits for industry, reducing pesticide use and minimising crop losses. The strategy has involved a multi-faceted approach, including the implementation of a "Best Management Practices" program attempting to; reduce farmers' use of endosulfan, aid the development of transgenic cotton varieties, and support the strategic use of different chemical groups to enable the suppression of pest populations at growing times without harming beneficial insects. At the same time, this framework has included strategies to avoid the build up of pest populations resistant to chemicals and transgenic crops. Weed management improvements generated by CRC research (with CSIRO playing a leading role) have included the development and adoption of Roundup Ready® cotton. This genetic management has also been applied in work aimed at controlling cotton diseases, through attempts to develop resistant strains.

One of the most significant impacts from the Cotton CRC's research output has been in the reduction of pesticide use. The CRC estimates that improved integrated pest management by industry has lead to a fall in chemical usage between 1999-00 and 2002-03 from approximately 6.5 kg per hectare to less than 2 kg per hectare. The CRC has played an important role in the process of replacing Bt (transgenic) and conventional cotton with the transgenic Bollgard II, where effective management of the release has prolonged the shelf life (and value) of this new variety from around 10 years to over 30 years – offering significant benefits from the capture of increased profits from this transgenic strain.[8]

The CRC also recommended strategies in response to a grower-identified problem with Silverleaf Whitefly in the Queensland central highlands in 2001-02. Through the introduction of management techniques, such as reduced use of broad spectrum insecticides and treatment with insect growth regulators, the CRC was instrumental in controlling the Whitefly population. This avoided a market discount for damaged

[8] BDA Group, 2006, *Economic Valuation of the Research and Development Outcomes of the Australian Cotton CRC*

cotton, thought to have been worth $2 million in 2004, as well as controlling the spread of the pest to surrounding producers. In addition to the economic benefits of lower pesticide use, this also has positive environmental impacts. While these are harder to quantify, the Cotton CRC estimates that over its life it has prevented 56 tonnes of active ingredient from reaching water ways.

The CRC's work in disease management has impacted significantly on the Australian cotton industry. Based on BDA modelling of the spread of fusarium wilt, it was estimated that CRC efforts resulted in a slowing of the disease by five years. Fusarium wilt is one of the most damaging diseases affecting cash crops around the world, and in addition to damaging cotton itself, the detection of the disease in export goods has led to quarantine concerns about Australian cotton. In 2004, concerns about the presence of fusarium in Australian cotton seed destined for California did not lead to suspension of export – and a net loss of $4.4 million – because the Cotton CRC enabled a quick response to show that Australia's existing sanitising practices were sufficient.

The CRC has also generated industry benefits through its water management initiatives, including the monitoring of water use patterns on cotton farms, and the development of best practice standards for water metering and irrigation scheduling. The Australian Cotton CRC in 1999 won its bid to conduct the R&D activities underpinning the Queensland State Government's Rural Water Use Efficiency Initiative. The impacts of these management improvements have been a saving in irrigation water use of over 67,000 megalitres a year. This has multiple benefits, including lower economic costs to growers, both of water entitlements and of pumping, as well as long term gains from a reduction in deep draining and slowing of future salinisation.

CRC for Welded Structures: cost reductions for industry

The CRC for Welded Structures (CRC-WS) operated for seven years between 1999 and 2006. The CRC-WS, in a joint committee with the Welding Technology Institute of Australia (WTIA) and industry partners, launched a project applying the CRC's In-Situ Laser Surfacing technology at the TXU Torrens Island power station in South Australia in 2004. This trial centre was developed in conjunction with eleven power stations from around Australia, including several members of WTIA's SMART Power Generation industry group. The laser surfacing technology is used to repair steam engine turbine blades on-site. These blades suffer wear from water droplets in the steam, and previously, cleaning them has been a costly process including removal, transport, cleaning and re-installation.

The WTIA notes that industry stakeholders have been concerned about the downtime cost of this maintenance to power stations, both in direct costs and in lost revenues. The Victorian Centre for Energy and Greenhouse Technology reports that revenue loss from cleaning turbine blades is $250,000 per turbine per day, while the WTIA has estimated that the use of the CRC developed technologies could save $10 million in maintenance over the lifetime of an average power station. The technologies developed at the CRC-WS also have potential application in gas turbines, boilers,

impellers, and hydroelectric turbines, and thereby have the potential to increase efficiency across a range of industry sectors.[9]

Australian Sheep Industry CRC: parasite management and precision production

The Australian Sheep Industry CRC provides research and education to producers of both wool and meat. Products developed by the CRC include the WormBoss system of internal parasite management, and the "e-sheep" precision production system.

The e-sheep system is based on a concept of individual animal management, and increases productivity and profit through faster rates of flock gain and more effective use of land and labour resources. The "precision sheep production" utilises a semi-automated database of performance data using the CRC's decision support software and direct links to automated sorting and management inputs. The e-sheep tool involves the use of knowledge about individual sheep to make targeted decisions about management of portions of the flock. While such individual management is costly and difficult to implement manually, the CRC's development of electronic systems using tags, readers, and recording and measurement devices make it viable in a commercial or stud flock. The CRC notes that quantitative measurement of the costs and benefits of the e-sheep system is difficult at this early stage, but points to small scale trials – on farms run by either private operators or research organisations – which return very positive results. The CRC suggests that approximately 600 000 sheep in Australia are tagged, enabling semi-automated data collection, with 55 per cent of these monitored for weight and around 70 per cent for fleece data. Based on user feedback, the CRC calculates that the value of reduced labour costs from these trials of the e-sheep system lead to net benefits from the use of the e-sheep system of approximately $4.40 per animal for fine wool Merinos, and $1.60 per animal for dual purpose wool/meat Merinos.

The CRC's WormBoss system for managing internal parasites has been developed in conjunction with Australian Wool Innovation. WormBoss represents a national body of knowledge about sheep worms. Its four general management guidelines to producers are:

- monitoring of worm populations using egg counts to detect infestations early;
- regularly test a property's drench resistance, to ascertain which drenches are suitable;
- maximising use of non-chemical strategies; and
- maintaining advisory centres, which can be approached for professional recommendations.

[9] CRC-WS, *Annual Report 2004-05*; http://csiro.au/csiro/content/standard/ps190,,.html#1; http://www.wtia.com.au/ozweld/pdf_registrations

WormBoss was launched in March 2005 with industry adoption in 2006 estimated at 14 per cent. Industry uptake is expected to grow to around 42 per cent by 2010.[10]

One element of the WormBoss system is the development of tests for drench resistance as well as diagnostic tests and genetic research into worm resistant sheep. While the current recommendation suggests worm egg counts are the best method of identifying internal parasites in a flock population, the CRC has developed a new diagnostic test for the *Haemonchus contortus* worm, which is a particularly important problem in areas of summer rainfall, when it can result in 5 to 10 per cent mortality rates. The new test, which can detect an increase in worm activity 7-10 days earlier than existing laboratory tests, retails cheaply, and can be used in the paddock for an immediate result. This test is a valuable tool in the management of internal parasites, with an estimated 5 per cent adoption rate in 2006 that is expected to increase to 24 per cent by 2010.

CAST CRC: delivering production cost reductions

The CRC for Alloy Solidification Technology, established in 1993, and its two subsequent forms (collectively known as CAST) provides research in light metals product design and processes to Australian manufacturers. Its creation of product and process technologies is complemented by the development of support for licensees and a strong emphasis on technology transfer. The CRC aims to engage companies across the entire metals value chain during all phases of technology development and deployment. Technological advances generated by CAST knowledge have helped companies increase their global competitiveness through achievement of production cost reductions, which the CRC calculates (on the basis of industry quantifications) to have been around $15.1 million over the past three years.

These savings have come from technologies such as the CAST-repair procedure, which uses fountains to cool line repairs on die casting dies, increasing die life, reducing maintenance costs, and raising productivity. This concept has been implemented by Nissan Casting Australia. Nissan, along with the Ford Motor Company Australia, have also made use of CAST expertise in the reduction of cycle times on high pressure die casting, again increasing productivity. This knowledge, along with other know-how relating to die design, has been transferred to the CRC's industry association partner, the Australian Die Casting Association.

CAST research has also helped the bauxite, alumina and primary aluminium supplier Comalco in reducing costs, through its development of techniques for optimising strontium additions in aluminium alloys, and for the refinement of grain in foundry alloys and in direct chill casting.

CRC for Sustainable Aquaculture of Finfish: improving farming processes of Southern bluefin tuna

The CRC for Sustainable Aquaculture of Finfish (Aquafin CRC) is a joint venture between research institutions, universities, industry groups, producers, and the Fisheries Research and Development Corporation (FRDC). Its main focus is on

[10] http://www.wormboss.com.au/LivePage.aspx?pageId=371

Atlantic salmon and Southern bluefish tuna (SBT). The commercial farming of tuna is the largest farmed seafood sector in Australia, with exports reaching $300 million and almost 8500 tonnes in 2002. All ranching occurs in a small region offshore of Port Lincoln, South Australia, where the industry developed following the decline of the wild fishery that occurred in response to international concerns about the sustainability of tuna fishing. Today, tuna fishers use aquaculture techniques to add value to wild catches. The tuna are found, seined and transferred between nets to specialised tow pontoons, then towed back to the Port Lincoln farm areas. Once at the farm sites, the tuna are swum into farm pontoons, where they are fed with fresh local pilchards or frozen blocks of bait fish.

These advances have resulted in a recovering SBT wild stock, currently estimated to be at about replacement yield. Research to stabilise spawning and farm transfer numbers, to increase control of fish growth rates and reduce mortality has played a significant role in the emergence and maintenance of a reliable, high quality farmed tuna industry. Research at the Aquafin CRC focuses on production, health, value-adding, and environmental aspects of tuna aquaculture, including improvements to husbandry techniques and feeding, which enhances fish health and product quality.

In 2005, the CRC collated data about the nutritional composition and quality of baitfish, and impacts on the performance of farmed SBT. This database was released as the Formubait© tool, allowing farmers to adjust tuna feeds to maximise performance and cost effectiveness. The choice of baitfish is dependent on a range of varying factors, including species, seasonal availability and price, and the Formubait© tool generates net benefits from feed cost reductions and improved growth.

The Aquafin CRC project to maximise quality control of SBT has involved the tracking of fish to the Japanese market-place, using both objective measures and sensory analysis to develop assessment scales which can be used by Australian producers exporting to Japan. CRC research found that vitamin fortified pellet diets were an important factor in reducing browning in sashimi grade tuna meat. This is a significant finding, as the current Australian industry practice is to not use pelleted feed. These feeding methods could lead to price premium gains, particularly for farmers exporting fresh chilled product. While there has been good industry uptake of these findings, the CRC notes that it is difficult to attribute any positive price effects directly to the research.

eWater CRC: reducing water infrastructure costs while maintaining quality

The current eWater CRC was derived from two previous CRCs, the CRC for Catchment Hydrology and the CRC for Freshwater Ecology. The CRC aims to build and support decision systems and models for water cycle management in urban and rural catchments. Through the integration of water quantity and quality measures, and the approaches of stream ecology and economics, the CRC develops and applies products improving water management. One of the most widely adopted CRC for Catchment Hydrology technologies has been the MUSIC urban stormwater modelling product, which has resulted in reductions of up to 50 per cent in infrastructure works costs around the country. The MUSIC software provides urban stormwater planners and managers with modelled management scenarios, resulting in significant savings on capital works, whilst still satisfying water quality criteria.

Currently, Melbourne Water is using MUSIC to plan future works and assess land development proposals, and to design stormwater treatment strategies for new and existing drainage schemes. Brisbane City Council uses MUSIC for urban catchment planning, and to design new stormwater treatment measures in Brisbane. The CRC's Catchment Management Support System software was designed to enable catchment stakeholders to improve land and catchment management strategies.

Decision-support tools based on CRC research have been used in the development of management strategies in the Great Barrier Reef, Port Phillip Bay, and Moreton Bay. They will underpin implementation of the Commonwealth Coastal Catchments Initiative, as well as any likely implementation of UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities.[11]

CRC for Sensor Signal and Information Processing: Reduction of environmental impacts of industry and agriculture through high-tech control systems

The CRC for Sensor Signal and Information Processing (CSSIP) Total Channel Control technology, continues to be applied in the operation control of irrigation systems in northern Victoria. The CRC developed technology was commercialised by Rubicon Systems Ltd, into the company's flagship product, the FlumeGate. It controls and measures water flows, enabling real time monitoring through radio communication. This continuous control of the distribution of water across the network has improved the reliability and accuracy of water provision to customers, reducing losses.

