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Economic analysis & strategy

Impact Monitoring and Evaluation Framework

Background and Assessment Approaches.

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CRC
AUSTRALASIA

CRC
ASSOCIATION

A report compiled by Deloitte - Insight Economics for the Cooperative Research Centres Association Inc.

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1.1 Project background and purpose

The CRCA has recognised that it increasingly important that CRCs are able to effectively and efficiently monitor their performance and articulate this performance to a range of stakeholders. In order to enhance the quality of these functions across CRCs and, to generate greater consistency in approaches and terminology, the CRCA has commissioned the development of a CRC monitoring and evaluation framework for use by CRCs when planning and managing their activities, undertaking performance reviews, and formulating new funding submissions.

This project has four core goals:

- To increase the overall level of methodological rigor applied in CRC performance (past and potential) assessments.
- To increase the level of consistency in performance assessment methodologies across the CRC Programme to better meet the expectations of Government decision makers.
- To simplify the process (and hence reduce the cost) of undertaking such assessments for individual CRCs by providing clear guidelines for acceptable evaluation approaches and clearly identifying the types of information that they should focus on collecting to support these evaluation processes.
- To establishing the Programme as a system wide leader in high quality and transparent performance measurement and reporting.

Compliance with increased quality and impact reporting requirements under the proposed changes to Australian research funding, under the RQF or a similar assessment mechanism, is not the purpose of this project. It is hoped, however, that the monitoring and evaluation framework will support CRCs in planning, collecting and interpreting data, in ways that consistently, comparably, and appropriately measure the effects of their research. With a likely increase in emphasis of program monitoring and evaluation towards impact and quality, identifying the ways R&D delivers benefits across the Programme will be a crucial process throughout the lives of both established and new CRCs.

The monitoring and evaluation framework consists of three parts:

1. a paper describing the background and approaches informing the monitoring and evaluation model;
2. a set of templates for inputs, activities, outputs, usage and impact that have been filled out with data from a hypothetical all sector CRC; and
3. a set of templates which can be used by CRCs in planning and carrying out data collection, and in organising this information to produce consistent statements about impact.

This discussion paper will provide a general overview of the approach to monitoring and evaluation – the input to impact chain – and the implications of this model for CRC assessment. An advantage of this framework is that it can be adapted to allow for different types of impact, and so can be used across CRCs in all six sectors. Section three of this paper outlines some of the different measurement approaches which may suit the different likely benefit channels appropriate to CRCs in these sectors.

This should not be regarded as a step by step guide that sets out all possible impact types; rather, it is best considered as a discussion of some of the most commonly seen elements of "chains" from inputs to impacts. It is clear that these should not be used as absolute classifications. For a particular CRC, not all of the suggested impacts will be relevant and there may be important impacts which are not included here.

1.1.1 Defining monitoring and evaluation

Monitoring refers to the ongoing process of collecting and using information to assess resource usage, and progress towards objectives, including delivery of outputs and achievement of outcomes and impacts. It usually involves assessment against agreed performance measures and/or performance indicators.

Effective monitoring and reporting should:

- provide managers with the knowledge they need to identify whether the implementation and outcomes of an initiative are unfolding as expected and to manage the initiative on an ongoing basis;
- provide other people involved in implementing the initiative with feedback about progress;
- meet the requirements for accountability for the expenditure of public funds; and
- inform decisions about future expenditure in conjunction with evaluation information.

When developing a monitoring framework, CRCs need to consider a range of matters including:

- specification of objectives;
- identification of existing reporting requirements;
- identification of any additional reporting that will be needed;
- development of performance measures and indicators;
- identify the existing baseline data available;
- setting of performance targets; and
- identification of data sources and data collection methods.

Evaluation refers to the formal systematic process of examining the context, design, implementation, and/or results of an initiative to determine as objectively as possible its relevance and/or performance, usually in terms of both effectiveness and administrative efficiency.

When developing an evaluation framework CRCs need to consider a range of matters including:

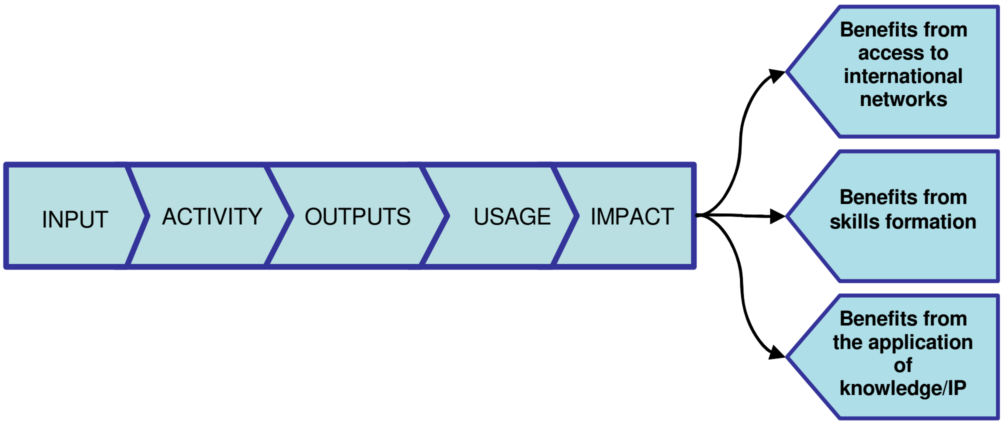
- identification of the intended users of the evaluation and their likely information needs;
- consideration of the type of the evaluation;

- consideration of how much focus needs to be on the cause-and-effect links underpinning the initiative;
- consideration of the timing of evaluation activity;
- identification of the types of data that could inform an evaluation;
- deciding how much contribution will be required from external evaluators and how much from internal staff; and
- estimating the budget allocation needed for the evaluation process.

1.2 Overview of benefit channels

The approach taken in developing this framework to help CRCs assess their impact is based on a model which identifies the process through which research leads to impacts on the end users of research as well as on the broader community.

Exhibit 1.1 The input to impact chain model, with multiple benefit channels



The input to impact chain model, by identifying the different stages leading to final impacts, involves a systematic grouping of information types. It allows, however, for the likelihood that research programs address different issues, and that this implies that the channels of benefit are going to vary.

The generic model sets out some potential classes of performance data at each stage. Determining which type of measurement is most appropriate for the particular program or project being evaluated will involve considering how it is expected that impact will be delivered.

Benefit channels may include:

- Benefits from the application of knowledge/intellectual property generated by the research.
- Benefits from access to international knowledge networks.
- Benefits from skills formation.

1.2.1 Benefits from the application of CRC generated knowledge and intellectual property

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

- industry development benefits through commercialisation of products based on CRC generated knowledge/intellectual property;
- performance gains and/or cost savings 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.
- non-market benefits enabled by CRC generated knowledge, including (but not limited to) gains in public health or social welfare, mitigation of environmental degradation, and improved capacity to deal with future challenges. Although it is often hard to assign a "market" value to these benefits, the economic value (particularly in a longer time frame) of these gains should not be ignored.

Some examples of potential specific indicators of impact through this benefit channel include:

- increased efficiency or productivity in an industry sector following the introduction of a new product or process generated by CRC research;
- reductions in expenditure in a public sector program, for example, spending on a particular section of the health care system, following the introduction of a new product or process;
- lower levels of environmental emissions or degradation among users of a newly introduced product or process based on CRC knowledge;
- improved safety in industrial production processes leading to reduced workplace accidents, and in turn reduced health costs and work-cover premium costs;
- current market value, level of employment, and/or turnover of spin-off companies established to commercialise CRC research;
- improved patient outcomes in a health program as a result of using a new product or process.

1.2.2 Benefits from access to international knowledge networks

Australia is a small part of the global economy – less than one per cent – and produces a small though significant amount of world research output (around two per cent of scientific literature). It is therefore crucial to develop and maintain strong pathways of access to internationally generated knowledge. By carrying out high quality research in Australia, and by building linkages and collaborative relationships with overseas researchers, Australia effectively gains a "seat" at the international R&D "table". In turn, this allows Australian researchers and end users early access to new knowledge. Examples of the ways CRCs may generate these benefits 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.

1.2.3 Benefits from skills formation

An important benefit occurring within CRCs is the contribution to research skill formation. In a context where skills are likely to be a critical factor in Australia's future capability and ability to respond to scientific and social challenges, this is a particularly important channel. Specific benefits include:

- 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.

Identifying the channels through which a CRC expects its work to have beneficial impacts is an important step in clarifying how its performance will be measured.

Working backwards from how CRC generated knowledge will have industry, government or community impacts, it is then possible to identify appropriate measure of where, and to what extent, research outputs have been used.

Clearly, this implies that suitable measures of output will be needed, as will data concerning the activities leading to this output. Finally, information about the inputs used in resourcing these activities takes us back to the "start" of the process.

This emphasises that all stages of the process from input to impact are linked, and should be consistent with one another, while recognising that the nature of appropriate measurements will be different along the chain.

1.3 Key challenges in measuring impact

Each of the above described benefit channels pose multiple measurement challenges that constrain the ability to fully quantify the specific benefits delivered from CRCs in Australia. Establishing a clear, verifiable, quantifiable and causal link between particular funded R&D and particular final economic impacts is an inherently difficult process due to issues such as:

- time-lags involved in the translation of research outputs into final outcomes for society may be considerable. It often takes time for the true quality and value of research to become apparent. For CRCs, which are expected to report on delivered impacts after seven years of operations, long time lags to innovation "pay-offs" is a real issue;
- difficulty in attributing outcome 'effects' to particular research 'causes'. The quality of research, the extent to which the knowledge is diffused to those in a position to

use the knowledge to generate impacts, and the ability of research users to extract full value from it will all influence the final impact of research;

- disentangling the contribution of research performed in Australia from research performed elsewhere when assessing the impact of research
- the fact that outcomes often require many non-research inputs for the "value" to be realised from the application of research;
- the lack of a contractual "paper-trail" in cases where public domain knowledge (such as that in academic publications) resulting from R&D may be taken up by many end users;
- some research outcomes with commercial potential are kept secret and are hence both unidentifiable and unmeasurable; and
- difficulties in attaching an economic value to outcomes in the environmental, health and social spheres where the outcomes are ends in themselves rather than means to deliver an economic value.

It is the presence of such challenges that often leads to reliance being placed upon top down "growth accounting"[1] approaches when the economic impact of research is being assessed. The problem, of course, with such top down approaches is that, by avoiding dealing with the above challenges, they do not establish a compelling causal connection between research and the economic impacts of the research.

While the challenges to clear measurement of impacts are numerous, two key issues which simply must be addressed when undertaking a performance assessment are:

- the *attribution* of impacts to particular causes; and
- determining the *additionality* of the impacts attributable to a CRC.

Attribution

When research does lead to success, the issue of attribution of this result is a substantial challenge. It is likely that many different groups can claim at least some responsibility for the research that lead to a particular breakthrough

Many R&D successes arise from multi-party long-term endeavours. Even if the value of particular outcomes can be approximated or modelled, there remains the challenge of linking the specific research efforts of one organisation (such as a CRC) to these results. To do this, it is necessary to determine the extent to which a CRC's research has been necessary to the outcome.

To demonstrate the difficulty of the "attribution" issue, it is helpful to consider the two extreme options. At one extreme, you could assume that if a CRC's research has been necessary (even if not sufficient) to a given outcome, 100 per cent of the impact should be "credited" to this CRC. At the other extreme, unless CRC activity has been both necessary and sufficient to generate an outcome, none of the impact should be "credited" to that CRC.

In a real world situation, it would be unlikely to find many impacts that can be solely attributed to one organisation or factor. This suggests that the first approach would risk over-estimation of the impact of any given CRC, by discounting the role of other factors in the generation of an outcome. On the other hand, the second approach would result in an unrealistically stringent exclusion of many benefits at least in part attributable to CRC

[1] Growth accounting refers to working backward from observed economic growth to apportion this growth to the range of factors that have contributed to it.

research. For that reason, we recommend a middle ground approach, which as far as possible assigns "credit" for an impact in proportion to the relative contribution to this outcome, while recognising that attribution will probably not be straightforward.

As a default, if the cost of inputs that the CRC has directed towards generating an impact is known and the cost of other inputs that other groups have directed towards generating the same impact is also known (most likely to be only known approximately), credit should be attributed in line with relative costs contributed to generating the impact. This default position should only be deviated from if a clear case can be made that the CRCs contribution was relatively more significant in generating the impact than its simple share of input costs would suggest.

Additionality

An important point to remember in the measurement of impacts is that the "true" effect of an innovative CRC generated output should be thought of as the benefit delivered *over and above* what would otherwise have occurred.

In general the Government should not provide funding to the private sector to do things that they would have done anyway without this Government funding. In such cases, public money would simply be subsidising private activity that would have occurred in any event. Such Government action would not be able to demonstrate *additionality* as it would not be causing any public benefit to occur that would not have occurred anyway without the Government funding.

Clearly, it is often not possible to make authoritative claims about the actual case in comparison with a counter-factual case. In many circumstances, the best that can be done is to compare what has actually happened with what could have been reasonably expected to happen – for example, an industry average, or a broad regional trend.

When assessing the additional benefit generated by a particular CRC, it is helpful to remember that in the counterfactual case, the resources expended on the CRC would have been used elsewhere. The key thing is how much greater the actual CRC's performance has been compared to the alternative use of these resources.

A useful standard counterfactual is that the government resources directed to a CRC could have instead been left with taxpayers by reducing taxes. The rule of thumb in this case is that for every dollar of taxation raised and then directed to a CRC, an initial twenty cents is lost from economic output. This is due to a range of factors such administrative costs, reduced incentives for private investment due to lower post-tax returns, transfer of consumption from private to public consumption, and a reduction in private savings due to a reduction in disposable incomes. What this means is that the first twenty cents in the dollar of returns that a CRC generates is required to simply return community welfare to where it would have been if the funding had been left with taxpayers rather than collected and directed to a CRC.

When considering how far the impact generated by a CRC is additional to what would have occurred in the absence of this program, it is important to be aware of the opportunity cost inherent in any action. When Government makes decisions on what actions to undertake, it must consider what the expected benefits are from the alternative actions that are available to it and prioritise its actions in accordance with the resources it has at its disposal. There is an "opportunity cost" involved in choosing to undertake a particular action. Opportunity cost is the benefit forgone from the best alternative that is not selected. Government, in choosing to use resources for one action is giving up the opportunity to use the resources to do something else. The case for an action therefore has to be based not just on the fact that it generates a benefit but rather on why its benefit is larger than that available from other uses of the resources.

Establishing a performance baseline is often important in assessment of additionality. The initial data against which performance measures or indicators are compared. Baseline data can be either static or dynamic. A static baseline is a fixed past measurement used for comparison. A dynamic baseline changes over time to show the projected value of an indicator in the absence of the intervention.

Another key mechanism for establishing additionality is the consideration of control group performance. In order to measure the size of a change resulting from research, it will be necessary to compare the performance of a group which *did* benefit from the introduction of a new product or process with that of a group which *did not* implement this innovation. This control group represents what would have been expected to happen in the absence of the research-generated improvement. Control group data may be from a group of users comparable to the "active" group, or it may be from industry or sectoral averages. In either case, the performance of the group affected by the research can be compared, as far as is possible, with the counterfactual case, to estimate the size of the actual impact. *For further discussion of control groups, see Appendix A.*

2 Framework for assessment

2.1 Impact evaluation model overview

The basic model of impact evaluation for this framework is based on the concept that, in order to assess the value of research, it must be possible to track the process along a chain, from inputs to impacts. It recognises that what is being measured (and the type of data required) will depend on the point reached in this process.

To track the progress of any project or program, it is important to establish a generic program logic (the input to impact chain) which articulates how, and by what mechanisms, planned activities will affect the intended impacts.

The evaluation model sets out what performance information is needed throughout the life of the project or program. This helps in planning, project management and monitoring, and retrospective evaluation of a project or program. Developing a framework at an early stage means that activities are linked at all stages along a chain from inputs to intended impacts.

This model of impact evaluation is a generic framework which can be adapted to research across a range of fields. This means that a consistent framework can be applied across projects and programs, but tailored so that important variations are captured. The exhibit below shows how the process from inputs through to impacts can be broken down into five stages.

Exhibit 2.1: Measurement along the input to impact chain

INPUTS	ACTIVITY	OUTPUTS	USAGE	IMPACT
People Infrastructure Money Prior IP Etc…	Research project Stakeholder engagement Monitoring and evaluation Training Etc…	Publications Prototypes Patents Databases Trials Products PhD, Masters, undergrad completions Etc…	External groups adapting/ adopting/ applying outputs. This may or may not involve a commercial transaction.	The outcomes from usage could include: Productivity gains, industry development, environmental benefits, health benefits, more options, etc…

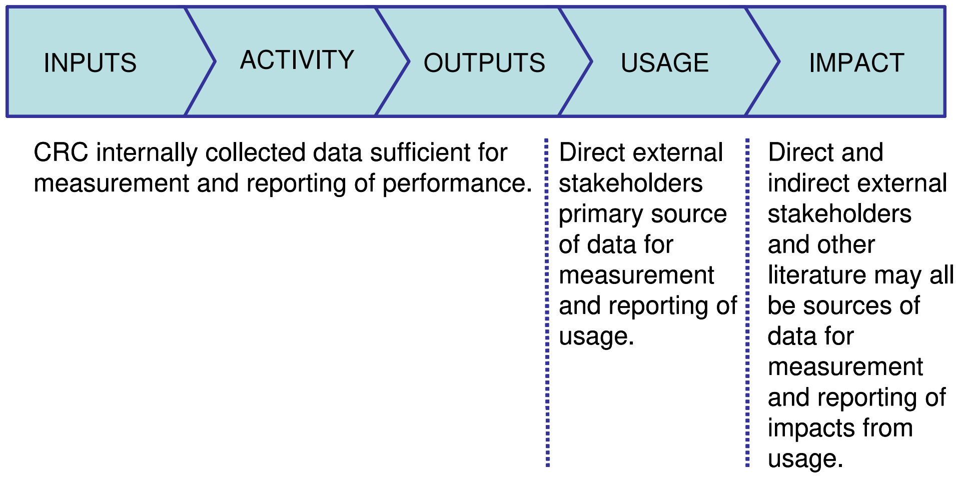
At each of these stages, the relevant performance metrics will be different; some of the key potential indicators at each stage are listed above. It is also likely that different measures will be more or less appropriate to each particular CRC.

- *Inputs* Measuring inputs will be essential in determining how much *net* benefit arises from research. Input measures are likely to include information about the resources committed to the project, including the people, infrastructure or facilities, financing, and IP.
- *Activity* Measuring performance in research activities is likely to involve data concerning projects, stakeholder engagement, monitoring and evaluation, training activities and so on. Collecting data about activities will require project managers to maintain information about appropriate performance measures. With research projects the key measures of activity will typically be the extent to which project milestones have been delivered upon.
- *Outputs* The appropriate output measure will depend on the nature of the research question and activity. Output types may include things such as publications, patents, trials, products, or course completions.
- *Usage* Measuring the ways external users apply research outputs may be more complex than the previous stages, which involve intra-organisation data. A key point at this stage is that the metrics of usage, and the data required, should be agreed upon as early as possible, so that the external users are able to keep accurate records of how research outputs are actually applied. If there has been proper planning, it is likely to be easier to gather consistent and relevant data from external users of the research or project outputs. Collecting information about how external groups have adapted, applied and adopted outputs is likely to require a balance between gathering enough to be representative, while minimising the coordination costs involved. One important factor will be to capture the significant information – from the large, important or influential users – without expending unnecessary energy on less useful sources. If the model has been used to specify the intended impact channels, usage can be measured against this. In addition, it will be important to gather at least some data about what other resources external users have incorporated into their use of the project outputs. This is so that there can be a credible attribution of the outcome to the project or program and so that benefits can be compared to total costs.
- *Impact* Quantifying the final impact of research is necessarily the most uncertain of the stages. Impact types, which may include productivity gains, industry development, environmental, health and social benefits, and value from broadening options, are not always easy to quantify. Many of these are highly contingent on future contexts. As well, in a real world situation, few of the outcomes we are considering – productivity gains, population health improvements, environmental benefits, etc – have only one cause. Even if it is possible to identify the other factors or resources involved in a particular outcome, it is unlikely that exact quantification will be viable. However, acknowledgement of the issue that other factors will likely contribute to an outcome, and a transparent attempt to account for it, is important in any impact evaluation.

At each of these model stages, the focus of measurement is different. This means that the types of information required are different; it also suggests that the process of collecting data, and using it in an estimation of effect, will not be the same along the whole input to impact chain. One important implication of this is that, even in cases where the final expected or intended impacts are highly uncertain, contingent or hard to quantify, we can still produce a rigorous assessment of the contribution of research by setting out clearly what are the intermediate processes and effects.

As the exhibit below indicates, sources of data along the inputs to impacts chain will vary.

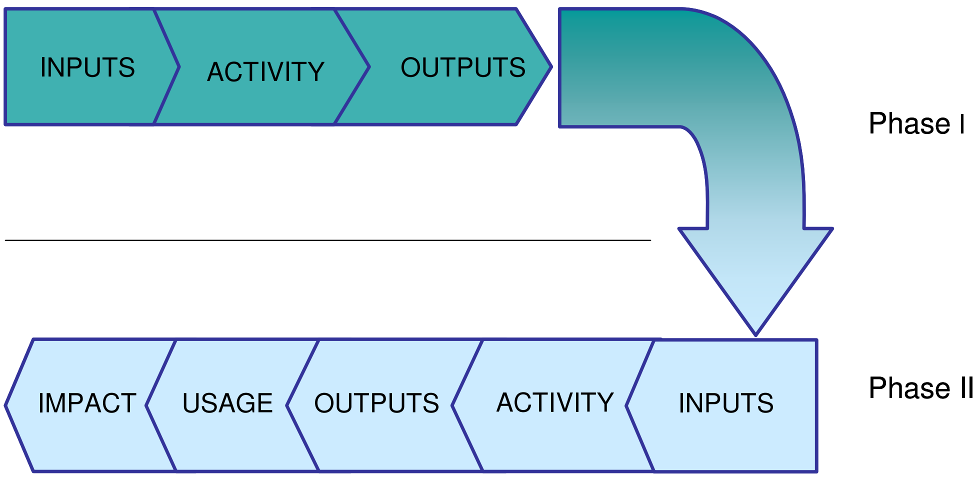
Exhibit 2.2: Sources of data along the inputs to impacts chain



2.1.1 Extending the model: phase I to phase II research projects

It is likely that, in many cases, the process from inputs to research outputs will be reiterated before there are industry or community impacts delivered. That is, for some research outputs – such as publications, patents, databases and graduations – the "external users" are likely to be other researchers, perhaps in the same organisation. The initial outputs then can be reframed as inputs to a follow on project.

Exhibit 2.3: Two-phase input to impact model



The activity and output measures will differ in the first phase from those in the second phase.

2.2 The key features of an impact evaluation model

2.2.1 Application of model at project planning stage

Identifying the intended impacts of a project leads to the development of appropriate performance measurements at each stage along the inputs to impacts chain. One benefit of this is that it clearly articulates the ways in which the project team expects to achieve its goals, with detailed intermediate metrics at each stage. This facilitates monitoring throughout the life of the project.

It is also important, in order to accurately assess the size of an impact, to be able to compare the situation "after" the application of project outputs with the "before" case. Early stage planning for the types of data which will be needed to evaluate the project when it ends means that these requirements are communicated to external users. Obviously, in order to be able to collect relevant data, it is necessary to tell these users what kind of information will be needed so that it can be recorded in the first place. Improving the accuracy and consistency of baseline data and "after" data will mean a more reliable evaluation of the true project impact.

2.2.2 Data availability and metric selection

In selection of performance measures/indicators, it is important to consider issues of:

- reliability, validity and credibility of the indicators; and
- cost-effectiveness in terms of cost to collect and process.

It is generally preferable that SMART (Specific, Measurable, Achievable, Relevant and Time-bound) indicators are used for monitoring and evaluation processes.

To ensure that the right performance measures and indicators are used, some useful checks that need to be made are:

- linking them to the logic model and the likely time frame for results;
- ensuring there are not too many indicators (so that too much time is spent collecting and not enough time on analysing and using) or too few (so that important aspects of performance are not included); and
- assessing the likely credibility of the measures and indicators to the intended users – including risks to its accuracy due to differing definitions, difficulties in collecting it, or disincentives to be accurate.

In terms of where performance data will be able to be sourced, there are generally three main types of sources:

- *administrative data:* information that is already being collected in administrative files or databases (for example data collected for the DEST Management Data Questionnaire), or could be collected with adjustments to regular processes;
- *primary data collection:* information that needs to be collected through specialised data collection exercises such as focus groups, file reviews, expert panels or surveys; and
- *secondary data:* data that have been collected for other purposes, but which could also be used in this context, such as national statistics on health or economic status.

Box 2.1 Management Data Questionnaire

To monitor the performance of individual CRCs and of the Programme as a whole, DEST requires CRCs to collect quantitative data to complement the financial information and qualitative data provided in Annual Reports. The Management Data Questionnaire (MDQ) asks CRCs to provide figures about its activities relating to output usage, research, and collaboration.