Rubicon believes that this technology, by increasing distribution efficiency from 65 percent to 90 per cent, will save a minimum of 350 000 megalitres per year in the state.

Victoria diverts around 5500 gigalitres of water a year for irrigation; this is 77 per cent of the state's water usage. Irrigated areas produces 30 per cent of the State's agricultural export income from 3 per cent of its land. The potential savings from the new control system therefore provide both economic and ecological benefits to the State as a whole and to agricultural water users.[12]

CRC for Enterprise Distributed Systems Technology: Health IT software

The CRC for Enterprise Distributed Systems Technology developed XML interoperative software which has a wide range of potential applications across the health, public services and defence sectors. In 2005, the HealthConnect project was trialled in Queensland using CRC-developed technology. Ultimately, this is planned to expand into a national health information system, overseen by the National E-Health Authority (NEHTA). The development of a health records network using interoperable systems, promises significant improvements in communication between health professionals and organizations, particularly in the areas of chronic disease management.

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11 DEST, 2003, *Evaluation of the CRC Programme*; http://www.catchment.crc.org.au; http://www.ewatercrc.com.au

12 CSSIP, *2004-05 Annual Report;* http://www.provincialvictoria.vic.gov.au

Extensia Solutions is a CRC spin-off whose major product, the RecordPoint data management tool, uses the Pegamento middleware technology developed at the CRC. It is expected to be used by health care organisations to improve electronic health records management, access and security. Pegamento allows organisations using different web services to connect with each other, enabling modular and open systems that are not tied to one technology. Additionally, the DSTC's Elvin technology (which limits message access to authorized recipients) increases security in data management architectures. The enterprise architecture middleware technology developed by the DSTC has the potential to improve quality of service and reduce costs, delivering better patient outcomes in the national health system in the health, social services, and defence sectors.

Other applications for CRC's products include the publicly available XML Metadata product, intended as an open source tool for the management of digitized collections of Indigenous cultural material. CRC's Pegamento project contributed in 2004 to OASIS legalXML e-contracts TC standardisation, leveraging research in the expression of contract semantics, i.e. Business Contracts Language Specification. OASIS (Organization for the Advancement of Structured Information Standards) is a not-for-profit, international consortium that drives the development, convergence, and adoption of e-business standards. The consortium produces standards for security, e-business, and standardisation efforts in the public sector and for application-specific markets.[13]

3.2.3 Non-market benefits from application of CRC generated knowledge

In addition to examples of CRC knowledge application where a "market" value can be determined, application of CRC knowledge has also often generated benefits that are very difficult to attach a short-term "market" value to. Examples of some of these difficult to "value" impacts include:

- The CRC for Tropical Savannas Management's research is focused on increasing knowledge of sustainable, wholistic management practices such as the restoration of traditional burning patterns. The incorporation of local knowledge, both Indigenous and non-Indigenous, into resource management strategies has both environmental and social benefits, especially through the CRC's programs which transfer this on country knowledge and training from older to younger people. Initiatives such as the West Arnhem Land Fire Abatement project, and the Dugong and Marine Turtle project provide employment opportunities for remote Indigenous communities, as well as delivering better environmental monitoring and management.

- The Desert Knowledge CRC aims, through its core projects, to encourage self-reliant regional economic development at the same time as acknowledging the cultural value of desert life. The CRC report on "Population and Mobility in the Town Camps of Alice Springs" was conducted by Indigenous researchers in local Aboriginal languages. Many of these researchers have subsequently been involved

[13] CRC for Enterprise Distributed Systems Technology, *Annual Report 2004-05*; http://www.oasis-open.org

in a local eye health project, and in conducting the census in the town camps. In addition to directly increasing skills, employment and information, this has encouraged the valuing of Indigenous knowledge, language and culture.

- The Vision CRC's research has contributed not only to technological advances in treating avoidable blindness, but in improving delivery methods and policy strategies. Impaired vision is estimated to affect around 480 000 Australians, with Aboriginal populations suffering around ten times the levels of blindness as the rest of the community. One of the programs to which Vision CRC research contributes is the VisionCare NSW, which delivers over 80 000 pairs of spectacles a year to low income earners in NSW.

- The CRC for Antarctic Climate & Ecosystems's sea ice modelling has enabled better understanding of the implications of climate variability and its impact on sea levels and biodiversity, including possible links between Antarctic and Southern Ocean processes and rainfall on the Australian mainland. Such knowledge is likely to inform future policy decisions on, for example, shipping and fishing regulation. Given the topical and political nature of climate change, robust scientific research into these areas is of national importance.

- The CRC for Plant-based Management of Dryland Salinity has a Salinity Policy project group whose focus is on policy mechanism choice and design, and the design of institutions to deal with dryland salinity. This group's main research impact is to increase the options for stakeholders in managing salinity. While there are substantial economic implications of such research – which may be expected to inform national salinity policy, currently with a budget of around $200 million per year – the main value of this knowledge is in increasing the options for all stakeholders in managing salinity.

- The Invasive Animals CRC provides knowledge about Australian flora and fauna which have evolved in geographic isolation. For most issues concerning invasive animals, scientists cannot simply leverage overseas research; rather, there is a need for the development of local knowledge to apply to local problems. The value of this creation and maintenance of a "critical mass" of research and researchers, therefore, goes beyond the one-off economic impacts of any invasive animal management strategies it may provide. The Vertebrate Biocontrol CRC (a forerunner to the Invasive Animals CRC) contributed substantially to the development of the "Western Shield" program in Western Australia, widely acknowledged as one of the best conservation programs in the world[14]. Western Shield involves baiting an area about three times the size of Tasmania for foxes, four times a year. Western Shield has brought back populations of the tammar wallaby, the quenda and the woylie in the wild to the extent that they have been taken off the endangered species lists in Western Australia. The program also brought back the WA animal symbol, the numbat, from the point of extinction. The fact that it is not possible to place an economic value on such achievements in no way suggests that such outcomes are not valuable.

[14] For instance, Western Shield won the prestigious Banksia Award for Conservation in 1998

3.3 Benefits from access to international knowledge networks

Australia accounts for less than 1 per cent of the global economy and in relation to research output produces around 2 per cent of the world's scientific literature. For Australia it is therefore critical that there are strong pathways for accessing internationally generated knowledge. The conduct of high quality research in Australia is generally essential for Australia to gain a seat at the international R&D table, which in turn brings Australia early access to new internationally generated knowledge. Specific examples of benefits CRCs may deliver in this area include:

- international researchers coming to work in Australia on CRC research projects, bringing with them valuable skills, the cost of whose development has been born overseas;
- participation by CRCs in international technical standards setting bodies that results in technical standards suited to Australian market needs;
- the total value of research being conducted within international research partnerships that CRC researchers participate in – Australia is in effect "buying" access to the total value of the partnership research program; and
- international industry partnerships or trade relationships that have been facilitated by CRC researchers participating in international projects or conferences.

Following are examples of some of these types of benefits that the CRC Programme has been delivering.

CRC for Sustainable Tourism: participating in global standards setting

The CRC for Sustainable Tourism's core focus is on the production of "knowledge products", that is, the conversion of research outputs into tools which can be used by individual tourist businesses and destinations. Its industry knowledge products include networks, models, evaluation tools, and best practice frameworks which are intended to aid tourism operators assess their performance, and improve both the economic and the ecological bottom lines.

The CRC's *Green Globe* accreditation program is a global certification and improvement system helping businesses in the tourism industry to reach sustainability. Its benchmarks include performance standards for companies, communities, ecotourism operations, in precincts, and in design and construction. The best practice standards developed by the CRC in each of these areas address major environmental issues, including over-use of water resources, waste production, maintenance of biodiversity, and socially responsible establishment of tourism. In 2005-06, the *Green Globe* program had over 300 benchmarked and certified customers around the world. The CRC has also produced *Earthcheck*, a set of key indicators for operators, destinations, infrastructure and ecotourism specific businesses which enables the quantitative evaluation of an enterprise's environmental sustainability. The *Earthcheck* tool is used by the Green Globe accreditation program.

The global nature of such standards is an essential part of how and why they can work. The CRC has used its expertise in tourism and hospitality planning, design, and management to establish the APEC International Centre for Sustainable Tourism (AICST), an international enterprise building relationships between governments, tourism organisations, education institutions, and researchers in the 21 APEC economies. Such worldwide communication networks are crucial to the development of reliable standards of environmentally and socially sustainable tourism, and will help to add value to operations while ensuring that they can be maintained in the long term.

CRC for Beef Genetic Technologies: Facilitating trade partnerships through long term collaboration from breeding to table

The CRC for Beef Genetic Technologies is a collaboration between research organisations in Australia, New Zealand, the US, and Korea. Korea is regarded as one of the most important export markets for Australian beef, and the development of beef gene technologies to produce meat with the characteristics preferred by Korean consumers is expected to significantly add value to the Australian industry. The development of meat eating quality standards and gradings, as well as palatability prediction models allowing targeting of meat characteristics to particular international market tastes, has been a key direction for the CRC's research.

The strong links with Korea have undoubtedly opened up Australian beef producers' knowledge about, and access to, this growing market. These links have been strengthened thanks to the professional relationship maintained with a CRC graduate that has gone on to work at the Korean National Livestock Research Institute. This CRC graduate is currently based in Korea, and is a key collaborating researcher with the CRC's High Quality Beef for Global Consumers program. The Rural Development Administration (RDA) branch of the Korean Livestock Research Institute has contributed $3.61 million in kind to the CRC program, making it an important supporting partner. This long running collaborative partnership between Australian and Korean researchers has meant gains for beef producers, consumers and scientists in both countries. The development and maintenance of relationships such as this is expected to widen the reach of benefits generated by the application of CRC research.

CRC for Integrated Engineering Asset Management: Facilitating international knowledge exchange

The CRC for Integrated Engineering Asset Management (CIEAM) conducts industry-directed R&D, education and commercialisation in an integrated approach to life-cycle physical asset management. CIEAM's vision is to develop and implement processes and programs that optimise asset management systems and improve the competitiveness of Australian industry.

CIEAM is playing a leading role in linking Australia into global engineering asset management knowledge networks. A key CIEAM initiative has been the establishment of the first World Congress on Engineering Asset Management (WCEAM), with a conference held in Queensland in June 2006.

The first WCEAM was a success as evidenced by the participation of 381 delegates, of which 94 were from overseas, representing the following countries: Austria, Bangladesh, Belgium, Cameroon, Canada, China, Finland, Germany, India, Japan, Korea, Malaysia, New Zealand, Poland, Portugal, Singapore, South Africa, South Korea, Sweden, Switzerland, Taiwan, The Netherlands, UK, USA.

A total of 162 papers were presented at the 1st WCEAM through 60 sessions which included industry forums and workshops. This conference provided access for Australian researchers and industry to leading global thinking in the engineering asset management field. In the absence of Australia public ICT R&D funding for CIEAM, this access would not have occurred.

CIEAM has also started a new network of peak bodies in Australia – the Australian Asset Management Collaborative Group.

3.4 Benefits from skills formation

The skills formation that occurs within CRCs, particularly in relation to research student training, delivers a number of economic benefits for Australia such as:

- benefits through the development of highly skilled post-graduates that build a critical mass of skills in a region that either attracts multinational companies to invest in the location or helps retain existing business activity levels;

- benefits through the development of highly skilled post-graduates who then work in industry and allow industry to be smart adopters and adapters of internationally generated technology/knowledge; and

- benefits through industry and academic researchers interacting and increasing their skills, and hence their future productivity, via this interaction. Collaboration across sectors and disciplines encourages researchers to develop an understanding of both research provider and end user perspectives and to maintain focus on the active planning for and management of pathways to application.

The examples below highlight some of the skills formation benefits that CRCs deliver.

The CRC for Viticulture: skilling up an industry for technological innovation

The CRC for Viticulture was intended from the outset to generate knowledge and intellectual property which could be captured via increased growth and profitability of the Australian wine industry. The CRC, emphasised the entrenchment of quality management throughout the industry, particularly through the development and dissemination of tools for planning and monitoring grape production. For example, the CRC's PAM AusVit computerised vineyard management system allows growers to record, monitor and analyse vine growth and seasonal performance, reducing the risk of crop loss and minimising chemical use. The AusVit product is administered by the CRC, and was developed and is supported based on CRC research.

In line with its focus on dispersed industry users, the CRC developed a range of educational material. It has produced vocational skills brochures for use by industry, including small growers. CRC research has also been compiled into VineLOGIC, a vine growth and yield simulation package currently in use in viticulture courses in schools, TAFEs, colleges and universities. In addition, the Centre provides "Research to Practice Training" in six areas. In 2004-05, the number of licensed training providers increased to 22. Attendance at the training workshops increased to 1300 in 2004-05 (up from 429 in 2003-04). In response to industry group requests, the CRC also developed vine sampling techniques for growers based on existing CRC research.[15]

CRC for Tropical Plant Protection

The CRC for Tropical Plant Protection, with the University of Queensland and the Queensland DPI&F, in 2005 launched a Graduate Certificate in Plant Protection on CD-ROM. This is intended to improve access to plant protection education to students who work in agricultural areas, for whom this education is particularly important. In recent years, plant industries have overtaken traditional agriculture leaders, and are now Australia's most valuable agricultural industry. However, the CRC identified a lack of capacity in the plant protection professions. The provision of remote access training is one means of skilling up this increasingly important industry. To this end, in 2005-06 the CRC developed a Graduate Diploma CD-ROM program.

CRC for Predictive Mineral Discovery: collaboration for better predictive exploration

The CRC for Predictive Mineral Discovery (pmd*CRC) develops advanced technologies for data acquisition, mapping and visualisation, and predictive modelling of potential deposit sites. Such surveys are crucial for mining companies, allowing targeted digging. Perhaps the most innovative move by the pmd*CRC has been not what it does, but the way it does it. With predictive exploration technology essential for all mining companies, the CRC partnership has enabled construction of models which can be used by all parties – reducing the costs to any one of the partners. The pmd*CRC has calculated that its construction of an integrated 3-D model of the Eastern Yilgarn goldfields in WA, funded by three major sponsoring companies, resulted in substantial net cost savings; this was possible because the CRC facilitated collaboration and information sharing. As Dr Scott Halley, then of the gold mining company Placer Dome Asia Pacific Limited[16], noted,

> 'The researchers from the pmd*CRC were able to do what no single company would be able to do on its own. Companies are usually protective of the competitive value of their in-house data, so they only end up with a detailed knowledge of their own patch of turf.'[17]

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15 CRC for Viticulture, *Annual Report 2004-05*; http://www.crcv.com.au; DEST, 2003, *Evaluation of the CRC Programme*

16 Placer Dome was recently acquired by Barrick Gold Corporation

17 Dr Scott Halley, from a supporting letter for CRCA Excellence in Innovation Awards 2005

As well as avoiding costly replication of model development, research carried out by the pmd*CRC has resulted in better surveys of mineral fields in Tasmania and in the Stawell corridor in northern Victoria. Because the pmd*CRC's advantage lies in producing the most comprehensive and coherent data sets and models, it can focus on collecting and managing this information, which adds value to the knowledge of individual companies.

Taking the concept of knowledge specialists a bit further, the pmd*CRC has initiated a program of 'embedded researchers,' where a CRC researcher works on-site with all parties to the exploration process, including core loggers, exploration geologists and target generators. The concept enables exploration specialists on the ground to work closely with researchers, providing two way benefits: the researcher gains a pragmatic and end-user focussed perspective, and workers in the field are able to access cutting edge knowledge and expertise.

CHAPTER 4
Approach to CRC Programme impact assessment

4.1 Overview of approach to impact assessment

In order to quantify the economic impact of the CRC Programme since its inception, we must consider how economic outcomes in Australia would have been different in the absence of the CRC Programme and its activities.

To create such a "without CRC Programme" scenario for economic performance, it is firstly necessary to reallocate the Government funding that has gone into the CRC Programme to some other use – in this study we assume the funding is used to reduce taxation. In this way the "expenditure" effects of the CRC Programme can be accounted for. The net "expenditure" effects of the Programme, which show the difference in initial economic outcomes associated with spending CRC Programme funding within the research sector of the economy rather than reducing taxation, represent the true initial cost of the CRC Programme to taxpayers.

BOX 4.1: ESTABLISHING THE TRUE COST TO TAXPAYERS OF THE CRC PROGRAMME

A crucial point in relation to the true "cost" to taxpayers of funding the CRC Programme is that this is not simply equivalent to the Government funding for the Programme. This is because the money expended in CRCs is not removed from the economy, but rather is spent within the economy. The true "cost" of the funding the CRC Programme is therefore the difference in economic performance between the following two scenarios:

- The "with CRC Programme" case – in this case the Government uses taxpayer funds to invest in CRCs which in turn expend this funding within the economy in the public services sector of the economy. The taxation has some negative effects on real consumption while the expenditure generates some offsetting positive effects on real consumption; and
- The "without CRC Programme" case – in this case it is assumed that the Government reduces taxation by an amount equivalent to CRC Programme funding and no longer provides funding to CRCs which in turn means this money is no longer spent within the public services sector of the economy. The taxation reduction has some positive effects on real consumption while the spending reduction results in some offsetting negative effects on real consumption.

The Centre of Policy Studies MMRF model is ideally suited to comparing the with and without CRC Programme cases to determine the true "cost" to taxpayers (in terms of levels of real consumption) of funding the CRC Programme.

Through adoption of the above approach, the true "cost" to taxpayers of Government funding the CRC Programme since its foundation can be considered. The key point here is that the simple expenditure effects associated with CRCs are taken into account in the overall assessment of the economic impacts of the Programme and this will to a degree offset the direct cost to taxpayers of the Government funding provided to CRCs.

Once expenditure effects are accounted for, it is then necessary to identify any discrete measurable economic outcomes (delivered through the benefit channels outlined in Chapter 3) that are attributable to the application of Government funds within the CRC Programme and to remove these impacts from the economy in the "without CRC Programme" scenario for economic performance. In this way the "investment" effects of applying resources to the CRC Programme can be accounted for.

By adopting the above approach, this study aims to measure both the simple "expenditure" effects of the CRC Programme and the more complex "investment" effects associated with CRCs' activities. Through removal of these impacts from the "without CRC Programme" scenario within the CoPS economic model, it will then be possible to establish whether the Australian community is actually better off (in terms of key economic indicators such as GDP, Consumption and Investment) under the "with CRC Programme" scenario than it would have been under the "without CRC Programme" scenario.

Expenditure effects of the CRC Programme

CoPS has modelled the national expenditure effects of CRC Programme funding versus the alternative "without CRC Programme" scenario that would reallocate this money towards tax reductions.

In dealing with expenditure effects, it is assumed that in the absence of the CRC Programme all non-CRC Programme resources that have gone into CRCs would have been expended in the same way as they were under the "with CRC Programme"

scenario, i.e. these resources provided by CRC participants would still have been directed towards research activities and would have had the same expenditure effects as occurred under the "with CRC Programme" scenario. In the absence of conclusive evidence in relation as to whether the CRC Programme "crowds in" or "crowds out" other research funding (no compelling evidence either way has been identified to date), this is the only reasonable assumption that can be adopted.

The assumption that, other than the Programme funds provided by the Government, the resources allocated to the CRC Programme would still have been directed towards research activities, does have important implications for the attribution of "investment" effects to the CRC Programme funding. As is explained in detail in relation to the different levels of impact assessment modelling conducted in this study (Section 4.2), the issue of the extent to which CRC outcomes are attributable to the CRC Programme funding is important and has been transparently addressed within the impact assessment.

Investment effects of the CRC Programme

The investment effects of the CRC Programme include all of the benefits that are attributable to CRC Programme funding that arise from the application of CRC generated knowledge and intellectual property, enhanced access to international research networks, and through skills formation.

These benefits from CRCs are often subject to considerable time lags between the commencement of a CRC and the delivery of measurable, quantifiable economic impacts. The 2005 CRC Association economic impact study, for instance, found that the average lag for impacts counted under the strict inclusion criteria used in that study was nine years. This implies that the investment effects from CRCs must be carefully allocated to the appropriate time period if their quantitative value is to be accurately captured.

4.2 Approach to developing modelling scenarios

This study includes quantitative assessment of the wide range of benefits from the CRC Programme in Australia out to the year 2009-10 using modelling of the impacts from the Programme in Australia by the Centre of Policy Studies (which conducted the economic modelling in the 2005 CRC Association Economic Impact Study). CRCs funded through Rounds One to Eight of the Programme, as well as new from existing CRCs funded in Round Nine of the Programme are the focus of this study (a change from the 2005 study which focused only on CRCs funded in Rounds One to Seven of the Programme).

A four level hierarchy of economic impacts have been considered within this report. The first three levels have been used as the basis for three economic impact modelling scenarios while the fourth level deals with some of the contingent benefits from the CRC Programme. Contingent benefits are benefits that carry an expected value but where that value will only be actualised if a certain set of conditions/events occur in the future. Contingent benefits are described in qualitative and quantitative terms in this study but have not been included within the economic modelling scenarios due to

difficulties associated with ascribing such benefits to a particular year and the fact that the delivery of such benefits is inherently uncertain.

Criteria used for inclusion of quantified benefits within the three levels of economic impact modelling are clearly articulated below. It is important to note that in all three impact modelling levels the end user "adoption costs" that have been incurred in relation to the delivery of benefits from CRC generated knowledge are explicitly taken into account in this study. It is only the benefits delivered net of such adoption costs that are counted within the impact modelling.

Level One impact modelling: Establishing a minimum bound estimate of delivered CRC Programme benefits

The first level of economic impact modelling is undertaken with a view to providing an incontrovertible minimum bound quantification of the economic impacts of the CRC Programme. This level of the modelling is effectively an update of the 2005 economic impact study and uses the following strict criteria (which are the same as those used for the 2005 study) for inclusion of an economic impact from the CRC Programme:

- The benefit must be attributable to the activities of CRCs – benefits must have been unlikely to have occurred in the timeframe under consideration without the presence of the CRCs – i.e. if the CRC Programme funding had not been provided, the CRC participants operating in isolation would not have been likely to achieve the outcomes that resulted from their collaboration within the CRC structure;

- The benefit must be a delivered benefit, not an anticipated future benefit – quantification of expected future outcomes is an uncertain process and will always be open to differing opinions; and

- The benefits must be verified and quantified by the end beneficiaries of the CRC generated knowledge, rather than by CRCs as the generator of the knowledge – for instance in the case of improved productivity through application of CRC technology in an existing industry, it should be the industry users of the CRC technology, not the technology generators that quantify the impact. It is understood that in cases where there may be many small end beneficiaries of research, collection of data via industry peak bodies or through the sampling of a subset of beneficiaries may be the most practical means for the provision of end user verification of impacts.

The advantage of using such a strict set of inclusion criteria in the level one economic modelling is that the eventual measured impact of the CRC Programme can be taken to be an incontrovertible minimum-bound estimate of impact. All "costs" related to the funding of the CRC Programme are accounted for (via an assumption that CRC Programme funding would otherwise have been returned to taxpayers as a tax reduction) while only identified and quantified benefits from CRCs are included in the assessment. It is important to note that in addition to the "costs" to taxpayers of Programme funding, the "costs" incurred by end users in applying CRC generated knowledge/intellectual property are also be factored into the economic impact assessment. This means that while the impact of the CRC Programme could not be

lower than assessed it could actually be significantly higher given the prospects of either unidentified or (more importantly) unquantifiable benefits from CRCs not being included in the minimum-bound analysis.

One important methodological difference between the level one modelling conducted in this study and the economic impact modelling conducted in the 2005 study must be noted. The change places downward pressure on the quantified benefits of the CRC Programme within this study when compared to the 2005 study. Box 4.2 provides further detail on the impacts of changing the "without CRC" counter-factual assumption from the assumption used in the 2005 study.

BOX 4.2: KEY DIFFERENCE IN METHODOLOGY BETWEEN LEVEL ONE MODELLING IN THIS STUDY AND THE METHODOLOGY IN THE 2005 CRCA ECONOMIC IMPACT STUDY

The key methodological difference between the *Level One* modelling in this study and the approach used in the 2005 economic impact study is that in the "without CRC Programme" scenario it is now assumed that CRC Programme funding would have instead gone to income tax reductions rather than be reallocated to other Government expenditure (as was assumed in the 2005 study). This change in assumption means that the two studies outcomes are not directly comparable. This change in methodology was made in light of feedback on the 2005 study received from the Treasury Department and the Productivity Commission. These bodies expressed a preference for use of tax cuts (rather than alternative Government expenditure) as the default "counterfactual" use of Government funds when assessing the impacts of Government spending programs. This is the standard counterfactual that they use in assessing spending programs.

The change in counterfactual (which involves taxation being higher due to the CRC Programme being funded) assumption drags down the results in this study (relative to the 2005 study) for a number of reasons:

- Imposition of taxation acts to reduce incentives for investment.
- Transferring consumption from private consumption, 30 per cent of which goes to capital expenditure, to a highly labour intensive public consumption area such as R&D, acts overall to reduce the capital intensity of Australia's industry structure. This in turn puts downward pressure on GDP growth.
- Increasing income tax rates decreases disposable income, some of which would have been saved. A reduction in savings leads to a decrease in the current account balance via a decline in the trade account balance.