Data required in the MDQ:

Commercialisation/technology transfer

Patents maintained and filed
Research contracts and consultancies
Technology commercialisation agreements and spin offs
Student employment destinations
Publications and reports for end users
Training courses for end users

Research

Formal publications (using the Higher Education Research Data Collection definitions)
Research collaborations: project/staff numbers
Research programs aligning with socioeconomic objectives; personnel numbers
Locations of research activities and staff
Number and value of Commonwealth competitive grant funding awarded to CRC researchers
Research student information: course type, supervision by CRC staff, completions.
Undergraduate educational activities

Collaboration

Large, medium, small/micro companies
International collaborative alliances: country, organisation, collaboration type

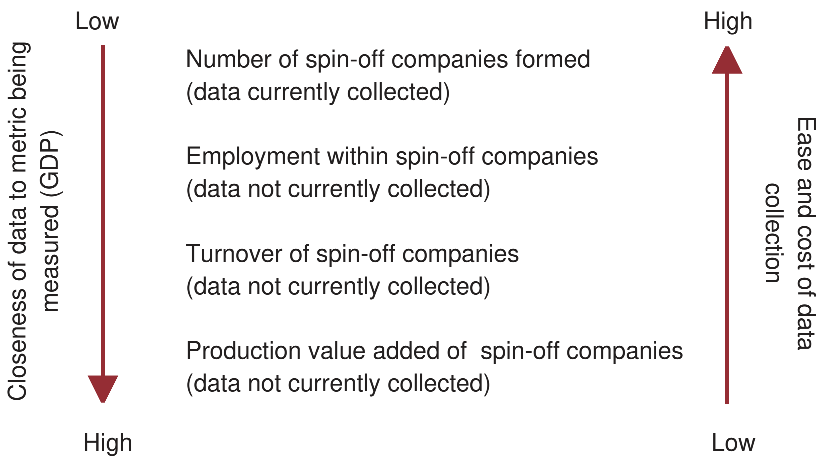
Source: DEST, June 2005, *Guidelines for 2004-05 Annual Reports*.

Box 2.1 outlines the data CRCs are required by DEST to collect as part of the MDQ. These figures include information about inputs (particularly staff numbers), as well as some key activity output measures, including the levels of patents, contracts, publications, partnerships and training activities. As suggested in the model underpinning this framework for impact monitoring and evaluation, many of the measures reported in the MDQ could be classified both as research activity outputs, and as inputs for a second phase research project. For example, a CRC's publications represent one output from a research program but the knowledge contained in these publications can also often be thought of as "inputs" into the next phase of a research program.

Since CRCs already collect the data reported in the MDQ, it makes sense for impact performance metrics to align with these.

The trade offs between accuracy and practicality can be illustrated by consideration of the different potential approaches that could be used to assess the material impacts of research that occur via the spin-off of companies from publicly funded research institutions. As Exhibit 2.4 indicates, the ease and cost of data collection is, in this case, inversely related to the closeness of the link between the metric being measured and the data being collected.

Exhibit 2.4: Balancing data relevance and cost of data collection



Source: The Allen Consulting Group (2004), *Measuring the impact of publicly funded research*, report to DEST

2.2.3 The evaluation process

By the time a program is ready to be retrospectively evaluated, the evaluation model will have ideally already been used in the project planning stage to identify intended benefits at the outset of the project and then work backwards to articulate how to get there, and what are the best indicators of performance.

In addition to the process advantages of this, it provides focus on the data needed to compare inputs with impacts right at the outset of project planning. The performance indicators identified can also serve as useful monitoring benchmarks.

The first three stages – measuring inputs, activities and outputs – generally are internal, that is, the information required will be found within the research organisation. This data should be regarded as the basis for any further assessment; there should be no excuses for inadequate specification or collection of performance data at these three stages.

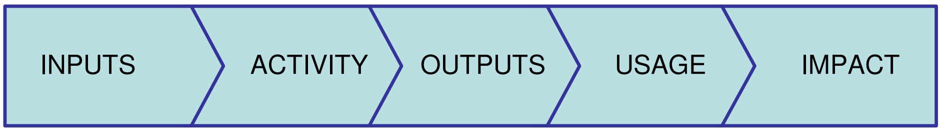
At the usage measurement stage, data collection is likely to be made more complex by the larger number of people and organisations involved. We should therefore be aware that, firstly, there cannot be the same hardline approach to information of this type. It is possible that there are going to be things out of the research organisation's control. At the same time, however, the collection of data will be made significantly more effective if it is properly planned, and the required measures have been clearly identified and communicated to likely output users.

As noted above, it may be hard to find verifiable and accurate measures for attributing impact, and this may affect some research areas more than others.

The key point is that, for data collected about actions in the first three stages of the impact process, there should be no excuses about shortfalls in performance information. For data concerning the fourth stage, and external user groups, proper planning will help in the collection of useful and relevant material. The identification of intended impact channels and the best ways of measuring these allows the best possible quantification of these outcomes. Even if there is a degree of uncertainty and imprecision at this stage, the rigorous foundation developed through the earlier stages will contribute to a useful and consistent evaluation.

The exhibit below summarises reasonable expectations for measurement along the inputs to impacts chain.

Exhibit 2.5: Measurement expectations along the input to impact chain



There are no excuses for failing to monitor and report against these three areas

In ex ante assessment it may be hard to be precise

In ex post assessment this should be relatively comprehensive

In ex ante assessment it may be very difficult to measure impact

In ex post assessment, while challenging, useful measures can be used

While we regard these expectations as reasonable, it is important to note that not every research impact occurs as part of a pre-conceived plan. It is not possible in every case to accurately forecast impacts, and to be ready to capture these impacts in advance. In reality, there are many factors, often outside CRC control, which may affect the impacts of research on the community. Research may lead to impacts that are in fact quite different to those that were originally envisaged. The above measurement expectations should therefore be viewed as a generally reasonable guide rather than standards that should always be able to be met.

3 Adapting the assessment framework

3.1 Tailoring the framework for the CRC sectors

The assessment templates provided in the *CRC monitoring and evaluation framework: templates* provide a framework which aids CRCs to plan and carry out the collection of data for the assessment of performance against intended impact goals. It is very clear, however, that the wide range of fields covered by CRC research, and the diversity of end users, means that the intended benefits – and therefore, the data needed to assess the delivery of these benefits – will vary substantially across and within CRC sectors.

In this section, factors specific to the assessment of research impacts in each of the six CRC sectors are considered. Some of the common challenges to measurement in each field are noted, as well as some likely types of benefits.

For each sector, a brief indicative example of CRC impact is provided, to demonstrate how the model may be used. These examples are necessarily heavily truncated versions of what a full input to impact chain description would entail and are provided only as examples of the way that the linkages in this chain can be described. Some notes are provided on where (and what type) additional information would strengthen the articulation of these input to impact chains. They draw only on *some* of the publicly available information surrounding these events and some data gaps have been deliberately left to highlight how the absence of certain information can weaken the presentation of an impact story.

Some generic sources of baseline data relevant to the various sectors are then listed. Many of these are significantly limited, and some have serious methodological constraints. At the same time, in many cases they are the most widely accessible, broad in scope and generally accepted sets of data available. They can be useful sources of information to provide a credible, if general, description of a sector or industry.

3.2 Agriculture and Rural Based Manufacturing

3.2.1 Common usage and impact measurement challenges

The measurement of research usage and impact in the agriculture and rural-based manufacturing sector is made more challenging by the characteristics of the sector. This includes a high proportion of relatively small businesses, with very heterogeneous patterns of adopting innovative products and processes. This can mean that it is harder to collect consistent and representative performance data.

Another key issue in the agriculture sector is the often significant time lags involved between commencement of research and the delivery of farm level productivity gains. Given CRCs are asked to demonstrate their delivered impacts after seven years, time lags to delivery can place some CRCs at a disadvantage relative to those operating in areas where time horizons to pay-off from innovation are shorter.

Also, when benefits from application of a new technology/variety/process do commence, these benefits may then persist for many years into the future. This raises the issue of appropriately discounting back future long run benefits into a net present value figure.

In the area of applied agricultural research, it may conceptually be relatively straightforward to assess the impact of the development of, for instance, a new crop variety. To do so it would be necessary to monitor the extent to which the new strain is adopted by farmers and to assess the changed value of the resultant crop when compared to the variety that had previously been planted. The difficulty lies here in the collection of adequate data, from both adopters and a non-adopting control group, to make an assessment of the impact. *For further discussion of sampling issues, see Appendix A.*

Another challenge, particularly applicable to the agricultural sector, is that it may be hard to distinguish impacts from innovation from impacts caused by other factors. For example, the performance of farmers over the short to medium term can vary very substantially as a result of external causes such as drought.

The inherent uncertainty of the agricultural sector can also mean that many of the benefits delivered by R&D will be contingent on essentially unpredictable environmental or weather factors. To some extent, forecasting and management can help to mitigate the impacts of climate variations such as drought, floods, or infestation, and R&D is likely to be an important contributor here. While such research may deliver benefits to the agricultural sector by reducing negative impacts in the case of such external shocks, it is clearly not going to be the only factor. While research may have a measurable impact if such an event occurs, it will be hard to measure this if the drought or flood doesn’t occur; this does not mean that it has no benefit. Similarly, if the contribution of innovative processes or products is to lessen damage that would otherwise have occurred, it may be hard to identify the extent of this impact – but again, it should not be ignored.

Another factor which may pose a challenge in the measurement of impacts generated by agricultural R&D is that, unlike the target user community in some other CRC sectors, the uptake of innovative products and processes among farmers is very varied. Many studies have focused attention on the variability of risk aversion amongst farmers – and therefore variability in the adoption of new technology – among Australian farmers.[2] The difficulty here, for a CRC attempting to estimate the extent of use for its research output, is that data based on a trial is likely to be significantly skewed. As discussed in the note on sampling issues (see appendix A), farmers who generally innovative are probably going to self select into trials of innovative products or processes. This means that, while, the results of such a trial will reflect the usage and impact levels of this particular group of farmers, this group may differ in important characteristics from the general population of farmers. Not only would it be misleading to judge average adoption of innovative technology based on the results from those farmers who participate in trials of CRC generated technology, but it is likely to be difficult to extrapolate in a meaningful way.

In the absence of comprehensive data collection in relation to the uptake of new technology by farmers, it is necessary to estimate likely levels of adoption through knowledge of details such as the areas of suitable soil types and climatic zones for application of the innovation, understanding of the nature of the technology (e.g. its complexity) and evidence from adoption rates of past analogous innovations.

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[2] Abadi Ghadim, Pannell & Burton, 2005, Risk, uncertainty, and learning in adoption of a crop innovation, Agricultural Economics 33.

3.2.2 Types of benefits from agricultural and rural based manufacturing research

The benefits generated by research in this sector may include

- Development of crop or animal strains that can produce more sellable product for the same level of inputs. Quantifiable measures of this may include
  - Value of additional production resulting from improved practice, plant varieties, livestock genetic improvements, disease resistance, etc.
  - Cost savings from reduced fertiliser use
  - Cost savings from reduced water use
  - Cost savings from reduced feed use
- Greater efficiency of use of natural resources. For example, developing locally viable crops which are less costly (both in monetary and environmental terms) to cultivate can lead to the planting of crops that grow faster and require less inputs to support their growth.
- Increased stability of output and hence, farm sector income. The development of crop or animal strains or cultivation processes which are less vulnerable to external shocks such as drought or changes in export markets.
- Reduced environmental impact. For example,
  - improved processes reducing salinity (may be measured in reduced concentration at a particular site); and
  - advances in fertiliser requiring lower quantities to be used with no adverse effect on output.

3.2.3 Indicative impact example

Beef CRC

Context

The CRC for Beef Genetic Technologies is the current incarnation of the Beef CRC, which has run since 1993. The Centre has focused on improving the quality of Australia's cattle and beef, through genetics research aiming to enhance breeding programs and disease management, as well as through activities aiming to improve beef producer marketing.