Due to the above factors, the overall effect of this important methodological change on the net results from the *Level One* modelling conducted in this study is to *reduce* the net beneficial impacts of the CRC Programme on GDP by around $450 million compared to the result that would have been found had the same methodology been applied in this study as was used in the 2005 economic impact study. Therefore, in comparing the results from the two studies, it is necessary to *add* approximately $450 million to the net impact found on GDP in this study if it is to be fairly compared to the results found in the 2005 study.

Aside from the above technical changes made in the modelling in this study when compared to the 2005 study, another important change in approach adopted in this study has been to extend the assessment of CRC Programme impacts beyond a focus on only establishing a minimum-bound of Programme impacts. To this end, in this study two additional levels of economic impact modelling have been undertaken. These impact assessment levels use broader sets of criteria for inclusion of impacts within the assessment than those used in the minimum-bound first level of the economic impact assessment. The inclusion criteria for the additional two levels of economic impact modelling are set out below.

Level Two impact modelling: "Attributed" delivered impacts from the CRC Programme

The level two impact assessment provides an extension of the 2005 study to include quantification of the delivered benefits from the Programme that were not quantified in the 2005 study due to "attribution" issues. Attribution issues arise in two forms. Firstly, in some cases a CRC is one of several important research drivers of an eventual outcome. It may be difficult to "attribute" the relative role of the CRC's research (compared to other research activities) in driving an outcome. Secondly, in some cases it is not clear how significant a role CRC Programme funding has played in driving the outcomes delivered by a CRC. For instance, in cases where the CRC participant's were already collaborating with one another prior to the CRC's formation, it may be difficult to determine whether the CRC funding has played any role (beyond incrementally increasing total research resources) in driving outcomes from the collaboration. In such cases it is possible that the allocation only of resources by the CRC participants may have generated similar positive results even in the absence of CRC Programme funding being provided.

In this study an attempt is made to resolve such attribution issues, whereas in the 2005 study when attribution was a concern no proportion of an impact was included in the study.

Level Three impact modelling: A realistic estimate of delivered and forthcoming non-contingent CRC Programme benefits

The level three assessment extends the 2005 study further to include quantification of forthcoming benefits expected from the Programme over the next five years. While forthcoming benefits are by their nature uncertain, due to the time lags involved in delivery of impacts from research, it was felt that it is important in this study to include some estimation of highly likely forthcoming benefits from CRCs. For a benefit to be included as forthcoming, the commencement of the benefit needed to be assessed as "imminent" – i.e. the technology has been demonstrated to work and the route to application is clear.

It is important to note that the level three impact modelling does not represent a comprehensive accounting of all of the non-contingent benefits delivered by the CRC Programme. This is because, within the time and information availability constraints that exist, not all benefits from CRCs have been able to be discretely identified and quantified in this study. The inability to capture and measure all benefits means that even the economic impact analysis conducted the level three impact modelling must be viewed as a partial rather than complete accounting of the non-contingent economic benefits of the CRC Programme. Nevertheless, the level three economic impact modelling scenario represents the "best estimate" of the non-contingent economic benefits delivered by the CRC Programme.

4.3 Additional benefits from the CRC Programme that are not included in the impact modelling

Two important types of benefits from the CRC Programme have not been included in any of the three levels of economic impact modelling conducted in this study. These are:

- cost savings to Government; and
- contingent benefits.

Cost savings to Government

Within the selection guidelines for the CRC Programme, cost savings delivered to Government alone do not provide a sufficient basis for demonstrating the economic impact of a prospective CRC. In keeping with this Programme selection approach, one benefit that was included in the 2005 CRC Association commissioned impact study has been excluded from the economic modelling in this study. The benefit excluded was in relation to the impact of the CRC for Asthma and Airways on corticosteroid prescribing patterns which has acted to reduce the call on Government PBS expenditure by around $6 million per annum.

A number of the "non-market" benefits delivered by CRCs (described in Section 3.2.3) will result in some longer term cost savings for Government. For instance, the CRC for Tropical Savannas Management's Dugong and Marine Turtle project, by providing employment opportunities for remote Indigenous communities will likely reduce the future call on Government funded health and welfare services. Such potential cost savings (which are still to be delivered and are to an extent contingent on other variables within the economic and social environment) have not been included in this economic impact assessment of the CRC Programme.

Contingent benefits

Contingent benefits primarily consist of cases where CRC research has reduced the risks of an economically negative event occurring, for instance bushfires and disease outbreaks, or where CRC research provides valuable options for action in the future if a given set of conditions come into place in the future. For instance, research into clean coal provides options for the future if carbon pricing signals are introduced.

Contingent benefits are, however, by their nature uncertain and it is not possible to "assign" these benefits to a particular year within an economic modelling scenario. For this reason, contingent benefits have not been included in any of the three levels of economic impact modelling conducted in this study. However, in order to provide a more complete picture of the impacts of the CRC Programme it was felt that some attempt should be made to capture benefits of this kind. A selection of these contingent benefits, while not modelled economically in the same way as results in the first three levels, are articulated in Section 5.4 of this study and the potential economic value associated with them considered.

4.4 Presentation of the economic impact assessment results

The economic impacts linked to each of the above described three levels of economic impact modelling are separately presented in Chapter Six. The levels are additive in nature – i.e. level two includes impacts included in level one plus level two impacts while level three includes impacts included in levels one, two and three.

The potential scale of contingent economic benefits being delivered by the CRC Programme is then separately considered in Section 6.4 of this study.

While the criteria for inclusion in the levels two and three economic impact modelling scenarios are broader than those for level one impacts (and when compared to the 2005 study), they are still robust and highly transparent. In borderline cases, the approach adopted as to whether benefits should be quantified and modelled has been to err on the conservative side. It is important to note that to be included within any level of the economic impact assessment, all impacts had to be verified and quantified by end-users of the CRC generated knowledge rather than by the producers of that knowledge.

CHAPTER 5
Details of economic modelling scenarios

5.1 "Minimum-bound" (level one) economic impact scenario inputs

The starting point for the development of the level one modelling scenario was to account for the expenditure effects of the CRC Programme funding between 1991 and 2005 over the 1991 to 2010 period. To this end, CRC Programme funding for the calendar years 1991 to 2005 was converted to constant 2005 dollars and then reallocated within the CoPS MMRF model from Commonwealth Government R&D expenditure to income tax cuts. In total, in constant 2005 dollar terms, this involved the reallocation of $2.33 billion from R&D expenditure to income tax cuts.

The second stage in the development of the level one modelling scenario was to include the "investment effects" of the CRC Programme that were included in the modelling undertaken in the 2005 CRC Association's economic impact study. As detailed in Appendix A.3.1, carry-over inputs from the 2005 CRC Programme impact study commissioned by the CRC Association have been included in the level one modelling in this study.

The third stage in the development of the level one modelling scenario was to include any additional impacts from the CRC Programme that have come to light since the conduct of the 2005 CRC Association study that meet the strict criteria for inclusion in the level one modelling scenario. In all, 11 additional impacts from the CRC Programme that meet the level one inclusion criteria have been identified and quantified.

Only brief descriptions of the additional impacts included in the modelling undertaken in this study are provided as industry end-users generally did not wish to have detailed information in relation to technology and commercial applications released into the public domain. Indeed, many only provided end impact quantification for this study on the proviso that no sensitive information would be published.

In addition to the events carried over from the 2005 study, 11 further events that meet the strict inclusion criteria for the level one impact modelling were identified in this study. These events are:

- CRC for Sensor Signals and Information Processing: $34 million sale in 2005 of spin-off software company Wedgetail Communications to foreign buyers.
- CRC for Advanced Composite Structures: Profit change in aircraft parts manufacturing due to CRC ACS developed technology lowering industry partner's cost base across various contracts by around $0.5 million per annum since 2001.
- CRC Mining: Output change in mining sector due to spin off company revenue averaging over $8 million per annum from 2005 onwards.
- CAST CRC: Output change in metals manufacturing sector due to additional export revenues of domestic companies based on CAST technology.
- CRC for Sensor Signals and Information Processing: $33 million per annum change in profit in mining sector from 2006 due to GroundProbe technology application allowing extension of a profitable mine's operating life.
- CRC for Australian Poultry Industries: Vaccine uptake related cost changed in poultry industry (confidential constraints were particularly high in this case).
- Predictive Minerals Discovery CRC: Direct cost savings totalling almost $14 million to date for mining exploration companies from 3D model development in WA, and application of numerical modelling targeting in Victoria.
- Australian Sheep Industry CRC: Application of RFID technology for sheep sorting has led to producer cost savings of almost $0.5 million to date.
- CRC for Viticulture: Change in revenue per hectare in wine production sector due to application of CRC developed selective harvesting techniques allowing for better grape grading/selection. Production value is increased by $1000 per hectare with uptake since 2005 of around 1600Ha.
- CRC for Viticulture: Change in retail value of wine due to average quality increase resulting from selective harvesting technique uptake. Retail value per hectare has increased by $55,000 (which equates to around $2.50 per bottle) with uptake since 2005 of around 1600Ha.
- CRC for Sustainable Aquaculture of Finfish: Cost savings for baitfish producers and southern bluefin tuna farmers, averaging over $3 million per annum, through application of CRC technology.

Table A.1 in Appendix A.3.1 sets out in detail the modelling scenario inputs that were developed following the aggregation of some of these specific impacts into overall effects on particular sectors and the conversion of impacts to 2005 dollars.

5.2 "Attributed delivered benefits" (level two) economic impact scenario inputs

The inputs included in level two of the economic impact modelling include all level one inputs. In addition, the level two scenario also includes nine specific impacts from CRCs where assignment of appropriate attribution levels was a significant issue. Estimates of the extent to which the impact could be attributed to CRC Programme funding have been made based on discussions with stakeholders and consideration of CRC Programme funding levels compared to other inputs contributing to an outcome occurring. The nine additional impacts included in the level two scenario are:

- Cotton Catchment Communities CRC: Change in profit in cotton growing sector due to extension of useful life of INGARD varietals. CRC Programme funding attributed 30 per cent credit for total CRC generated outcomes based on the relative contribution of Programme funding to total research costs within the CRC.

- Cotton Catchment Communities CRC: Cost change in cotton growing sector from application of CRC knowledge in areas of integrated pest management, weed management, disease management and water use efficiency. CRC Programme funding attributed 30 per cent credit for total CRC generated outcomes based on the relative contribution of Programme funding to total research costs.

- CRC for Beef Genetic Technologies: Change in value added in beef production sector due to application of Meat Standards Australia system. This involved research from multiple parties with value added increase per research dollar calculated in excess of $8 per $1 in research expenditure. Benefits attributed to CRC Programme funding based on dollar allocation ($27 million over 10 years) of funds to the contributing research.

- CRC for Beef Genetic Technologies: Net profit increase in feedlot sector from application of around 2.75 million doses to date of the CRC developed Bovine Respiratory Disease vaccine Bovillus MH (marketed through Intervet Australia Pty Ltd) in backgrounding feedlot cattle. An attribution rate to the CRC of 50 per cent has been applied to the net cost savings delivered.

- CRC for Advanced Composite Structures: Change in output in aircraft parts manufacturing due to CRC ACS contribution to partners securing multiple major export projects. Attribution rates to the CRC Programme funding range from 2 – 10 per cent depending on the specific situation relating to each contract.

- CRC for Cochlear Implant and Hearing Aid Innovation: Revenues generated by spin-off companies plus a small attribution of the gross output of major industry partner since 1996. CRC Programme funding has accounted for 4.5 per cent of total partner product development funding over that period.

- CRC for Forestry: Change in forestry profitability due to uptake of new seed varieties to which the CRC was a major (50 per cent minimum) contributor. These varieties allow 20 per cent less planting being required for a given output level. This equates to a $6000 per Ha cost saving with $3500 of this saving coming in year of planting. There has been 70 per cent uptake across 100 000 Ha per annum of new industry plantings.

- CRC for Viticulture: Change in costs in wine production across South West NSW, North West Victoria and North East SA due to reduced water use resulting from adoption of irrigation approaches partially (50 per cent) developed by CRC. There has been 26 per cent adoption of new approaches across regions totalling 47 135 Ha, with 5Ml/Ha average water use saving per annum occurring at average water costs of $55/Ml.

- Skills formation impacts: Gross output change due to labour productivity change resulting from CRC Programme funding increasing the production of research postgraduates that have gone on to employment in industry. Since 1991 there have been over 4000 research post-graduate degrees completed through CRCs. Given CRC Programme funding has represented approximately 25 per cent of total CRC resourcing, it is reasonable to suggest that the removal of that funding from the research system would have reduced the total number of post-graduate degree completions by around 1000 over the 1991 to 2006 period. Given that the wage premium for post-graduate degree holders when compared to bachelor degree holders is $20,000 per annum, that 80 per cent of the wage premium is attributable to the qualification not the individual and that half of total output on average is returned to labour, there is an output premium of around $32,000 per annum per research post-graduate in Australia.

Table A.2 in Appendix A.3.2 sets out in detail the modelling scenario inputs (additional to the level one inputs) that were developed following the aggregation of some of these specific impacts into overall effects on particular sectors, and the conversion of impacts to 2005 dollars.

5.3 "Best estimate of non-contingent benefits" (level three) economic impact scenario inputs

The inputs included in level three of the economic impact modelling include all level two inputs. In addition, the level three scenario also includes seven specific impacts from CRCs where benefits are either recently commenced or imminent (with the majority of benefits therefore still forthcoming) and/or where impact valuation had to be estimated from a small sample of end users. The seven additional impacts included in the level three scenario are:

- Australian Sheep Industry CRC: Net cost savings totalling $9 million between 2006 and 2010 from application of CRC developed Haemonchus Diagnostic Dipstick

- Australian Sheep Industry CRC: Net cost savings totalling $17 million between 2005 and 2010 from application of CRC developed and WormBoss products.

- CRC for Sustainable Tourism: Gross output increase of over $30 million for the tourism sector based on delivered and projected revenues from spin off companies between 1997-98 and 2007-08.

- CRC for Sustainable Tourism: Gross output increase of over $30 million for the tourism sector between 2005 and 2010 resulting from the use of Encore reports and VIC Kits.

- CRC for Sustainable Tourism: Cost savings generated between 2003 and 2010 through application of Green Globe standards since 2003. Based on a sample of end user impacts and known uptake rates, total net cost savings are estimated at over $80 million.

- CRC for Railway Engineering and Technologies: Impact on freight rail sector costs by extending ballast life and stability. New ballast standards have been accepted with uptake now imminent, with $9 million per annum in net cost savings expected.

- CAST CRC: Currently commencing cost savings for domestic companies based on use of new CAST technology. Cost savings are expected to total more than $55 million over the 2006 to 2010 period.

Table A.3 in Appendix A.3.3 sets out in detail the modelling scenario inputs (additional to the level one and level two inputs) that were developed following the aggregation of some of these specific impacts into overall effects on particular sectors, and the conversion of impacts to 2005 dollars.

5.4 Contingent benefits identified where some benefit quantification is available

A number of "contingent" benefits have been delivered by CRCs. Such benefits are not amenable to year by year economic impact modelling in the same way that the discrete delivered and forthcoming benefits assessed in the first three assessment levels of this study are. Examples of the some of the contingent benefits being delivered by CRCs and where some quantification of the scale of the benefit has been possible include:

- the role of the CRC for the Great Barrier Reef World Heritage Area in reducing the risk of economic damage to the tourism sector in the Great Barrier Reef catchment area;

- the role of the CRC for Coal in Sustainable Development in providing better options for action if carbon price signals are introduced in the future; and

- the role of the Australian Biosecurity CRC for Emerging Infectious Diseases in reducing the risk of economically costly disease outbreaks and in reducing the potential cost of such outbreaks if they do occur.

CRC for the Great Barrier Reef World Heritage Area

The role of the CRC for the Great Barrier Reef World Heritage Area in applying knowledge of the reef to mitigate against the risk of a serious environmentally negative event occurring in the Great Barrier Reef World Heritage Area (GBRWHA) may be given some economic valuation. An estimate of the value of the CRC's research in avoiding the costs of environmental degradation can be derived by considering the economic performance of the economically vital tourism sector in the region.

Under a "business as usual" scenario (based on projections set out in the 2003 Productivity Commission study *Industries in the GBR Catchment and Water Quality*), the tourism industry's output in the GBR catchment is projected to increase over the 2001 to 2020 period from a base level of $4228 million per annum in 2001 to $4878 million per annum in 2010 and to $6367 million per annum in 2020. These projections are based on an assumption that the GBR does not suffer significant environmental quality decline.

The recent introduction of a new zoning plan and a comprehensive water quality protection plan for the GBRWHA, based on data provided by the CRC has been important to the development of, are specifically targeted at preventing such environmental degradation of the GBR occurring. In the absence of these best practice environmental management policies, environmental quality may begin to suffer from 2012. Results of a 2006 study published by the Fondazione Eni Enrico Mattei, *Effects of GBR degradation on recreational demand: A contingent behaviour approach*, into the link between GBR quality and recreational demand suggest that 35 per cent of tourists who visit the GBRWHA would not do so if the quality of the GBR significantly declined. Given this, it can be inferred that a steady decline in tourism output in the region would occur as a result of "significant environmental decline" occurring. The CRC, in playing a role in reducing the risk of environmental decline, is thereby reducing the risk of economic damage occurring to the region's tourism sector.

CRC for Coal in Sustainable Development

In a 2006 assessment of the value of the CRC for Coal and Sustainable Development (CCSD) research program, *CCSD Value for Stakeholders: an economic assessment of CCSD research*, ACIL Tasman considered the present value of the research under a set of emission cost scenarios. It concluded that the value of CCSD research – that is, comparing industry performance with improved low or zero-emission technologies developed by the CRC to the case where this CRC research did not occur – was likely to be large in terms of avoided future costs. After research costs, the Net Present Value of the research was estimated to be within a $500 million to $1.6 billion range with a carbon price of $15/t CO_2 emitted, and within a $1.4 billion to $4.2 billion range with a carbon price of $45/t CO_2 emitted. The ranges allowed for uncertainty in the extent of adoption of research generated applications, which would affect the degree to which research had resulted in an improvement of the "availability gap" in power generation. Additionally, the price of emissions in an as-yet unknown market gives rise to significant variations in estimated value.

As an alternative to this conventional estimate of the value of "avoided costs," ACIL Tasman proposed that the CRC's research could also be valued in terms of the options it provides. Using this methodology, they conclude that, if research yields high prospects, or on the other hand if the event (e.g., the introduction of an emissions trading scheme) becomes more likely, the value of the research will rise accordingly.

Using this model, ACIL Tasman estimates that the expected net value of the CRC's research is $749 million, which represents a weighted average of the possible outcomes under a range of emission price schemes. However, this value is dependent on the successful deployment of the low emissions technology, which has a built-in probability of only 25 per cent.

Australian Biosecurity CRC for Emerging Infectious Diseases

The Australian Biosecurity CRC for Emerging Infectious Diseases estimates the value of its research by calculating the costs to industry and the healthcare system of outbreaks of diseases such as foot and mouth disease (FMD), influenza and Severe Acute Respiratory Syndrome (SARS), given the probabilities of such events. It then estimates the role of CRC research in mitigating the impact of these outbreaks – reducing their probability, limiting their extent, or minimising costs in management.

The CRC estimates that, for example, in the case of influenza, its research has the ability to reduce the likelihood of a mid-level pandemic from 0.05 per cent probability in any given year to a range of 0.0495 to 0.025. Given the potentially high costs of a flu pandemic – which could reach 0.8 per cent of GDP – the average expected value of achievement of this level of risk reduction would range from $3.9 million to $195 million per annum.

CHAPTER 6
Findings from economic impact assessment

6.1 "Minimum-bound" (level one) economic impact scenario outcomes

Table 6.1 sets out the estimated net economic impacts of the CRC Programme over the 1991-2010 period when only those outcomes that meet the strict level one inclusion criteria are considered. The table shows, in 2005 dollar terms, the net impact of the Programme on the following key economic variables:

- Gross Domestic Product;
- Total Consumption, and its component parts; Private Consumption and Public Consumption; and
- Investment.

The table presents the change in these variables that would have occurred if the CRC Programme had not been funded and the Programme funding had instead been left in the hands of taxpayers. Overall, what the table shows is that:

- Due to "expenditure effects" alone, funding the CRC Programme initially has negative effects on GDP, private consumption and investment and positive effects on public consumption levels; and

- Over time, as "investment effect" benefits from the CRC Programme begin to be generated, positive effects are generated on GDP, private consumption and investment. By 2003 the Programme is positively impacting on GDP and by 2005 the CRC Programme is having clearly positive effects on all of the key economic variables considered.

TABLE 6.1: SCENARIO ONE OUTCOMES - VARIATION FROM WITHOUT CRC PROGRAMME CASE (2005 $ MILLION)

	91	92	93	94	95	96	97	98	99	00
Change in real gross value added (GDP)	-4.4	-12.2	-25.5	-33.9	-44.2	-50.1	-56.1	-45.9	-53.7	+1.7
Change in real private consumption	*-17.2*	*-41.4*	*-78.0*	*-85.9*	*-101.3*	*-105.0*	*-104.1*	*-96.8*	*-90.0*	*-53.5*
Change in real public consumption	*+41.4*	*+97.4*	*+180.9*	*+188.6*	*+218.3*	*+219.4*	*+211.5*	*+195.5*	*+181.6*	*+166.1*
Change in real total consumption	+24.2	+56.0	+102.9	+102.7	+117.0	+114.4	+107.4	+98.7	+91.6	+112.6
Change in real investment	-14.2	-34.1	-64.2	-65.1	-75.2	-72.8	-67.9	-52.0	-47.1	+6.3
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Change in real gross value added (GDP)	-2.0	-29.5	+113.2	+166.5	+202.4	+186.3	+208.2	+233.5	+254.2	+267.2
Change in real private consumption	*-65.7*	*-68.4*	*-22.7*	*-14.3*	*+41.6*	*+79.1*	*+97.9*	*+117.0*	*+132.5*	*+144.8*
Change in real public consumption	*+158.7*	*+154.5*	*+148.3*	*+178.0*	*+163.1*	*+37.2*	*+35.6*	*+33.9*	*+32.1*	*+30.3*
Change in real total consumption	+93.0	+86.1	+125.6	+163.7	+204.7	+116.3	+128.6	+150.9	+164.6	+175.1
Change in real investment	-25.8	-38.4	+49.6	+31.6	+63.8	+90.8	+83.7	+80.7	+72.5	+73.7

Source: CoPS, Insight Economics

When the results from the scenario one modelling are converted to 2006 NPV terms (future impacts discounted using a 5 per cent real discount rate), the following conclusions can be made regarding the cumulative impact of the CRC Programme funding between 1991 and 2005 on Australian economic performance over the 1991-2010 period:

- GDP is cumulatively $1157 million higher than it would otherwise have been;

- Total Consumption is $2264 million higher than it would otherwise have been (Private consumption is $394 million lower and Public Consumption is $2657 million higher); and

- Investment is almost exactly the same ($4 million lower) as it would otherwise have been.

For *each dollar* invested in the CRC Programme, rather than left with taxpayers, the results are:

- GDP is cumulatively $0.50 higher than it would otherwise have been;

- Total Consumption is $0.97 higher than it would otherwise have been (Private consumption is $0.17 lower and Public Consumption is $1.14 higher); and

- Investment is the almost exactly the same as it would otherwise have been.

It is important to note here that the above results should not be directly compared to the findings from the 2005 CRC Association study. This is because of the important methodological change that has been made between the two studies in relation to the "counterfactual" use of CRC Programme funding (the effects of which are discussed in detail in Box 4.2). In the 2005 study other Government expenditure was assumed to occur, whereas in this study it is assumed that tax reductions would have occurred. If the same counterfactual had been applied in the 2006 study as was applied in the 2005 study, for each dollar allocated to the CRC Programme the net impact on GDP would have been to increase GDP by around $0.70 compared to what it would otherwise have been. This result compares favourably with the headline finding from the 2005 CRC Association study that GDP was $0.60 higher than it would otherwise have been as a result of each dollar of CRC Programme funding.

6.2 "Attributed delivered benefits" (level two) economic impact scenario outcomes

Table 6.2 sets out the estimated net economic impacts of the CRC Programme over the 1991-2010 period when those outcomes that meet the somewhat broader level two inclusion criteria are considered.

The table presents the change in these variables that would have occurred if the CRC Programme had not been funded and the Programme funding had instead been left in the hands of taxpayers. Overall, what the table shows is that:

- Due to "expenditure effects" alone, funding the CRC Programme initially has negative effects on GDP, private consumption and investment and positive effects on public consumption levels; and

- Over time, as "investment effect" benefits from the CRC Programme begin to be generated, positive effects are generated on GDP, private consumption and investment. By 2000 the Programme is positively impacting on GDP and by 2003 the CRC Programme is having clearly positive effects on all of the key economic variables considered.