Inputs *Here it would be helpful to describe the exact contribution of the relevant partner – in this case, the MLA. The number of researchers involved in the relevant research program should also be indicated.* The Beef CRC, over its first two rounds, had total cash funding of over $60 million, of which approximately half was in CRC Programme funding with the remainder from State governments, universities, and industry partners. From 2000-01, Meat and Livestock Australia (MLA), has been an important partner. Over the 1993 to 2005 period, the average number of FTE researchers per year within the CRC was between 30 and 35.
Activities *Details of the research programs leading to the relevant outputs should be described.* The Beef CRC's research has included work to improve feed efficiency, maternal productivity, and better parasite control, in addition to its broad program of beef quality improvement through genetic technology; however, resources have been skewed towards this latter aspect. Among the CRC's activities to improve the quality of Australian beef, and the profitability of the beef industry, two key elements were the development of genetics technology to identify cattle with desirable marbling and tenderness characteristics, and the role played in developing the Meat Standards Australia (MSA) Grading Scheme, which provides a consistent measure of meat quality.
Outputs *Specific details of the outputs should be provided.* The genetics research resulted in five patents for gene marker technology. The MSA grading scheme was introduced in 1999-2000. The scheme is a voluntary grading system aiming to improve consumer knowledge about beef quality and characteristics. MSA certified beef is processed according to standards, and carcasses are labelled according to breed content, meat colour, fat depth, marbling, maturity and ultimate pH. The meat is then given a three, four or five star rating based on value, days of ageing required, and appropriate cooking methods.
Usage *Data about usage of research outputs is likely to be obtained from the external end user.* The gene marker technology was commercialised by Genetic Solutions Pty Ltd as the GeneSTAR Gene Markers. The Gene Marker technology has sold well, with CRC estimates of 20 per cent penetration of the relevant breedstock herds. Technology of this kind contributes to beef producers ability to manage and improve the quality of their stock, an essential part of a improving beef quality. In relation to the MSA system introduced in 1999-2000, by June 2005 the annual number of carcasses graded under the MSA system reached 626,000, which represents around 8 per cent of total cattle slaughtered (7.58 million in 2005-06) in Australia.

Impact

This information describes the effect of using research outputs in the broader community. If appropriate, there should also be some discussion comparing the costs of the innovation to the benefits it generated – its "additionality". The appropriate attribution should also be considered.

The Beef CRC and MLA have attempted to measure the impacts of their programs to improve beef quality and beef grading. One of the key indicators of value added is to compare the prices of MSA-graded meat compared with non-MSA-graded meat. It is estimated that, based on a pricing survey from 2005, MSA graded meat carried a national average retail premium of $2.18 per kg. Applying the 2005 premia across the different cuts to the number of carcases known to have been graded from 1999-2000, the retail value of MSA grading is found to reach $39 million by 2004-05, with a cumulative value of $159 million in 2005 dollars.

The suite of Beef CRC research work has clearly been an essential part of the value generated by the MSA and the associated technologies which have improved the quality of Australian beef. The MLA spent approximately $81 million on its Meat Standards eating quality program, of which only a very small amount (~$5.5 million) was for the Beef CRC. However, the MLA is the core industry partner in the CRC, and it is reasonable to suppose that a significant portion of the underpinning science for the MSA program was generated by the Centre; a case could therefore potentially be made for attribution of higher share of the overall impact to the CRC than would be suggested by a purely proportional relationship between Beef CRC inputs into the projects and total Beef CRC and MLA inputs to the project.

3.2.4 Agricultural and rural based manufacturing data resources

ABARE

ABARE's farm surveys collect detailed financial, physical and socioeconomic data for the agricultural, grazing and dairy sectors. This is presented in the triennial summary publication, *Australian Farm Survey Results.* Despite limitations associated with the survey data collected, it is the most comprehensive source available.

Specific information is released in the beef, grains, wool and lamb reports, and is presented in the interactive Agsurf package, which can be accessed at http://www.abareconomics.com/interactive/agsurf/index.htm

Data in the *Australian Commodities* quarterly releases covers production and trade in agricultural subsectors, including summer and winter grain and oilseed crops, industrial crops, livestock slaughter and meat production, livestock products, forestry, and fisheries, as well as energy, minerals and metals.

ABS

A wide range of agricultural statistics can be found through the ABS Agriculture theme page.

The ABS' *Australian Industry* (cat.no. 8155.0) provides key figures for agricultural and manufacturing businesses, broken down into detailed subsectors by ANZSIC division.

Tabulated data about rural manufacturing is more difficult to access. *Manufacturing in Australia* release (ABS cat.no. 8221), contains general manufacturing data by state and territory. The quarterly *Manufacturing Indicators Australia* (cat.no. 8229) presents key performance indicators of the Australian manufacturing industry, including income from sales, inventories, employment, capital expenditure, Performance of Manufacturing Index (PMI), and value of manufacturing exports and imports.

Other data relating to manufacturing industry subsectors can be accessed by following the Manufacturing theme on the ABS website, at www.abs.gov.au. The *Australian Industry* (cat.no. 8122.0) provides key figures for manufacturing businesses by ANZSIC class.

The ABS uses ATO data to produce figures about businesses, broken down into industry divisions, by statistical divisions and local government area. However, there is no regular publication which presents these data. It may be helpful to go to the ABS' Regional Statistics theme page, where some information is available about the characteristics of manufacturing businesses, searchable by SD or LGA.

Bureau of Rural Sciences

The BRS is the scientific branch of the commonwealth Department for Agriculture Forestry and Fisheries. It produces a wide range of data and tools, with a focus on scientific measures, covering the agricultural, food, fisheries and forestry industries.

National Agricultural Monitoring System

http://www.nams.gov.au/

The National Agricultural Monitoring System (NAMS) is an RBS tool which contains a range of climatic and production information for dryland/broadacre industries, for over 600 regions throughout Australia.

3.3 Environment

3.3.1 Common usage and impact measurement challenges

It is well recognised that the quantification of the environment presents significant challenges. Many CRCs generate benefits which can be assigned a market value, and in such cases it is often possible to determine an economic impact value for these benefits. This is considerably more difficult when considering benefits to which we cannot easily attach a short term market value, such as improvements (or reductions to degradation) of the environment; this is not to say that these benefits are intangible, or do not have any economic impact.

"Valuing" the environment in monetary or economic terms is still an evolving challenge. One indicator of the international importance placed on research into the environment can be seen in levels of expenditure; for example, the European Union has committed 2.1 billion Euros between 2002 and 2006 to its sustainable development, global change and ecosystems thematic priority.

Approaches to attaching value to non-market goods such as ecosystem quality entail using methods such as revealed preferences and contingent valuation, which are open to debate. The central difficulty of revealed preference approaches, such as hedonic pricing or travel cost pricing, is that, given their basis in market goods, it is unclear how useful prices derived in this way are when applied to non-market goods such as biodiversity, sustainable practices, or increased capacity for abatement technology innovation. However, these methods can certainly be indicative, and there is a fairly solid body of work using them to create shadow "markets" for non-market goods such as clean air or national parks. The other set of valuation techniques, the contingent valuation methods, are perhaps even more open to argument. While these are one of the few commonly used tools to assign monetary value to environmental amenities which have no obvious market or "use" value, they require significant caveats. Relying on survey or referendum techniques, these tools may be indicative but should be used with care.

Alongside ongoing work attempting to “value” the environment, as well as debate about whether this is indeed an appropriate approach, what is clear and economically quantifiable is that the direct costs associated with fixing environmental damage can be very high and that research that mitigates against environmental damage can therefore deliver high value.

Measuring the impact of using CRC generated knowledge for environmental benefits is often made more challenging because there is frequently either no or very limited scientific or demographic baseline data – this means that current levels of environmental health or degradation cannot be compared with historic levels. In many cases, this is a result of less interest in the widespread measurement of environmental indicators in the past, and it is likely that the situation has and will continue to improve as environmental awareness increases.

Another challenge in measuring the impacts of environment focused R&D is that, as with any complex problem, the contributions of any one research group are unlikely to have effected the whole of any change. That is, even if a change in environmental outcomes can be observed, it may be difficult to determine the contribution of a particular CRC.

The contingent nature of benefits associated with environmental R&D also make measurement significantly more challenging. For sectors where benefits are largely delivered in a short time frame, issues of uncertainty are less important; when dealing with environmental research, however, the time frames are long, and any benefits are uncertain and highly contingent. While no amount of research effort can guarantee a particular outcome, in the long term, this does not mean that we cannot assign a value to present day R&D, based on the expected future value of environmental improvements generated by CRC knowledge.

The core focus of most environment CRCs is on building understanding of the environment and in particular the impacts of human activity on ecosystems. In many cases, this knowledge is utilised in the formation of management policies for such ecosystems. Doing the best possible in the present to assure the future wellbeing of these ecosystems, may, in turn, flow through to measurable economic effects on industries such as tourism and fisheries.

The underlying goal of most environmental research is to mitigate the risks of significant, perhaps irreversible, degradation occurring. However, even the most stringent environmental management policies can not guarantee that environmental degradation will not occur. Natural events such as cyclones, earthquakes, tsunamis or disease outbreaks have the potential to inflict enormous damage to ecosystems, and it can not be known if such natural events will occur in the future. Therefore, any future estimation of the effect of environmental research is contingent on what “natural” events may or may not occur to impact upon them. Nonetheless, the fact that the benefits derived from improved environmental practices may be contingent on unforeseeable events does not mean that these should not be assigned some expected future value in the present.

Similarly, an estimate based on current knowledge about likely future outcomes in the presence or absence of improved environmental practices cannot capture the impacts of these practices in the event of unpredicted environmental change. Given the high levels of scientific uncertainty in many of these areas, it is likely to be very difficult to assign precise values to these future impacts.

3.3.2 Types of benefits from environmental research

The benefits from environmental R&D can be thought of both in terms of the intrinsic, scientific improvements, and in terms of economic measures. These benefits may include:

- Lower carbon emissions resulting from research generated technology advances
  - The introduction of a carbon price, whether via a tax or a carbon credit trading scheme, will allow a reduction in emissions can be given a clear economic value. It is anticipated that a price somewhere in the $10 - $25 per tonne of carbon dioxide range is likely within the next five to ten years.
  - From a scientific perspective, lower carbon emissions may be measurable in terms of lower aggregate emissions (less likely to be a viable measure, though, as carbon is a global pollutant)
- Reduced water usage, arising from CRC generated knowledge leading to better agricultural practices, or improved crop strains requiring less water.
  - Current estimates of the long run costs of urban water put prices at anywhere between $1.20 to $1.50 per kilolitre (or $1,200 to $1,500 per megalitre). In rural areas, irrigated water is currently somewhat cheaper, although the introduction of water trading has meant higher (and more variable) market prices. For example, in late 2006 permanent water entitlements were trading for $700 per megalitre in the Murrumbidgee, $900/ML in the Lower Murray, and for as much as $3000/ML in the Hunter Valley. Temporary permits are also traded, usually at significantly lower prices. It appears, however, as if the cost of agricultural and industrial water is likely to continue to increase, particularly if Government buy-backs of entitlements are implemented. Reductions in water consumption therefore may deliver substantial economic benefits. As well as reducing producers' input costs, a trading scheme allows some revenue to be generated by selling excess entitlements.
  - Reduced water usage may also be measured in environmental terms, perhaps in improved river health, in lower levels of salinity in a particular area, or in increased biodiversity.
- Environmental research may contribute to increased productivity of agricultural land, both in the short and longer terms. For example, in the shorter term, research may develop improved strains of crops more tolerant of local conditions (and therefore needing less fertiliser, or less water); in a longer time frame, the reduction of salinity or erosion, or the maintenance of biodiversity, are likely to contribute to the future productivity of land.

3.3.3 Indicative impact example

eWater CRC

Context
The eWater CRC was formed in 2006 following a merger of the earlier CRCs for Catchment Hydrology and Freshwater Ecology. The Catchment Hydrology CRC ran, in two versions, from 1992 to 2005, when it became the new from existing eWater CRC.

Inputs *Details of the resources used in the relevant research or development activities should be described here.* The original CRC's Urban Hydrology research program involved the development of an urban water-balance model (Aquacycle) that simulates scenarios for storing and reusing stormwater and wastewater, and of a pollution 'mass balance' for three urban catchments to help managers identify pollutant sources more effectively. The CRC also piloted a new short course for the industry to inform them about recent advances in stormwater management techniques and to provide them with the necessary training to design stormwater management facilities. This research was a key input into the later development of the Centre's stormwater modelling and decision support toolkit. The original level of support for research at the second round CRC was $46 million in cash and in kind contributions, across all programs.
Activities *Specifics of the research program activities should be noted, as well as non-research activities such as the development of training courses for industry.* Based on the earlier CRC research, the second round CRC for Catchment Hydrology had two programs in this area, Predicting Catchment Behaviours, which focused on creating software and applications to support management decisions, and Urban Stormwater Quality which involved the scientific assessment of stormwater treatment and drainage systems.
Outputs *Details of the research outputs should be described here. In this case, it would be helpful to have some more precise information about the MUSIC software, as well as about the industry training courses developed by the CRC.* Based on these research programs which integrated water quantity and quality measures, and stream ecology and economics approaches, the CRC for Catchment Hydrology developed the MUSIC software, a technology which provides modelled management scenarios to support planning of future works and development of catchments and stormwater treatment systems.
Usage *Data about usage levels may need to be collected from external users.* At the end of 2004, over 400 individuals had downloaded the latest release of MUSIC (v.2) and over 250 licences had been issued. Over 650 attended Industry Seminars run by the CRC surrounding the release of MUSIC, and over 120 had attended training courses. The Brisbane City Council and Melbourne Water have made extensive use of the MUSIC decision support tool, which has also been used by engineering consulting firms such as EarthTech, Ecological Engineering, Sinclair Knight Merz, and WBM.