TABLE 6.2: SCENARIO TWO OUTCOMES - VARIATION FROM WITHOUT CRC PROGRAMME CASE (2005 $ MILLION)

	91	92	93	94	95	96	97	98	99	00
Change in real gross value added (GDP)	-3.8	-10.0	-20.1	-24.9	-31.0	-25.9	-27.2	-13.6	-22.4	+40.2
Change in real private consumption	*-17.1*	*-40.8*	*-76.5*	*-83.3*	*-97.3*	*-98.5*	*-95.7*	*-86.9*	*-81.2*	*-42.5*
Change in real public consumption	*+41.4*	*+97.4*	*+180.9*	*+188.6*	*+218.3*	*+219.4*	*+211.5*	*+195.5*	*+181.6*	*+166.1*
Change in real total consumption	+24.3	+56.6	+104.4	+105.3	+121.0	+120.9	+115.8	+108.6	+100.4	+123.6
Change in real investment	-14.1	-33.8	-63.4	-63.7	-73.1	-66.4	-60.9	-44.3	-40.1	+14.2
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Change in real gross value added (GDP)	+41.6	+33.2	+274.7	+299.6	+345.4	+332.2	+356.3	+382.4	+402.0	+414.2
Change in real private consumption	*-53.4*	*-48.4*	*+38.1*	*+41.7*	*+103.9*	*+145.3*	*+166.4*	*+187.4*	*+204.1*	*+217.6*
Change in real public consumption	*+158.7*	*+154.4*	*+148.2*	*+177.8*	*+162.7*	*+36.6*	*+34.7*	*+32.8*	*+30.8*	*+28.7*
Change in real total consumption	+105.3	+106.0	+186.3	+219.5	+266.6	+181.9	+201.1	+220.2	+234.9	+246.3
Change in real investment	-15.4	-20.1	+110.1	+71.9	+106.8	+132.0	+128.6	+128.5	+125.9	+120.8

Source: CoPS, Insight Economics

When the results from the scenario two modelling are converted to 2006 NPV terms (future impacts discounted using a 5 per cent real discount rate), the following conclusions can be made regarding the cumulative impact of the CRC Programme funding between 1991 and 2005 on Australian economic performance over the 1991-2010 period:

- GDP is cumulatively $2554 million higher than it would otherwise have been;
- Total Consumption is $2838 million higher than it would otherwise have been (Private consumption is $187 million higher and Public Consumption is $2651 million higher); and
- Investment is $384 million higher than it would otherwise have been.

For *each dollar* invested in the CRC Programme, rather than left with taxpayers, the results are:

- GDP is cumulatively $1.10 higher than it would otherwise have been;
- Total Consumption is $1.21 higher than it would otherwise have been (Private consumption is $0.08 higher and Public Consumption is $1.13 higher); and
- Investment is $0.16 higher than it would otherwise have been.

Comparison to 2005 methodology

It is important to note that if the same counterfactual had been applied in the 2006 study as was applied in the 2005 study, for each dollar allocated to the CRC Programme the net impact on GDP under scenario two would have been to increase GDP by around $1.30 compared to what it would otherwise have been rather than the $1.10 increase noted above.

6.3 "Best estimate of non-contingent benefits" (level three) economic impact scenario outcomes

Table 6.3 sets out the estimated net economic impacts of the CRC Programme over the 1991-2010 period when those outcomes that meet the broader level three inclusion criteria are considered.

The table presents the change in these variables that would have occurred if the CRC Programme had not been funded and the Programme funding had instead been left in the hands of taxpayers. Overall, what the table shows is that:

- Due to "expenditure effects" alone, funding the CRC Programme initially has negative effects on GDP, private consumption and investment and positive effects on public consumption levels; and
- Over time, as "investment effect" benefits from the CRC Programme begin to be generated, positive effects are generated on GDP, private consumption and investment. By 2000 the Programme is positively impacting on GDP and by 2003 the CRC Programme is having clearly positive effects on all of the key economic variables considered.

TABLE 6.3: SCENARIO THREE OUTCOMES - VARIATION FROM WITHOUT CRC PROGRAMME BASE CASE (2005 $ MILLION)

	91	92	93	94	95	96	97	98	99	00
Change in real gross value added (GDP)	-3.8	-10.0	-20.1	-24.9	-31.0	-25.9	-27.2	-13.6	-22.4	+40.2
Change in real private consumption	*-17.1*	*-40.8*	*-76.5*	*-83.3*	*-97.3*	*-98.5*	*-95.7*	*-86.9*	*-81.2*	*-42.5*
Change in real public consumption	*+41.4*	*+97.4*	*+180.9*	*+188.6*	*+218.3*	*+219.4*	*+211.5*	*+195.5*	*+181.6*	*+166.1*
Change in real total consumption	+24.3	+56.6	+104.4	+105.3	+121.0	+120.9	+115.8	+108.6	+100.4	+123.6
Change in real investment	-14.1	-33.8	-63.4	-63.7	-73.1	-66.4	-60.9	-44.3	-40.1	+14.2
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Change in real gross value added (GDP)	+41.6	+33.2	+274.7	+299.6	+345.8	+357.4	+384.7	+414.2	+437.6	+453.5
Change in real private consumption	*-53.4*	*-48.4*	*+38.1*	*+41.7*	*+104.9*	*+150.1*	*+173.3*	*+196.3*	*+214.8*	*+230.0*
Change in real public consumption	*+158.7*	*+154.4*	*+148.2*	*+177.8*	*+162.7*	*+36.6*	*+34.7*	*+32.7*	*+30.7*	*+28.6*
Change in real total consumption	+105.3	+106.0	+186.3	+219.5	+267.6	+186.7	+208.0	+229.0	+245.5	+258.6
Change in real investment	-15.4	-20.1	+110.1	+71.9	+106.8	+77.1	+145.8	+144.1	+141.1	+136.1

Source: CoPS, Insight Economics

When the results from the scenario three modelling are converted to 2006 NPV terms (future impacts discounted using a 5 per cent real discount rate), the following conclusions can be made regarding the cumulative impact of the CRC Programme funding between 1991 and 2005 on Australian economic performance over the 1991-2010 period:

- GDP is cumulatively $2697 million higher than it would otherwise have been;
- Total Consumption is $2876.7million higher than it would otherwise have been (Private consumption is $225 million higher and Public Consumption is $2651 million higher); and
- Investment is $436 million higher than it would otherwise have been.

For *each dollar* invested in the CRC Programme, rather than left with taxpayers, the results are:

- GDP is cumulatively $1.16 higher than it would otherwise have been;
- Total Consumption is $1.24 higher than it would otherwise have been (Private consumption is $0.10 higher and Public Consumption is $1.14 higher); and
- Investment is $0.19 higher than it would otherwise have been.

Comparison with 2005 methodology

It is important to note that if the same counterfactual had been applied in the 2006 study as was applied in the 2005 study, for each dollar allocated to the CRC Programme the net impact on GDP under scenario three would have been to increase GDP by around $1.36 compared to what it would otherwise have been rather than the $1.16 increase noted above.

6.4 Quantification of contingent benefits

Section 5.4 sets out three examples of the type of contingent benefits that the CRC Programme delivers. Unfortunately, given the generally long running time horizons for the delivery of these benefits and the high levels of uncertainty surrounding when they may be converted from a contingent to an actual benefit, it was not felt that it would be appropriate in this study to quantify such impacts in the same way that other kinds of benefits from CRCs have been quantified in this study. However, difficulties associated with quantification of contingent benefits do not imply that such benefits are either insignificant or unlikely to become actual at some future time. Quite the contrary, contingent benefits such as those considered above may in fact be amongst the largest that are provided by the CRCs (and by public R&D more broadly). The contingent benefit associated with reducing the risk of severe infectious disease outbreaks, for instance, could carry a value of hundreds of millions of dollars per annum.

CHAPTER 7
Conclusions

7.1 The economic impact of the CRC Programme

The inability to capture and measure all benefits (within the time and information constraints of this study) means that the economic impact analysis conducted in this report must be viewed as a partial rather than complete accounting of the economic benefits of the CRC Programme. Notwithstanding this constraint, the outcomes of the level three economic impact modelling scenario undertaken in this study represent the "best estimate" of the non-contingent benefits of the CRC Programme for Australia. Based on the results from the level three economic modeling scenario, the key findings from this study are that:

For each dollar invested in the CRC Programme (rather than left with taxpayers):

- **Australian Gross Domestic Product is cumulatively $1.16 higher than it would otherwise have been.**
- **Total Australian Consumption is $1.24 higher than it would otherwise have been (Private consumption is $0.10 higher and Public Consumption is $1.14 higher).**
- **Total Investment is $0.19 higher than it would otherwise have been.**

It is important to note that if the same counterfactual had been applied in the 2006 study as was applied in the 2005 study, for each dollar allocated to the CRC Programme the net impact on GDP under scenario three would have been to increase GDP by around $1.36 rather than the $1.16 increase noted above.

Table 7.1 sets out the cumulative impact of the CRC Programme funding between 1991 and 2005 (totalling $2.33 billion in 2005 dollar terms) on Australian economic performance over the 1991-2010 period estimated under the level one, two and three economic modelling scenarios. Results have been converted to 2006 NPV terms with future impacts discounted using a 5 per cent real discount rate.

TABLE 7.1: NET ECONOMIC IMPACTS OF THE CRC PROGRAMME

Economic Variable	Level One Finding (2005 dollars)*	Level Two Finding (2005 dollars)	Level Three Finding (2005 dollars)
Gross Domestic Product	+$1,157 million	+$2,554 million	**+$2,697 million**
Total Consumption	+$2,264 million	+$2,838 million	**+$2,877 million**
Investment	-$4 million	+$384 million	**+$436 million**

* It is important to note that the findings from the level one impact assessment should not be directly compared with the findings from the 2005 CRCA commissioned impact study. This is because an important methodological change was made between the two studies. In the 2005 study the counterfactual alternative use of CRC Programme funding was that it would have gone to other Government expenditure. In the current study, the counter-factual used was that the CRC Programme funding would have instead gone to tax reductions. If the same methodology had been applied in this study as was applied in the 2005 study, the impact on GDP under each assessment level would have been approximately $450 million higher than the result presented here.

The overall conclusion to be drawn from the three economic impact modelling scenarios is that the CRC Programme, under all scenarios, is delivering very clear net benefits for Australian economic welfare and that, particularly when methodological changes are taken into account, the impact of the program is higher than was previously measured in the 2005 CRC Association study.

In relation to contingent benefits considered in level four of the impact assessment, the difficulties associated with quantification of contingent benefits do not imply that such benefits are either insignificant or unlikely to become actual at some future time. Quite the contrary, contingent benefits considered in this study may in fact be amongst the largest that are provided by the CRC Programme and could result in the Programme delivering benefits considerably in excess of those quantified in the first three economic impact levels.

Comparisons with the 2005 CRC Association commission impact study

When compared to the results of the 2005 CRC Association study, in this study a number of additional delivered benefits have been identified and quantified. In the 2005 study, 25 quantified CRC impacts were identified and included in the impact modelling. In this study, in addition to impacts from the 2005 study, an additional 27 quantified CRC impacts were included across the three economic impact modelling levels. The most dramatic change was in the relation to Agriculture & Rural Based Manufacturing CRCs; two impacts from such CRCs were included in 2005 compared

to 14 in this study. This change largely reflects the significant effort that a number of Agriculture focused CRCs have made since the 2005 study to gather more end user verification of the impacts of application of the CRCs research.

As a consequence of "capturing" in this study more of the benefits generated by CRCs it has become apparent that the net benefits of the CRC Programme are higher than the lower bound calculation of benefits found in the 2005 study. In particular, when those benefits where "attribution" is an issue are included, the net benefits from the Programme (even without factoring in the impact of the change made in the assumed counterfactual without CRC Programme case) emerge as being twice as high as the level calculated in 2005. Given this result, the *prima facie* case for continuation of the CRC Programme is even stronger than that which emerged from the 2005 study.

While the magnitude of benefits identified in this study has increased considerably when compared to the 2005 study findings, a number of other important points to emerge from the 2005 study have not changed. For instance:

- Benefits delivered through the end user application of research by means other than direct commercialisation processes (spin-offs and licensing) remain the most significant channel of quantified benefits from the CRC Programme.

- Time lags between the formation of a CRC and the generation of measurable end impacts are still significant – time lags between the commencement of a CRC and the delivery of measurable end impacts are generally between five and ten years.