Impact

Impacts may include both monetary benefits, and non-economic benefits.

Use of MUSIC software by urban stormwater planners (Melbourne Water; Brisbane City Council) has helped reduce water infrastructure costs by up to 50 per cent while maintaining water quality. In Melbourne, the annual inspection, maintenance and upgrade costs for the urban drainage system are approximately $16 million.[3]

The case for the impact of the MUSIC software could be more compellingly presented if more detail from the user could be presented, for example, if it was possible to say "following use of the CRC output, Melbourne Water's annual inspection and maintenance expenditure has fallen by $xx"

In addition, the increasing market acceptance of Water Sensitive Urban Design, facilitated by tools such as the MUSIC software, will allow urban water systems to be designed and maintained with less environmental impact. For instance, improved stormwater drain design acts to reduce run-off into waterways.

If scientific measurements of this improvement would create a stronger case; for example, an improvement in water quality at a site affected by a system planned using MUSIC.

3.3.4 Environmental research resources

ABS

The ABS now compiles data for a number of metrics relating to biodiversity and the quality of land, air and inland waters. Measures for the quality of marine systems appears to be more limited, with no first order metrics apparent. In most cases, these data are available by region.

A useful summary publication is *Australia's Environment: Issues and Trends* (cat.no. 4613.0), which collates selected environmental statistics relevant to topical issues. Other ABS releases can be accessed through the Environment and Energy theme link.

Examples of first order metrics for the environmental dimension include:

- number of extinct, endangered and vulnerable birds and mammals – while numbers of extinct species remained steady from 1993 to 2001, the number of species classified as endangered or vulnerable has increased considerably;
- the annual area of land cleared – hectares cleared per annum has increased from around 370,000 to 470,000 per annum during the 1990s;
- days that fine particle concentrations in selected urban areas exceeded health standards – the number of days healthy levels were exceeded has declined fourfold since 1994;
- areas with high potential to develop dryland salinity – the National Land and Water Resources Audit has assessed current levels at 5.7 million hectares and forecast a threefold increase to occur by 2050; and

[3]http://www.melbournewater.com.au/content/drainage_and_stormwater/the_drainage_system/the_drainage_system.asp?bhcp=1

- proportion of water management areas and units where use exceeds 70% of sustainable limits – in 2000, 15 to 20 percent were assessed as highly developed and over 10 percent were assessed as overdeveloped.[4]

In addition to the above first order metrics, data relating to a number of more particular second order metrics are also collected by the ABS, including:

- cattle and sheep numbers;
- plantation forests;
- native forest tenure;
- Australia's greenhouse emissions – these rose by 17 percent between 1990 and 1999;
- Murray-Darling basin water diversions;
- urban water use rates;
- fisheries production data;
- oil spill sightings and national plan responses; and
- coliform (certain bacteria) density at beaches.

Some other relevant ABS publications include

Water Account Australia triennial publication, ABS cat. no. 4610.0

Energy Statistics, Australia, 2001-02 (cat.no. 4649.0.55.001)

Salinity on Australian Farms, 2002 (cat.no.4615.0)

Year Book Australia annual publication which has included up to date statistics about energy and natural resource use as well as environmental attitudes.

National Pollutant Inventory

http://www.npi.gov.au/index.html

Information on the types and amounts of pollutants being emitted, by location, substance, source and facility (grouped into industry sectors). Emissions are self-reported by larger facilities and are estimated by state and territory governments for small facilities and mobile sources.

Department of the Environment and Water Resources

A useful search engine to government held databases can be found at http://www.environment.gov.au/metadataexplorer/explorer.jspA

The department maintains many databases containing information about Australian flora, fauna, soil, water etc..

http://www.environment.gov.au/index.html

Australian Greenhouse Office

http://www.greenhouse.gov.au/

The AGO implements Australian Commonwealth climate change policy. One of the most useful datasets available from its website are published as *Australia's National Greenhouse Accounts*. These reports set out Australia's greenhouse gas emissions in aggregate as well as by state and industry.

[4] ACG, 2004, *Measuring the impact of publicly funded research*, report to DEST

National Land and Water Resources Audit

http://www.nlwra.gov.au/

The NLWRA was carried out between 1997 and 2002; it was established to:

> "provide a baseline for the purposes of carrying out assessments of the effectiveness of land and water degradation policies and programs…. [and]…. to improve Australian Government, State and regional decision making on natural resource management."

Reports based on the audit data are available from the website, and the BRS maintained dataset can also be accessed. This data is held in the Australian Natural Resources Data Library; all information is accessible and may be downloaded.

http://audit.deh.gov.au/ANRA/atlas_home.cfm

3.4 Manufacturing Technology

3.4.1 Common usage and impact measurement challenges

While the ways in which research and development can generate benefits for the Manufacturing sector are relatively straightforward, there are still likely to be some challenges in collecting data to measure this. One of the most important, which is likely to affect CRCs in this sector more than those in some others, arises from commercial confidentiality. In manufacturing industry sectors, users of research generated innovation are likely to be private sector businesses, for whom the benefits of adopting new products or processes are, principally, that they lead to a commercial advantage over competitors. Industry CRC participants or users of CRC generated research may therefore be constrained in the amount of data they are able or willing to provide to CRCs for monitoring and evaluation.

The need for confidentiality, however, must be balanced with CRC monitoring data requirements. To maintain appropriate levels of commercial confidentiality while still collecting data required, CRCs may find it helpful to agree to:

- anonymise any data provided;
- only use aggregated data (where multiple parties are supplying data); and
- sign confidentiality agreements.

Using a monitoring and evaluation framework to identify data requirements at an early stage is likely to make this process easier.

3.4.2 Types of benefits from manufacturing research

Commonly, benefits in this sector are in the material sphere, and data about activities, outputs, usage and impacts will be found here also. When compared with the types of benefits delivered in other CRC sectors, particularly those where the impacts are largely intangible, non-market goods, the benefits from manufacturing research appear relatively amenable to quantification and valuation.

Improvements in manufacturing will take the form of increases in the quantity and quality of the goods and services available to society, arising from better use of physical capital, more productive labour, and the development of new or improved products.

Some of the ways that research can contribute to these advances may include:

- increases to the quality and efficiency of use of physical capital, as research leads to improved physical equipment, for instance, a better metal stamping press, or new production processes that allow more products to be produced from a given piece of physical capital;
- increasing the productivity of labour, directly through the training of researchers who then apply their skills within industry, and indirectly through research into management practices that can lead companies to better manage their workforce to improve productivity; and
- the creation of new products through applied research or indirectly to the creation of new products as basic research pushing out the technological frontier and allowing things that were previously technologically impossible to be created. The latter process requires action by both research producers and, just as importantly, research users who take research outputs and translate them into new products.[5]

In relation to skills formation, one approach that may be viable for tracking impacts is to collect information from postgraduates as to both their employment destination and their starting incomes. This information could be compared to the average level of income associated with a particular qualification in Australia (Gradlink provides data on employment and wage outcomes each qualification level in Australia). If CRC graduates secure higher salary levels than the average, this could provide evidence of the skills formation "additionality" occurring through the CRCs activities.

3.4.3 Indicative impact example

CRC for Advanced Composite Structures

Context
The CRC for Advanced Composite Structure (CRC-ACS) was established in 1991, and is currently in its third round of funding. CRC-ACS generated knowledge was a factor in Hawker de Havilland (HdH) winning its bid for a major contract to supply composites technology for the Boeing 787.
Inputs
If possible, details of the IP portfolio would be useful here. Information about where in the CRC staff and financial resources are directed would also help.
The reasonably long lifespan of the CRC means that it has generated a significant IP portfolio. In most of the Centre's research contracts, leverage of this IP is a crucial factor. The CRC-ACS core industry partner, Hawker de Havilland (HdH) has invested around $17 million in advanced composites R&D at the CRC, and the CRC-ACS provides an important portion of the company's R&D.
Activities
Details of the CRC's research and other activities, including relationships with partners should be included.
The CRC-ACS has two broad sets of activity, R&D and research contracts. This is often in conjunction with an established industry partner such as Hawker de Havilland, who have incorporated many of the CRC's research outputs as well as contracting in CRC experts. The CRC-ACS' Aerospace program involves a significant proportion of the Centre's 30 researchers.

[5] ACG 2004, *Measuring the impact of publicly funded research*, report to DEST.

Outputs *Specific information in relation to the research outputs arising from the above activities should be discussed here.* A range of innovations have been developed by the CRC-ACS that relate to the 777 rudder, 777 elevator, FA-18 E/F flaps, and the A330/340 main landing gear door. These innovations include improved techniques of process simulation, postbuckling design, liquid moulding manufacturing, DDF (double diaphragm forming) technologies, birdstrike simulation, and new design optimisation tools.
Usage *Note that where there is a single end user, details of usage are much easier to obtain. Data about the CRC-ACS' research contract activity has not been included below as it involves many companies.* A range of innovations developed by the CRC-ACS have been applied by Hawker de Havilland to existing contracts, including improvements to the 777 rudder, 777 elevator, FA-18 E/F flaps, and the A330/340 main landing gear door. CRC-ACS technologies were a significant factor in the HdH proposal for securing the contract to provide innovative wing moveable trailing edge components for the Boeing 787. 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.
Impacts *Even though not all of these impacts have been realised, it may be useful to provide some contextual information which indicates the scale of the forthcoming benefit. The CRC-ACS has also explicitly considered the attribution of credit for these impacts.* 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, significantly as a result of the CRC-ACS generated knowledge. The HdH contract with Boeing has the potential to provide substantial flow on benefits to the broader economy and community. HdH estimates that by 2013, production of components will have reached its full rate, employing 250 skilled workers, and potentially flowing on to as many as 3,300 additional Australian jobs. The CRC notes that in the context of the composites industry, and the inherently high costs of implementation and development of innovative technologies, it takes a conservative approach to attribution, and generally claims around five to ten per cent of credit for impacts relating to its role in HdH securing and delivering upon major contracts.

3.4.4 Manufacturing data resources

Australian Industry Group

The Australian Industry Group produces a monthly report on the status of manufacturing in Australia, the *Performance of Manufacturing Index* (PMI). This presents up to date, aggregated figures for the major industry groups in the manufacturing sector.

AIG also publishes quarterly *Australian Business Monitors*, which provide snapshots of economic conditions in six sectors

- paper and printing;
- construction materials;
- commercial construction;
- basic metals;
- fabricated metals; and,
- machinery and equipment sectors.

The *PMI* reports and the *Australian Business Monitors* can be downloaded from the AIG website, http://www.aigroup.asn.au/

IBISWorld

IBISWorld produces reports containing detailed statistics, analysis of trends and forecasts for 164 manufacturing subsectors.

Reports are regularly updated, and can be purchased from http://www.ibisworld.com.au/

ABS

The ABS collects large amounts of data relating to the manufacturing sector. A key document is the annual *Manufacturing in Australia* release (ABS cat.no. 8221), which contains data on wages and salaries, sales and service income, and industry value added classified by industry. It also includes industry data classified by state and territory.

The quarterly *Manufacturing Indicators Australia* (cat.no. 8229) presents key performance indicators of the Australian manufacturing industry, including income from sales, inventories, employment, capital expenditure, Performance of Manufacturing Index (PMI), and value of manufacturing exports and imports.

Other data relating to manufacturing industry subsectors can be accessed by following the Manufacturing theme on the ABS website, at www.abs.gov.au

The *Australian Industry* (cat.no. 8122.0) provides key figures for manufacturing businesses by ANZSIC class.

3.5 Information and Communication Technology

3.5.1 Common usage and impact measurement challenges

One of the most significant challenges associated with measuring R&D in this sector is that ICT is often embedded throughout the economy and society. This includes the increasing depth and sophistication of ICT use through diverse spheres including large and small business, public sector infrastructure including health, education, transport, defence and in private use. As well, as an enabling technology, ICT plays an important role in research in fields including the physical and social sciences, engineering, and biotechnology.

The challenge of estimating the impacts of public ICT research is in some ways analogous to the challenge of trying to get a handle on the size of the ICT sector itself. ICT is the major enabling technology of our times and therefore is incorporated into many sectors and activities that are not “labelled” as ICT. In a similar way, ICT R&D is an aspect of R&D in many research fields that are primarily described in other terms. Significant levels of ICT

R&D in Australia are now conducted outside the traditional ICT industry, in financial and insurance services, industrial machinery, marketing and business management services, cultural and recreational services and scientific research. In addition, there is substantial spending on fields of research broadly related to ICT such as electronics R&D, manufacturing R&D, and materials R&D, as well as increasing proportions of multidisciplinary research in which ICT plays a central facilitating role.

In terms of capturing the usage of ICT research outputs, one implication of this is that it could be harder to collect data from users who are spread across a wide range of industries, sectors, and activity types. It is very likely that the most important way ICT innovation can generate impacts in user groups is going to be both through the development of technologies, and through the user groups themselves having the skills to apply these technologies. Therefore, it is possible that the role of a CRC will need to be considered beyond the simple development of products, and that activities in training and user support should also be seen as having potentially significant impact.

There are likely to be challenges in definitively measuring the role ICT innovation has played in any performance outcomes. By its nature, an enabling technology form such as ICT will improve performance by allowing better, more efficient, more powerful ways of carrying out existing tasks; systems innovation of this kind is likely to have been generated by a whole suite of factors, rather than arising from a linear process of one research output being adopted and leading to better outcomes. This is not at all to say that ICT innovation is not a necessary element, or even that it will not be the driving force. However, for the purposes of measuring impact, it is important not to simply attribute all improvement to the ICT.

3.5.2 Types of benefits from ICT research

The benefits delivered by ICT research are shaped by the diffuse and embedded nature of ICT itself. The diverse fields in which ICT is used means that there is potential for many forms of impact.

Seven key benefit channels from public ICT R&D in Australia were identified in a 2006 study for DCITA[6]:

- Benefits through commercialisation of new products based on Australian public ICT R&D via spin-off companies or licensing to existing companies.
- Benefits through the application by industry of new products or processes enabled by Australian public ICT R&D generated knowledge and technology.
- Environmental, health and social benefits through the application of Australian public ICT R&D generated knowledge and technology.
- Productivity gains from access to internationally generated knowledge secured through active engagement with international knowledge networks.
- Economic benefits through the delivery of enabling ICT skills capability to other industry sectors (including the R&D sector more generally).
- Benefits through the development of highly skilled ICT 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 activity levels of multinational companies and other firms.
- Benefits through improved public policy delivery and outcomes.

[6] Insight Economics, 2006, *The impact of public ICT R&D in Australia*

Some examples of these benefits may be things such as

- Research generated technology advances which allow industry to manage administrative and other functions, through better ICT systems. This may result in reduced costs, or increased output efficiency, and may occur across all industry types as well as in the public sector
- Improved forecasting or other ecological modelling, enabled by research driven ICT advances, which allow better environmental management
- Advances in embedded ICT products or processes resulting in increased skills among workers, both ICT specialists and those with non-ICT core roles.

3.5.3 Worked impact example

CRC for Sensor Signal and Information Processing (CSSIP)

Context
The CSSIP was established 1992. Its research and development of sensor signal technology has been used in a range of applications including water management, radar signal processing in an aerospace or defence context, medical imaging and surveillance technology. One of its most successful outputs has been the development of the GroundProbe technology used in mining.
Inputs *More detailed information about the resource levels contributed to the development and commercialisation of the GroundProbe technology would assist here.* The CSSIP had first round funding of approximately $5 million per annum from 1992-99. Each year, the CRC had approximately 30 researchers, of whom a small number worked on research programs focused on the development of sensor tools for applications within the mining sector. In order to develop the breakthrough radar technology, the R&D project and associated technical teams received $200,000 from the Commonwealth Government, and $85,000 from the Queensland Government. Additional support for the development and commercialisation of the technology came from the Australian Coal Association Research Program (ACARP) and local companies.
Activities *Detailed information about the specific research activities undertaken can strengthen future claims about attribution.* A PhD, supervised by David Noon (who later became the COO of GroundProbe) at CSSIP led to the development of an innovative radar system for monitoring rock wall stability. The further research and technical development leading to the GroundProbe application was carried out at CSSIP.
Outputs *Information about the specific research outputs, in terms of any patents, prototypes, publications is needed.* The work in radar systems for monitoring rock wall stability resulted in four patents assigned to CSSIP researchers, and the formation of the GroundProbe spin-off in 2001 to commercialise the technology.

Usage *In this example, information about use is taken from the GroundProbe spinoff's sales data.* Based on this technology, GroundProbe supply Slope Stability Radar and Ground Penetrating Radar services to provide precise analysis of rock wall stability, reducing risks of rock slides and collapses. These products have been applied by mining end users, with over 40 devices in operation around the world. Revenues from sales to the mining sector exceeded $12.5 million in 2005-06.
Impacts *Note that the impacts may be quantified in monetary or physical terms, and there is also a non-quantifiable benefit (increased safety).* The Slope Stability Radar has detected the precursors to wall failures and given warning of the impending failure in more than 30 instances, and has a 100 per cent record in warning of impending rock falls. As well as improving the safety of mine workers, this allows mine managers to more efficiently decide the optimal exploitation of a mine without unacceptable risk, the technology is estimated to have increased profitable mine life. For example, in the Leigh Creek coal mine in South Australia, use of the Slope Stability Radar technology allowed the recovery of an extra 130,000 tonnes of thermal coal; at the average 2004-05 export prices of $59.55 per tonne, this equates to around $7.75 million in additional revenue at this mine alone. *Information on the excess of revenue over costs associated with extension of the mine's life would strengthen claims regarding net benefits delivered.*

3.5.4 ICT data resources

ABS

Since 1998, the ABS has conducted a biennial survey of the Australian ICT industry, *Information and Communication Technology, Australia*, cat. no. 8126.0.

Statistics about ICT use in Australia can be found in the following publications (the most recent release is in brackets):

- *Business Use of Information Technology, Australia*, cat. no. 8129.0 (2004-05)
- *Household Use of Information Technology, Australia*, cat. no. 8146.0 (2004-05)
- *Government Technology, Australia*, cat. no. 8119.0 (2002-03)
- *Internet Activity, Australia*, cat. no. 8153.0 (March 2005)
- *Use of Information Technology on Farms, Australia*, cat. no. 8150.0 (2004-05)

Department of Information and Communication Technology and the Arts

- A range of analytical and research reports can be found on the department website, at http://www.dcita.gov.au/all_publications_research_and_reports/#communication
- The Department's Research, Statistics and Technology branch also produces a periodic *Statistical Highlights* package of ICT in Australia, which is linked to the http://www.dcita.gov.au/all_publications_research_and_reports/research_statistics_technology

- The most recent package is available at http://www.dcita.gov.au/__data/assets/pdf_file/14310/Statistical_Highlights_Feb_2006.pdf

Productivity Commission

A range of research reports relating to ICT use and R&D by the Productivity Commission can be accessed at www.pc.gov.au

3.6 Mining and Energy

3.6.1 Common usage and impact measurement challenges

The challenges of measurement are shaped by the patterns of usage and impact of R&D in the mining and energy sectors. One important factor in these capital intensive industries is the high application costs associated with innovation. This may mean that performance trends are significantly lumpy over time or over industry players. However, these factors may also make data collection somewhat easier – the high entry costs and need for deep capital investment result in an industry structure dominated by few, large companies. As a result, the users of research outputs are likely to be relatively concentrated, so that gathering performance data requires dealing with fewer external users than is typically the case in sectors such as agriculture and the environment.

This industry's structure, however, lies behind another important challenge to usage and impact management in the mining and energy CRCs. As with those in the manufacturing sector CRCs, the issue of commercial confidentiality is likely to affect information gathering. It may restrict industry users' ability or willingness to provide CRCs with data for monitoring or evaluation, something which should be considered when these data collection processes are being planned.

Some strategies to ensure that adequate data is collected may include the CRC agreeing, with the user, to anonymise any data provided, to sign confidentiality agreements, or to only use aggregated data. This may be problematic in the mining sector, however, as the industry structure makes it likely that there will often be only a few key end user companies.

3.6.2 Types of benefits from mining and energy research

The benefit channels through which R&D may deliver benefits include:

- Improved exploration efficiency, as the development of improved data acquisition, mapping and visualisation, and predictive modelling allow mining companies to target extraction efforts with greater precision, delivering cost savings.
- Improved efficiency of use of natural resources. Research may improve efficiency of use of natural resources if it results in, for example, processes for extracting more useful minerals from a given stock of raw material.
- Increased processing efficiency. Research and development of processing technology can improve efficiency – either allowing production of the same level of output for a lower level of inputs, or by allowing increased levels of output for a given amount of input.
- Reduced environmental impact. Improved exploration, extraction and processing efficiency all, in the first instance, may reduce the impact of mining or energy companies on the natural environment. In addition, R&D may lead to technological advances in the equipment or processes involved in these industries, so that they produce fewer emissions and less waste product.

3.6.3 Indicative impact example

CRCMining

Context   The CRC Mining was established in 2003, from the existing Cooperative Research Centre for Mining Technology and Equipment (CMTE) which had run since 1991. The Centre's industry partners include mining companies with Australian and international operations. One of the Centre's best known successes has been the development of an innovative dragline technology.
Inputs   *Information about the resources available at the CRC during the time the UDD technology was being developed would be more relevant here.*   BMA (BHP Billiton Mitsubishi Alliance) has been an industry partner of the CRC Mining and its earlier version, the CMTE. BMA's total expenditure on the CRC project to develop new dragline technology has been approximately $70 millon. CRC Mining has Programme funding of $27 million over seven years, with total resources $130.2 over this period. It has approximately 40 full time equivalent researchers.
Activities   *Further information about the activities at the CMTE would allow a clearer articulation of the role of the CRC research in the final impacts.*   From 1999, Jeff Rowlands led the Open Cut Excavation research group at the CRC Mining's predecessor, the CMTE. The group's work involved the development of a one-tenth scale machine to demonstrate the new, lighter dragline configuration.
Outputs   *Details of the relevant research output(s)*   The output of this research has been the development of the Universal Dig and Dump dragline technology. This technology is lighter and more flexible than the standard version. A medium sized dragline costs between $40 and $100 million, and moves around 13 million cubic tonnes of dirt each year, equivalent to approximately $75 million worth of coal. Prior to the UDD innovation, each of these machines weighed 3,000 tonnes. Weight savings from the new technology is estimated to result in a ten per cent increase in the amount of dirt which can safely be moved. Additionally, it means a reduction in overall cycle as well as greater operational flexibility.
Usage   *Note that the single end user means that usage data is relatively easy to acquire.*   The UDD dragline technology was trialled in 2002 at BMA's Peak Downs mine. In a presentation to the CRCA in 2006, Cam Davison, the research manager at BMA, noted that the company has now converted 5 of its 30 dragline fleet to UDD and is in the process of converting two others.   It is expected that two to three draglines per year will be retrofitted with the UDD technology.

Impacts

A strength in the presentation of impact is that it focuses on the productivity gain achieved and the net benefits delivered.

In a 2004 benchmarking study, Dragline 24 at BMA's Gregory Mine, which has converted to the 'Universal Dig and Dump' system, is the eleventh most productive in the world.

Recent analysis of benefit capture confirms productivity improvement of 14 per cent and BMA expects to achieve 20 per cent with future optimisation and enhancement of UDD. Conversion of between five to seven draglines results in productivity improvements equivalent to $100 million – the cost of adding a new dragline.

Compared to BMA's investment of $70 million, this is a very substantial return, with the prospect of continuing gains in the future.

3.6.4 Mining and energy data resources

ABARE

http://www.abareconomics.com/

ABARE produces an annual summary publication, *Energy in Australia*, which covers all aspects of the Australian energy industry from resource extraction through to trade and consumption. Interactive data tables relating to energy consumption and production statistics at an industry specific level are maintained at http://www.abareconomics.com/interactive/energy/htm/tables.htm

ABARE develop energy consumption, production and trade forecasts, projecting out 25 years with a focus on the medium term future (five years).

Detailed statistics about the minerals sector are published in ABARE's quarterly *Australian Minerals Statistics* release, which can be found at http://www.abareconomics.com/interactive/ams_mar07/. Data in these tables include production and trade figures across all mineral types in the mining sector.

ABARE's quarterly *Australian Commodities* publication also contains data concerning production and trade of energy and other minerals.

ABS

www.abs.gov.au

The ABS has carried out irregular surveys of Australian energy use, including *Detailed Energy Statistics, Australia, 2001-02* (cat.no. 4648.0.55.001). This survey included information about energy use across the non-household sectors of the Australian economy. It covered a range of energy and fuel types including electricity, natural gas, petroleum products, coal and renewable energy. The survey also collected data on the supply of petroleum products, electricity and natural gas, and the associated conversion, transmission and distribution losses.