- Challenges in the quantification of impacts, and particularly of contingent benefits, remain high and continue to result in an under-accounting of impacts in studies, such as this one, that focus on measuring "delivered" impacts and require end user verification and quantification of impacts.

7.2 Observations potentially relevant for future CRC Programme design

This study is quite explicitly an impact assessment study of the CRC Programme and is not a CRC Programme design review. Nevertheless, through the course of this study a number of things have emerged that may be relevant to future CRC Programme design reviews that DEST may wish to undertake. Given the limited remit of this study, the following articulation of two key "lessons learned" should be viewed only as observations of possible interest and not as a set of recommendations for future Programme design.

Two lessons learned

Lesson One: Different types of CRCs face very different degrees of difficulty in quantification and verification of their impacts. For some it is as simple as asking one key industry partner to quantify a benefit they have realised, for others it involves complex sampling of end user groups or tracking of final retail outcomes. An example of the type of challenge sometimes involved in quantifying impacts can be seen in the amount of work that was required for the benefits to be calculated of the Beef CRC's contribution to the Meat Standards Australia (MSA) grading system. The benefits could only be calculated because extensive point of sale price information had been

collected across Australia that allowed the producer price premium associated with the utilisation of the MSA system to be determined.

Lesson Two: CRCs that are focused on fostering the development of "new" industries or companies face a harder challenge to deliver benefits than do those CRCs that are focused on promoting incremental performance improvement within existing large sectors or companies. In part this is because when attempting to develop new areas of economic activity, a lot of factors (such as state of the venture capital market) beyond the quality and relevance of research come into play. For CRCs that are focused on solving problems of current concern to big existing industries or companies, the equation for success is somewhat simpler, namely: to deliver a benefit it is necessary to solve the problem identified by your industry partners and disseminate the solution to those partners.

The extent to which these lessons learned should be taken into account when consideration is given to future CRC Programme design is very much an issue for DEST and is not something that falls within the scope of this impact assessment study. What is within the scope of this study to conclude is that, quite clearly, the CRC Programme is delivering strong net positive economic benefits for Australia.

APPENDIX A
Modelling details

A.1 The CoPS Model

The Centre of Policy Studies (CoPS) has been commissioned by Insight Economics to simulate the economic impacts of public ICT R&D in Australia. The analysis reported here is undertaken using the MONASH Multi-Regional Forecasting (MMRF) model. MMRF is a bottom-up model of Australia's six states and two territories.

This report contains a brief overview of the model and simulation results are then reported.

A.2 Model Overview

MMRF is a very detailed dynamic, multi-sectoral, multi-regional model of Australia. The current version of the model distinguishes 49 industries, 54 products, 8 states/territories and 56 sub-state regions.

MMRF is founded on the Monash Multi-Regional (MMR) model, and was built in three stages. In the first stage, MMR was transformed into a dynamic system by the inclusion of dynamic mechanisms. These were added as self-contained blocks, allowing MMRF to include MMR as a special case. The second stage involved a range of developments designed to enhance the model's capacity for environmental analysis. In the third stage, a regional disaggregation facility was added, which allows state-level results to be disaggregated down to sub-state regions.

MMR

MMR divides Australia into the six states and two territories. There are five types of agents in the model: industries, capital creators, households, governments, and foreigners. The number of industries is limited by computational constraints. For each industry in each region there is an associated capital creator. The sectors each produce a single commodity and the capital creators each produce units of capital that are specific to the associated sector. Each region in MMR has a single household and a regional government. There is also a federal government. Finally, there are foreigners, whose behaviour is summarised by export demand curves for the products of each region and by supply curves for international imports to each region.

MMR determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders so that each region's stock of productive resources reflects regional employment opportunities and relative rates of return.

The specifications of supply and demand behaviour co-ordinated through market clearing equations comprise the general equilibrium (GE) core of the model. There are two blocks of equations in addition to the core. They describe regional and federal government finances and regional labour markets.

From MMR to 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.

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 for, 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 region r, 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 processes is included in MMRF. This relates to the operation of the labour market in year-to-year policy simulations.

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

1. the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or

2. 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 policy 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 basecase-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 NAIRU is exogenous.

MMRF: Disaggregation to sub-state regions

Few multi-regional models of the Australian economy have the level of sectoral detail supported by MMRF. This detail is usually more than adequate for contributions to public discussions on the effects of changes in policies concerning taxes, trade and the environment. However, people wanting to use MMRF in business and public sector planning are often frustrated by the lack of relevant regional detail. This applies especially to people interested in regional adjustment issues.

It is with these people in mind that we have incorporated into MMRF a tops-down method that enables disaggregation of state-level results for output, employment and greenhouse-gas emissions down to projections for 56 sub-state regions.

These regions are based on the Statistical divisions defined in the Australian Standard Geographical Classification (ABS catalogue number 1216.0). Our division structure differs slightly from that of the ABS. We combine the ABS's Darwin and Northern Territory - balance divisions into one division, Northern Territory. Similarly, Canberra and ACT - balance are combined into one division, Australian Capital Territory. Note that both territories are distinguished as separate regions in MMRF. Hence, the tops-down disaggregation facility provides no additional detail for them. We also adopt a slightly different regional classification for WA than that defined by the ABS. Our WA regions are based on the classification used by the WA department of Commerce. Finally, we identify the energy intensive La Trobe Valley in Victoria as a separate region (region 24), with 23 Gippsland defined to include all areas in the ABS statistical division Gippsland other than the La Trobe Valley.

A.3 Modelling scenario inputs

Only brief descriptions of the additional impacts included in the modelling undertaken in this study are provided as industry end-users did not wish to have detailed information in relation to technology and commercial applications released into the public domain. Indeed, many only provided end impact quantification for this study on the proviso that no sensitive information would be published.

A.3.1 Scenario One inputs

Carry over inputs from the 2005 CRC Programme impact study commissioned by the CRC Association included in the level one modelling in this study were the following impact events:

- CRC Mining. Application of universal dig and dump technology in the coal mining sector. Industry (BHP Billiton Mitsubishi Alliance) incurred costs of $37 million to further develop CRC technology between 2001 and 2003 then from 2003 started reaping a net average cost saving of $8 million per annum through fitting technology to its existing draglines, and hence reducing the need for purchase of expensive new draglines .

- CRC Welded Structures. Application of CRC technology to allow faster laying of gas pipelines (primarily in Queensland) has resulted in net industry savings of $20 million per annum since 2001. Pipeline laying rates have achieved record performance levels.

- CRC Welded Structures. In 2004 the CRC proved that a $30 million solution for a defence shipbuilder was a viable alternative to the $150 million solution that was going to be used. This allowed a saving of $120 million in costs to be achieved.

- CRC for Bioproducts. A brewer (CUB) adopted strategies to improve the temperature stability of beer, leading to net cost savings totalling $5 million between 2003 and 2005. A food producer (Goodman Fielder) adopted analytical methods for assessing polymer purity that has resulted in a net cost saving of $3 million per annum since 2004.

- CRC for CAST Metals Manufacturing. Adoption of a range of technologies by CRC industry partners since 2004 has been generating net cost savings of $6.6 million per annum in the metals manufacturing sector.

- AJ Parker CRC for Hydrometallurgy. The adoption by industry partners of outcomes from its thickener project led to a $22.3 million increase in industry costs in 2002 to adopt technology followed by a $99 million fall in capital expenditure costs in 2003 and annual net cost savings of $20.6 million being achieved from 2003.

- AJ Parker CRC for Hydrometallurgy. The adoption by industry partners of outcomes from its solvent extraction project lead to $0.6 million per annum net industry cost savings commencing in 2004.

- AJ Parker CRC for Hydrometallurgy. The adoption by industry partners of outcomes from its thickener project led to $6.2 million per annum net increase in industry output from 2003 onwards through increasing the capacity of existing infrastructure.

- AJ Parker CRC for Hydrometallurgy. The adoption by industry partners of outcomes from its solvent extraction project led to $6.7 million per annum net increase in industry output from 2004 onwards, again through increasing the capacity of existing infrastructure.

- CRC for Advanced Composite Structures. An Australian defence company (ADI Ltd) generated gross increases in revenue of $6 million over the 2002 to 2004 period through sale of products based on the CRC's research.

- Australian Photonics CRC. A number of spin-off companies (the Redfern group of companies) have been formed that have generated significant gross revenue (totalling $178 million to date) through the sale of products based on the CRC's technology. It should also be noted that the overall revenue of the companies has been considerably higher than just the revenue associated with CRC research based products.

- CRC for Cattle and Meat Quality. Gross revenue from the sale of CRC developed products (vaccines and gene marker tests) by commercialisation partners (Pfizer Vaccine Animal Health, Intervet Australia Pty Ltd and Genetic Solutions Pty Ltd) between 2001 and 2005 has totalled $6 million.

- CRC for Sensor Signal and Information Processing. Gross revenue has been generated through the sale of radar and communications products by two CRC spin-off companies (Wedgetail TRDC Pty Ltd and GroundProbe Pty Ltd). Revenue from sales to the defence sector totalled $3 million between 2002 and 2004 while sales to the mining sector totalled $12.5m in 2005.

- CRC for Technology Enabled Capital Markets. Spin-off companies (Capital Markets Technology Pty Ltd, Capital Markets Surveillance Services Pty Ltd, Dtecht Pty Ltd and Capital Markets Consulting Pty Ltd) generated gross revenue of $1.2 million in 2005 through sale of new data gathering software and services in the finance sector.

- CRC for Polymers. Gross revenue of $16.6 million between 2004 and 2005 has been generated from sales by commercialisation partners (Olex and Orica) of CRC research based polymer cable products (Pyrolex CeramifiableTM and cellular cable insulation and sheathing materials). Around $11 million of these sales represents import replacement activity.

- CRC for International Food Manufacture and Packaging Services. A spin-off company from the CRC (Plantic Technologies Ltd) has generated gross revenue of $3.7 million between 2003 and 2005 from sale of CRC developed technology. This revenue is largely from import replacement (of plastic resins).

- CRC for Cardiac Technology. A spin-off company (Elastomedic) was sold to a foreign buyer (Aortech International Plc) in 2000. CRC partners received $26 million from the sale (valued at $75 million) which they then reinvested in the Australian medical research sector.

- CRC for Broadband Telecommunications Networking. A spin-off company (Atmosphere Networks) that developed an Autologous Transfer Mode Local Area Network product was sold to a foreign buyer in 2000. CRC partners received $6 million from the sale (valued at over $150 million) which they reinvested in the Australian telecommunications research sector.

- CRC for Water Quality and Treatment. Application of CRC technology by water treatment authorities has resulted in net cost savings of $26 million per annum since 2004 through reduced chemical and sludge disposal costs and reduced equipment needs for the management of pathogen movement into drinking water sources.

- Vision CRC. Net licensing revenue received by the CRC partners averaged $2.2 million per annum between 1999 and 2004 due to licensing of SEE3 contact lens technology to a foreign company (Novartis).

- CRC for Sustainable Aquaculture of Finfish. Application of research into use of lights to influence growth of salmon was trialed by two companies who realised a net revenue benefit through higher salmon growth rates of $3.2 million in 2004.

- CRC for Clean Power from Lignite. A spin-off company (Laser Analysis Technologies Pty Ltd) has generated gross revenues of $0.8 million between 2003 and 2005.

- CRC for Vaccine Technology. Licensing revenue totalling $0.6 million has been received between 2003 and 2005 from an international pharmaceutical company.

- CRC for Environmental Biotechnology. Spin-off companies have generated gross revenue of $2.7 million over the 1998 to 2004 period, largely through sale of new environmental management services to the construction industry.

In addition to these events, 11 further events that meet the strict inclusion criteria for the level one impact modelling were identified in this study. These events are:

- CRC for Sensor Signals and Information Processing: $34 million sale in 2005 of spin-off software company Wedgetail Communications to foreign buyers.

- CRC for Advanced Composite Structures: Profit change in aircraft parts manufacturing due to CRC ACS developed technology lowering industry partner's cost base across various contracts by around $0.5 million per annum since 2001.

- CRC Mining: Output change in mining sector due to spin off company revenue averaging over $8 million per annum from 2005 onwards.

- CAST CRC: Output change in metals manufacturing sector due to additional export revenues of domestic companies based on CAST technology.

- CRC for Sensor Signals and Information Processing: $33 million per annum change in profit in mining sector from 2006 due to GroundProbe technology application allowing extension of a profitable mines operating life.

- CRC for Australian Poultry Industries: Vaccine uptake related cost changed in poultry industry (confidential constraints were particularly high in this case).

- Predictive Minerals Discovery CRC: Direct cost savings totalling almost $14 million to date for mining exploration companies from 3D model development in WA, and application of numerical modelling targeting in Victoria.