There is always a substantial amount of information relating to energy consumption in the ABS' annual *Year Book Australia*, available from the ABS website.

ABS releases of mining statistics can be accessed through the Mining theme page, and include quarterly publications of mining industry indicators, and quarterly data about mining and petroleum exploration.

Additionally, an annual *Mining Operations* publication presents data on employment levels; wages and salaries; sales and service income; as well as selected components of and totals for income and expenditure; trading profit; operating profit before tax; industry value added; assets and liabilities; and net capital expenditure; value and quantity data for mineral, oil and gas production are shown by state and territory.

Bureau of Rural Sciences

The BRS provides an interactive map of Australia's biomass resources at http://adl.brs.gov.au/mapserv/biomass/index.phtml

3.7 Medical Science and Technology

3.7.1 Common usage and impact measurement challenges

One of the key challenges in measuring the impact of medical science and technology research on health outcomes is that there are many factors which may have significant effects on health – these include age, family history, socioeconomic status, occupation, co-morbidity, social networks, and the quality of health care (made up of technological levels, training of staff, effective health education, availability of health insurance, etc). As well, many of these factors are themselves interlinked and mutually dependent. Clearly, it will be difficult to definitively attribute a change in the end results to particular changes to any one of these causal factors.

Complicating this, there are a range of ways in which health research can act to improve outcomes. To some extent this is dependent on the type of research; clearly basic science will have different impacts to service provision research, which will differ again to product development processes. Improvements in diagnosis may, depending on the disorder being considered, mitigate the long-term severity of the condition (as in stroke), delay onset (as with dementia), or improve chances of treatment (as with brain tumours). It is very likely that more than one of these types of research will be involved in any observable outcome.

As well, the time frames involved from research, through to adoption of an innovative product or process, and then to a health impact are likely to be very long. In the case of biomedical science, for example, the process of putting a therapeutic discovery through animal and human trials can take a decade or more; once a drug is approved, it may then take further time for the new therapy to be adopted by clinicians, and for the health effects to become visible. The point here is that, in the case of medical science and technology research, it is often unreasonable to expect that there will be significant short term pay-offs.

Another factor which potentially affects impact measurement of health research is that advances in medical knowledge can have two distinct, and counteracting, effects on health outcomes. The "treatment substitution" effect is the classic model of technical innovation, where new treatment methods and drugs replace the old ones; this effect generally implies that treatment efficiency has increased – so the that is, the same number of people can receive this new therapy for a lower level of economic, staff or time resources. Alternatively, research may drive "treatment expansion," where the discovery of new, effective diagnostic tools and treatments increases the number of patients diagnosed with a particular condition. Because of these effects, it is important to be wary of simply reading, for example, an increased number of diagnoses as suggesting that a condition has become more prevalent, or of interpreting higher health system spending on a particular illness as meaning that that condition has become worse.

3.7.2 Types of benefits from health research

For the purpose of impact assessment the benefits from medical science and technology research may be categorised in the following groups:

1. Improved health outcomes in the population.
2. Improved healthcare system value for money.
3. Increased productivity and workforce participation.
4. Industry development through commercialisation opportunities.

1. Improved health outcomes in the population

The relative lack of weight placed on the immeasurable benefit of "improved health outcomes" is not to suggest that the advantages to individuals and to society of better health and wellbeing and less illness are not important; rather, it seeks to focus on those benefits which are more easily measured. Some of the common ways of capturing the intangible costs of illness are measures such as Quality Adjusted Life Year (QALYs) and "value of life" models.

QALYs provide a measure of the benefits of good health. This incorporates a "quality" dimension into the traditional life expectancy measure, a system of weighting is used to modify the raw number of years that would be added to life by a particular medical or health advance or intervention. The cost or burden of an illness can therefore be expressed in terms of the QALYs lost. In Australia, health system interventions that cost less than $70,000 per QALY gained are generally considered to be cost-effective[7].

A related measure is used in the burden of disease approach, which quantifies ill health using disability adjusted life years (DALYs) to represent the burden of ill health in terms of premature mortality as well as the loss of healthy years of life.

The "value of life" approach assigns a monetary value to human life, so that extending that life can be seen as adding value. Some pricing methods for assigning this value of life include statistical calculations, such as those used by insurance companies, and hedonic pricing, which creates a value based on revealed "willingness to pay" for reduced risk. It is important to note, however, that these measures, while they may be indicative, can never fully capture the value of things such as better health and welfare.

2. Improved healthcare system value for money

The economic costs of ill health are also important when considering the benefits of medical research. These costs include direct costs, such as public and private spending on the health care systems, and indirect costs such as lost productivity. As well, substantial resources are used in informal or community care, and in preventative health programs. Research, by discovering new and improved tools and processes for managing illness, can potentially reduce these costs.

Due to the treatment substitution and treatment expansion effects, there is not necessarily a simple inverse relationship between advances in medical science and costs of health care. However, when the quality of care and the quality of health outcomes is taken into account, new research based advances are highly likely to translate into improved value for money

[7] NCIRS, *Economic Evaluation and Decision Making*, presentation given by Philippe Beutels, as quoted in Allen Consulting Group (2005), *Immunisation in Australia: Delivering Sustainable Access.* This study also notes that interventions in the $70,000 to $100,000 per QALY gained are considered a grey area in terms of cost-effectiveness.

within the health care system as cost increases are more than offset by improvement in the quality of health outcomes.

3. Increased productivity and workforce participation

As well as incurring these direct costs, illness involves indirect economic costs, including”

- earnings foregone due to ill health, including early retirement, absenteeism and underemployment;
- earnings foregone as a result of premature mortality;
- carer earnings foregone; and
- expenditure in other areas such as disability welfare payments.

Research which leads to improved population health outcomes can lead to people who have been unable to work being able to return to the labour force, increase working hours, or decrease “presenteeism” or under-performance at work due to ill health. The impacts on the economy of increased participation rates and productivity as a result of better health are potentially very substantial.

To gain a sense of how a monetary value can be imputed from improved work attendance resulting from better health, we can consider the economic value based on average labour costs (wages) compared to output (profits). The average full time wage in Australia is now around $58,000 per annum. With on costs factored in, the total cost of an average employee is therefore around $70,000 per annum.

It is reasonable to assume that employers will not pay this cost unless economic returns over and above this level are being generated by employees. Given average company profitability in Australia is around 25 per cent, it may be reasonable to assume that for an average full time employee, their labour will generate revenue of around 1.25 times their cost each year and profits of around 0.25 times their cost each year. This suggests that the “value” of each additional work year allowed by better illness rehabilitation could be expressed in terms of either $87,500 per annum of extra output or as $17,500 per annum of extra profits.

We can also think of improved population health as leading to savings in the costs of rehiring workers to replace people unable to work because of illness. Industry average recruitment costs are around 15 per cent of the first year salary of the new hire, if we count indirect costs such as training, time to get the new hire productive, lost productivity from having a vacancy, lost productivity from having a colleague stand in for the vacant role, losses of tacit job knowledge or customer relations and so on, which can add up to a significant amount, which increases in more “intellectually intensive” industries. This cost is thought to be equivalent to around 100 to 200 per cent of an employee’s annual wage – which at the national mean is anywhere between $58,000 and $116,000 for every replaced worker. Reductions in churn or retirement due to ill health may therefore bring substantial monetary cost savings to firms.

We might think that the early return to work of an employee would simply displace another worker; however, given the current low unemployment rate and widespread skills shortages in Australia, this issue is not as significant as it would be during times of high unemployment or plentiful skills availability.

4. Industry development through commercialisation opportunities

The economic benefits of industry development associated with medical science research are potentially very significant.

There are several examples where publicly funded medical research and development has been the driver behind the establishment or development of a local industry. In addition to direct initial effects of funding (if money is spent on a sector, that sector is likely to develop), there are two main ways that public research funding can contribute to the development of industries in and around the medical and health sciences. Firstly, the formation of a pool of skilled scientists creates a valuable resource that can be drawn upon by industry. Secondly, the public nature of basic knowledge in this area can provide an intellectual foundation for later commercial applications. As an example of the scale of industry use of fundamental research, a United States study has estimated that each $1 of funding for basic biomedical science stimulates a further $3.15 in pharmaceutical industry R&D.[8]

3.7.3 Indicative impact example

CRC HEAR and Cochlear technology

Context   The core Cochlear technology was developed from work undertaken by Graeme Clark and others at the University of Melbourne in the 1960s and 1970s. The bionic ear technologies were commercialised by a spin off company, Cochlear Ltd during the late 70s. More recent research has focused on advancing the technology.
Inputs   *Data about the proportion of resources devoted to the relevant research programs would be noted here.*   The expertise and experience in early generation bionic ear technology was crucial to the development of more advanced cochlear products. This background knowledge and expertise was an important input into the CRC which was first formed in 1992. The current CRC HEAR has built on the relationship between Cochlear Limited and The University of Melbourne, and also incorporates The Bionic Ear Institute and the National Acoustics Laboratories (Australian Hearing).
Activities   Research at the CRC HEAR participant organisations from the late 1990s has included programs focused on the development of an electrode array that can be safely positioned in close proximity to neural elements.   Following initial development of the technology the CRC HEAR was involved in activities to test the new technology.
Outputs   *Information about the patent outputs from CRC research would be inserted here.*   The Centre's electrode array research led to a patent being taken out for the Contour technology, a central element in the Nucleus 24 version of the bionic ear.   The CRC's associated commercial and technology transfer company, HearWorks, has managed the commercialisation of the research through two spin-off companies, Dynamic Hearing Pty Ltd and Microphones Pty Ltd.

[8] Toole, A., 2002, *Does Public Scientific Research Complement Industry R&D Investment? The Case Of NIH supported Basic And Clinical Research And Pharmaceutical Industry R&D*

Usage   *Details of usage may include sales figures, extent of penetration in overseas markets, patient numbers etc.*   Base on the Conture technology, Cochlear developed the Nucleus 24 Contour Electrode which was introduced to the market in 2000. It has now been implanted in over 35,000 patients around the world.
Impacts   *Note that quantification of the benefits of better hearing may not be possible. An approximation, such as data describing QALY gains to recipients of the improved implant, would be advantageous.*   Cochlear Ltd is now a large company, with revenues over $350 million a year. The firm continues to participate in the CRC HEAR, which also includes Australian Hearing, the Bionic Ear Institute and the University of Melbourne.   In addition to economic benefits associated with the research driven growth of Cochlear, there have been significant human health benefits associated with the improved hearing function for the 35,000 people who have received the Nucleus 24 implants.

3.7.4 Health data resources

AIHW

http://www.aihw.gov.au

The Australian Institute for Health and Welfare is an Australian government agency responsible for health and welfare information and statistics.

The AIHW manages a range of national data collections covering health, housing and community services. Its data management role includes the promotion of consistency among national, state and territory statistics, and the production of comprehensive national data.

Key AIHW publications include:

- the biennial Australia's Health and Australia's Welfare reports to the Australian Parliament.
- working papers and reports covering topics by disease, population group, health service area etc.

Online data available at the AIHW website includes:

- METEOR, the national online metadata registry for health, community services and housing assistance.
- Data standards - National Health Data Dictionary, National Community Services Data Dictionary, National Housing Assistance Data Dictionary.
- Data cubes with an interactive, "build-your-own data table" facility. Topics covered include: Alcohol and other drug treatment; cancer; chronic disease; disability; expenditure; general practice; hospital morbidity; mortality; mental health; and risk factors.

ABS

http://www.abs.gov.au/

ABS health-related information includes the results of the triennial National Health Survey, which collect information about the health status of Australians, their use of health services and facilities, and health related aspects of their lifestyle.

In addition to the summary publications, the ABS releases topical health “snapshots” covering disease areas or population subgroups.

Australian DoHA

Links to health and ageing data sources can be found at http://www.health.gov.au/internet/wcms/publishing.nsf/Content/Statistics-1

The department manages a number of data sets, relating to Casemix, covering hospital activity in both the public and private sectors.

- National Admitted Patient Care Dataset
- Elective Surgery Waiting Times Additions and Removals
- Elective Surgery Waiting Times Census
- Non-admitted Patient Emergency Care
- Public Hospital Establishment Collection
- National Hospital Cost Data Collection (NHCDC)
- The Hospital Casemix Protocol (HCP) data collection
- Private Hospital Data Bureau (PHDB)

These are available, with details of the data collected, from http://www.health.gov.au/internet/wcms/publishing.nsf/Content/health-casemix-data-collections-about

OECD

http://www.oecd.org/ then go to Health topic.