- Australian Sheep Industry CRC: Application of RFID technology for sheep sorting has led to producer cost savings of almost $0.5 million to date.

- CRC for Viticulture: Change in revenue per hectare in wine production sector due to application of CRC developed selective harvesting techniques allowing for better grape grading/selection. Production value per hectare is increased by $1000 per hectare with uptake since 2005 of around 1600Ha.

- CRC for Viticulture: Change in retail value of wine due to average quality increase resulting from selective harvesting technique uptake. Retail value per hectare has increased by $55,000 (which equates to around $2.50 per bottle) with uptake since 2005 of around 1600Ha.

- CRC for Sustainable Aquaculture of Finfish: Cost savings for baitfish producers and southern bluefin tuna farmers, averaging over $3 million per annum, through application of CRC technology.

Following the aggregation of some of these specific impacts into overall effects on particular sectors, and the conversion of impacts to 2005 dollars, the following level one modelling scenario inputs were developed.

TABLE A.1: SCENARIO ONE INPUTS - VARIATION FROM WITH CRC PROGRAMME BASE CASE (2005 $ MILLION)

	91	92	93	94	95	96	97	98	99	00
Change in income tax collected	-29.1	-71.3	-138.4	-149.6	-180.4	-188.1	-187.6	-178.6	-170.8	-160.1
Change in Commonwealth Govt expenditure into R&D	-29.1	-71.3	-138.4	-149.6	-180.4	-188.1	-187.6	-178.6	-170.8	-160.1
Cost changes in coal mining sector.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost changes in gas pipeline sector.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost changes in ship and aircraft building	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost changes in food and beverage manufacturing.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost changes in metals manufacturing.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost changes in minerals extraction and exploration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Output change in electronic equipment sector	0.0	0.0	0.0	0.0	0.0	-1.3	-1.3	-11.1	-6.0	-50.1
Output change in beef service sector	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Output changes in IT software sector.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Change in foreign IP sales revenue	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.6	-39.8
Cost change in water treatment sector.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cost change in agriculture, forestry fishing.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Output change in services to construction industry.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	-0.8	-0.8
Change in foreign sale of IT companies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Change in profit in tourism sector	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1

TABLE A.1 CONT…

	01	02	03	04	05	06	07	08	09	10
Change in income tax collected	-157.8	-159.2	-157.9	-208.0	-194.6	0.0	0.0	0.0	0.0	0.0
Change in Commonwealth Govt expenditure into R&D	-157.8	-159.2	-157.9	-208.0	-194.6	0.0	0.0	0.0	0.0	0.0
Cost changes in coal mining sector.	-13.9	-13.5	-4.6	8.2	8.0	7.8	7.5	7.3	7.1	6.9
Cost changes in gas pipeline sector.	22.6	21.9	21.3	20.6	20.0	19.4	18.9	18.3	17.8	17.3
Cost changes in ship and aircraft building	0.6	-1.6	-1.6	122.2	0.5	0.5	0.5	0.5	0.4	0.4
Cost changes in food and beverage manufacturing.	0.0	0.0	1.8	4.8	4.7	0.0	0.0	0.0	0.0	0.0
Cost changes in metals manufacturing.	0.0	0.0	0.1	6.9	6.8	14.7	31.0	37.0	46.6	53.3
Cost changes in minerals extraction and exploration	2.8	-21.7	136.4	37.7	78.3	74.8	71.4	69.4	67.3	65.4
Output change in electronic equipment sector	-32.8	-29.6	-25.4	7.6	-23.6	-1.9	0.0	0.0	0.0	0.0
Output change in beef service sector	-1.1	-1.1	-1.1	-1.0	-2.0	-1.9	-1.9	-1.8	-1.8	-1.7
Output changes in IT software sector.	0.0	0.0	-8.5	-13.4	-21.2	-26.7	-37.7	-48.5	-59.5	-70.7
Change in foreign IP sales revenue	-2.5	-2.4	-2.4	-2.5	-2.5	0.0	0.0	0.0	0.0	0.0
Cost change in water treatment sector.	0.0	0.0	0.0	26.8	26.0	25.2	24.5	23.8	23.1	22.4
Change in costs in agriculture, forestry and fishing.	0.0	0.0	0.0	-6.0	82.3	61.4	60.0	72.3	76.3	74.1
Change in output in services to the construction industry.	-0.2	-0.2	-0.2	-0.3	0.0	0.0	0.0	0.0	0.0	0.0
Change in sale of IT software companies to foreign buyers	0.0	0.0	0.0	0.0	-34.0	0.0	0.0	0.0	0.0	0.0
Change in profit (due to revenue increase) in tourism sector	0.1	0.2	0.2	-0.5	-0.2	-0.3	-0.8	-0.7	0.0	0.0

Source: CoPS, Insight Economics

A.3.2 Scenario Two inputs

The inputs included in level two of the economic impact modelling include all level one inputs. In addition, the level two scenario also includes nine specific impacts from CRCs where assignment of appropriate attribution levels was a significant issue. Estimates of the extent to which the impact could be attributed to CRC Programme funding have been made based on discussions with stakeholders and consideration of CRC Programme funding levels compared to other inputs contributing to an outcomes occurring. The nine additional impacts included in the level two scenario are:

- Cotton Catchment Communities CRC: Change in profit in cotton growing sector due to extension of useful life of INGARD varietals. CRC Programme funding attributed 30 per cent credit for total CRC generated outcomes based on the relative contribution of Programme funding to total research costs.

- Cotton Catchment Communities CRC: Cost change in cotton growing sector from application of CRC knowledge in areas of integrated pest management, weed management, disease management and water use efficiency. CRC Programme funding attributed 30 per cent credit for total CRC generated outcomes based on the relative contribution of Programme funding to total research costs.

- CRC for Beef Genetic Technologies: Change in value added in beef production sector due to application of Meat Standards Australia system. This involved research from multiple parties with value added increase per research dollar calculated in excess of $8 per $1 in research expenditure. Benefits attributed to CRC Programme funding based on dollar allocation ($27 million over 10 years) of funds to the contributing research.

- CRC for Beef Genetic Technologies: Net profit increase in feedlot sector from application of around 2.75 million doses to date of the CRC developed Bovine Respiratory Disease vaccine Bovillus MH (marketed through Intervet Australia Pty Ltd) in backgrounding feedlot cattle. An atribution rate to the CRC of 50 per cent has been applied to the net cost savings delivered.

- CRC for Advanced Composite Structures: Change in output in aircraft parts manufacturing due to CRC ACS contribution to partners securing multiple major export projects. Attribution rates to the CRC Programme funding range from 2 – 10 per cent depending on the specific situation relating to each contract.

- CRC for Cochlear Implant and Hearing Aid Innovation: Revenues generated by spin-off companies plus a small attribution of the gross output of major industry partner since 1996. CRC Programme funding has accounted for 4.5 per cent of total partner product development funding over that period.

- CRC for Forestry: Change in forestry profitability due to uptake of new seed varieties to which the CRC was a major (50 per cent minimum) contributor. These varieties allow 20 per cent less planting being required for a given output level. This equates to a $6000 per Ha cost saving with $3500 of this saving coming in year of planting. There has been 70 per cent uptake across 100 000 Ha per annum of new industry plantings.

- CRC for Viticulture: Change in costs in wine production across South West NSW, North West Victoria and North East SA due to reduced water use resulting from adoption of irrigation approaches partially (50 per cent) developed by CRC. There has been 26 per cent adoption of new approaches across regions totalling 47 135 Ha, with 5Ml/Ha average water use saving per annum occurring at average water costs of $55/Ml.

- Skills formation impacts: Gross output change due to labour productivity change resulting from CRC Programme funding increasing the production of research postgraduates that have gone on to employment in industry. Since 1991 there have been over 4000 research post-graduate degrees completed through CRCs. Given CRC Programme funding has represented approximately 25 per cent of total CRC resourcing, it is reasonable to suggest that the removal of that funding from the research system would have reduced the total number of post-graduate degree completions by around 1000 over the 1991 to 2006 period. Given that the wage premium for post-graduate degree holders when compared to bachelor degree holders is $20,000 per annum, that 80 per cent of the wage premium is attributable to the qualification not the individual and that half of total output on average is returned to labour, there is an output premium of around $32,000 per annum per research post-graduate in Australia.

Following the aggregation of some of these specific impacts into overall effects on particular sectors, the following level two modelling scenario inputs (in addition to the inputs from the level one modelling scenario) were developed.

TABLE A.2: SCENARIO TWO INPUTS - VARIATION FROM WITH CRC PROGRAMME BASE CASE (2005 $ MILLION)

	91	92	93	94	95	96	97	98	99	00
Change in profit (due to revenue increase) in Beef Sector	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Change in Output in aircraft parts manufacturing	0.0	0.0	0.0	0.0	0.0	-0.4	-0.4	-0.4	-0.4	-0.3
Cost change in cotton growing sector	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.1	-4.4
Change in output in medical devices sector	0.0	0.0	0.0	0.0	0.0	-4.2	-4.1	-4.5	-6.7	-7.3
Output change due to labour productivity change	-0.3	-1.2	-3.0	-5.3	-8.0	-10.8	-14.2	-16.2	-19.1	-23.2
Change in forestry sector costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**
Change in profit (due to revenue increase) in Beef Sector	0.0	0.0	-28.7	-29.1	-30.8	-33.5	-32.5	-31.6	-30.7	-29.8
Change in Output in aircraft parts manufacturing	-0.5	-0.4	-0.5	-0.5	-0.5	-0.5	-6.1	-9.6	-11.1	-10.8
Cost change in cotton growing sector	-5.8	8.4	50.0	12.5	15.3	13.2	11.1	9.9	8.2	9.3
Change in output in medical devices sector	-10.7	-12.3	-14.3	-12.8	-18.6	-18.1	-17.5	-17.0	-16.5	-16.0
Output change due to labour productivity change	-25.6	-27.9	-30.7	-33.6	-32.7	-34.0	-33.0	-32.0	-31.1	-30.2
Change in forestry sector costs	0.0	0.0	26.0	26.7	27.3	27.9	28.4	28.8	29.2	29.6

Source: CoPS, Insight Economics

A.3.3 Scenario Three inputs

The inputs included in level three of the economic impact modelling include all level two inputs. In addition, the level three scenario also includes seven specific impacts from CRCs where benefits are either recently commenced or imminent (with the majority of benefits therefore still forthcoming) and/or where impact valuation had to be estimated from a small sample of end users. The seven additional impacts included in the level three scenario are:

- Australian Sheep Industry CRC: Net cost savings totalling $9 million between 2006 and 2010 from application of CRC developed Haemonchus Diagnostic Dipstick

- Australian Sheep Industry CRC: Net cost savings totalling $17 million between 2005 and 2010 from application of CRC developed and WormBoss products.

- CRC for Sustainable Tourism: Gross output increase of over $30 million for the tourism sector based on delivered and projected revenues from spin off companies between 1997-98 and 2007-08.

- CRC for Sustainable Tourism: Gross output increase of over $30 million for the tourism sector between 2005 and 2010 resulting from the use of Encore reports and VIC Kits.

- CRC for Sustainable Tourism: Cost savings generated between 2003 and 2010 through application of Green Globe standards since 2003. Based on a sample of end user impacts and known uptake rates, total net cost savings are estimated at over $80 million.

- CRC for Railway Engineering and Technologies: Impact on freight rail sector costs by extending ballast life and stability. New ballast standards have been accepted with uptake now imminent, with $9 million per annum in net cost savings expected.

- CAST CRC: Currently commencing cost savings for domestic companies based on use of new CAST technology. Cost savings are expected to total more than $55 million over the 2006 to 2010 period.

Following the aggregation of some of these specific impacts into overall effects on particular sectors and the conversion of all impacts into 2005 dollars, the following level three modelling scenario inputs (in addition to the inputs from level two modelling scenario) were developed.

TABLE A.3: SCENARIO THREE INPUTS - VARIATION FROM WITH CRC PROGRAMME BASE CASE (2005 $ MILLION)

	01	02	03	04	05	06	07	08	09	10
Cost saving in Sheep production	0.0	0.0	0.0	0.0	-0.8	0.4	2.7	4.9	6.9	8.9
Cost saving in tourism	0.0	0.0	6.1	7.1	8.2	28.4	20.9	21.7	22.3	23.0
Cost saving in rail freight	0.0	0.0	0.0	0.0	0.0	0.0	8.5	8.2	8.0	7.8
Cost saving in metal manufacturing	0.0	0.0	0.0	0.0	0.0	8.5	9.0	9.5	11.3	13.5

Source: CoPS, Insight Economics