Health information from the OECD includes:

- country reports (submitted by country government agencies)
- statistics from OECD countries
- a range of research projects, working papers, and other publications.

These contain health, mortality and morbidity data, health system policy, expenditure and use information, and historical comparison for the countries considered.

A good place to start is the annual OECD health statistics database (access or CD-ROM to be purchased). OECD Health Data 2006: Statistics and Indicators for 30 Countries

WHO

The WHO’s health statistics and information program can be accessed online. The details of indicators and methods used are discussed in the Guide to statistical information at the WHO which can be found at http://www.who.int/whosis/en/index.html

The indicators fall into categories including:

- Core Health Indicators

- Mortality and health status
- Disease statistics
- ICT statistics
- Health system statistics
- Risk factors and health service coverage
- Inequities in health

Useful papers

Australia

Productivity Commission, 2005, Impact of Advances in Medical Technology

Productivity Commission, 2005, Economic Implications of an Ageing Australia

Access Economics, 2003, Exceptional returns: the value of investing in health R&D in Australia

AIHW, 1999, The burden of disease in Australia (the original national study. An updated version for 2003 data should be out soon)

Victorian DHS, 2005, Victorian burden of disease study (authors of the national study)

Queensland Health, 2002, Quantifying the burden of disease and injury in Queensland 1996-1998

http://www.health.qld.gov.au/publications/infocirc/burden.pdf

International

Derek Wanless, 2002, Securing Our Future Health: taking a long term view

Funding First, 2000, Exceptional Returns: the economic value of America's investment in medical research

4 Implications for framework

This section summarises the key issues arising from the background discussion of the monitoring and evaluation framework.

4.1 General monitoring and evaluation issues

The use of the “input to impact” framework in the monitoring and evaluation of CRC performance is underpinned by some crucial assumptions.

4.1.1 Range of benefit channels

One of the main reasons to use a framework in monitoring and evaluating performance is to allow consistent data collection and comparison across CRCs which may be working in very diverse research fields.

Even within one research centre, it is likely that the benefits generated will not all be of the same type. An important process in using the framework to monitor and evaluate CRC performance is to identify the likely channels through which research is expected to deliver benefit. Three broad categories of benefit have been described, including those from application of research generated knowledge, from access to international R&D networks, and from skills formation. The first of these categories is perhaps the broadest, and the application of CRC knowledge may deliver benefits in a wide range of ways, including through industry development, performance improvements and cost savings to users, and non-market gains to health, social welfare, and the environment.

An additional reason why identifying the expected channels of delivering benefit is important for all CRCs is that it facilitates and clarifies what types of data will be required to effectively monitor and evaluate the process from research inputs, through activities, outputs, usage and impacts.

4.1.2 Attribution

Recognising that attribution of the various contributions to the end impacts of research is likely to be challenging, the use of a systemic framework can help in this task. While there still may be uncertainty in estimating the exact paths and precise extent of the connection from research “causes” to external “effects,” having a set of clear, verifiable and (as far as possible) quantifiable measures from each stage of the process from input to impact makes this substantially more reliable.

4.1.3 Additionality

Underlying all measurements involved in this monitoring and evaluation framework is the assumption that the true extent of an impact should be seen as the benefit *over and above* what would otherwise have occurred. That is, an assessment of the benefits derived from any research should include a consideration of the opportunity cost – the foregone benefits which could have arisen had the resources been alternatively allocated. The crucial measure of the “true” impact of any CRC’s research is the extent to which its performance has exceeded the alternative (counterfactual) use.

This has some important implications for the measurement of performance data, and the ways in which this data will be used to develop a narrative of the CRC's impact. It highlights the necessity of not simply reporting a CRC's performance in isolation, but suggests that this should be put in the context of a relevant industry baseline or some other control group from a comparable, non-user, population.

4.2 Use of the framework

4.2.1 Key features of the framework

By thinking of the data as being grouped into five stages recognises that at each of these stages the thing being measured will differ – and so, by implication, should the data required to assess this. This emphasises that there is a process through which impact is delivered, and that tracking this along its steps gives a more transparent and verifiable record of performance.

The "two phase" extension recognises that in many cases, some of the most important outputs of research projects feed back into the R&D process.

4.2.2 Planning

Many of the consistency and comparability benefits come from the early use of a framework – this means that data requirements are known early and can be properly put into practice.

As well as assisting management while CRCs are running, more effective monitoring and evaluation can provide useful information when CRCs re-bid, or for prospective CRCs developing proposals.

4.2.3 Data collection and interpretation

The framework is intended to help CRCs identify the data which are most important in developing a narrative of research impact. Prioritising data means that better decisions can be made, which balance the cost of collecting data with its relevance.

While planning the indicators which will be used to measure performance, it is also possible that CRCs will find that some of this data is already collected, perhaps to fulfil DEST or other requirements. Designing performance metrics which make use of this data will increase efficiency.

4.2.4 Measurement expectations

Grouping the data into the five types (reflecting what can be usefully measured at each stage) means that we can differentiate between these types, and can perhaps internalise some of the collection problems by recognising that some data groups are more easily, fully, and accurately acquired than others.

4.3 Adapting the framework

4.3.1 Usage and measurement challenges

In addition to the generic challenges of developing a clear, measurable causal link between research, the use of innovative products and processes, and improved outcomes for industry and the community, there are some variations in the ways these will affect CRCs in the six sectors of research type.

These derive from differences in the constitution of the sectors – and hence, the different patterns of using, and collecting use data for, research generated innovation – as well as variations in the ways research may be applied in these sectors. In many ways, the use of research is shaped by the core business of the sector itself, and there are clearly great differences between the business of, say, mining technology, and health services.

4.3.2 Benefit types

For many of the same reasons as the measurement challenges differ between the CRC sectors, it is important to note that there are likely to be different ways in which benefits are delivered. As noted earlier, identifying appropriate benefit channels is an important step in developing suitable monitoring and evaluation metrics, and may be helpful to consider some of the ways these channels may be shaped by the type of research involved.

Appendix A

Sampling issues

To provide a quantitative measure of the impacts resulting from the usage of outputs produced by research, it is important to be able to establish a causal chain from the usage of outputs to their impact.

Exhibit A.1 Input to impact model

INPUTS	ACTIVITY	OUTPUTS	USAGE	IMPACT
People Infrastructure Money Prior IP Etc…	Research project Stakeholder engagement Monitoring and evaluation Training Etc…	Publications Prototypes Patents Databases Trials Products PhD, Masters, undergrad completions Etc…	External groups adapting/ adopting/ applying outputs. This may or may not involve a commercial transaction.	The outcomes from usage could include: Productivity gains, industry development, environmental benefits, health benefits, more options, etc…

When collecting the data to measure usage, it is important to be aware of potential bias arising from control and sampling issues. In some cases, there will be techniques which can minimise this bias.

Key terms

Outputs Specific results produced immediately by initiative activities, including papers, products, processes, skills, and IP.

Usage Application of outputs by stakeholders.

Impacts Results for the broader community in terms of economic, social and environmental effects.

User groups The users of research outputs; may include other researchers, industry, government, the community.

Bias The over- or under-estimation of the effects from the action being measured.

Sample The affected group considered in the measurement; will be selected from the population.

Population The entire group of users affected by the action being measured.

Control group A non-active group or set of figures who are not affected by the outputs - the comparison case.

Issues

When developing an estimate of the size of impacts, the **types of user groups** will differ according to the output – and therefore its impact – being considered.

Types of user groups

There are two broad ways in which users of a research output may be organised:

1. a few, big users, or
2. many small users.

If the effect being estimated involves the first group, it is important to be aware of potential biases introduced by **control issues**.

In the case of the second set of users, there may still be **control group** biases. In addition, the nature of the users means that to collect information about the effects of the action being measured from every participant is complex, time consuming and costly. It is likely that a representative group – a sample – will be surveyed. **Sampling issues** can therefore be another source of bias in estimating effects.

Control issues

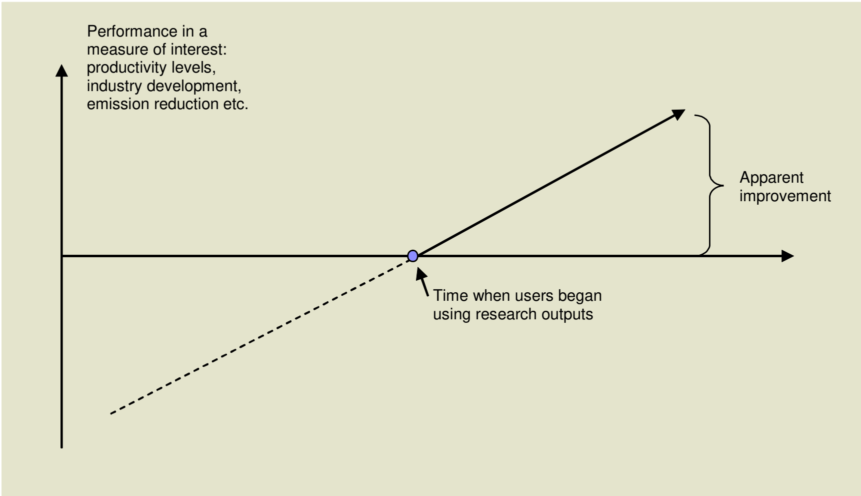
The effect of a new process or product will be seen in increased performance from some earlier baseline measure. It is important, however, to make sure that the affected group is compared both against itself in the past and against other, non-affected groups in the current timeframe, in order to correctly estimate the effect of usage of outputs we are considering.

For example, consider an output which is used by farmers to improve the yield of a particular crop. Perhaps the most obvious approach is to simply measure the output of a particular farmer before starting to use the innovative process, then to compare this with output after using the new method. However, there are significant limitations to this approach.

An example of the problem shows how this can confuse the issue, and make it difficult to ascertain what part of the total effect can be attributed to the action we are trying to measure.

Exhibit A.2 illustrates a case where, for example a group of external users begins applying the outputs of a research group at a time as indicated. However, the impact of this research on our outcome of interest – say, productivity levels – is unclear, as the introduction of the new behaviour or product occurs in the context of an already-present industry trend. If we were to naively estimate the impact of the innovation as being simply the improvement between introduction and the present, we would not capture the effects of the underlying trend.

Exhibit A.2 Incorrect assessment of performance improvement



That is, an end user may have been improving output independently of the contribution of research. In order to accurately measure the impact of the research, it is important to correctly attribute any change in end results.

When measuring, or estimating, the effect of a research output on its users' outcomes, using a control is an important concept. A "control" group or set of figures represents an alternative outcome, or a counter-factual – what would happen *without* the action being considered. By comparing this with what actually did occur, we can quantify the effect.

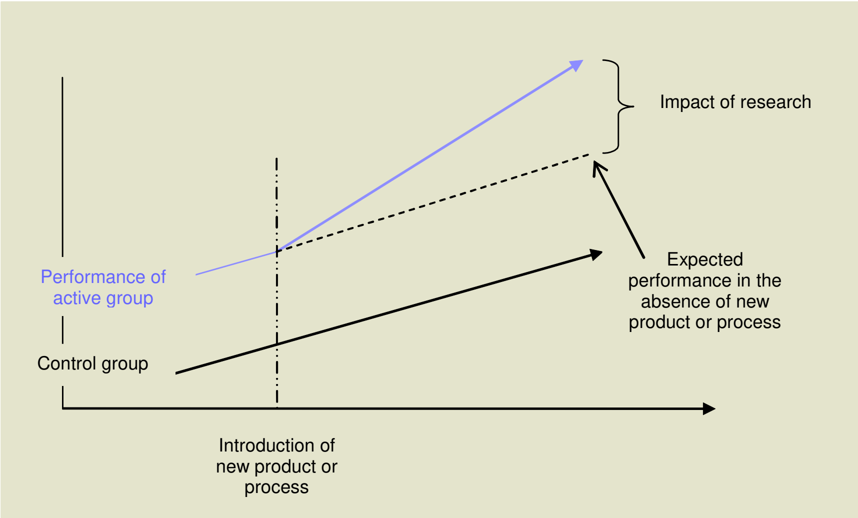
This comparison of the counterfactual with the actual cases has two dimensions:

i. difference over time, and

ii. difference between groups.

If we consider two groups: an active group (which uses research outputs) and a non-active group (the control group), the actual effect should be thought of as the change between the starting gap and the finishing gap. Alternatively, if the control data being used are industry standard levels, we can describe the impact of using the research as being the difference between the user's expected performance, and the actual performance.

Exhibit A.3 Actual impact of research is the difference between start and end gaps



As Exhibit A.3 illustrates, the difference between expected and actual performance is equivalent to the difference between the starting and ending gaps.

It is important that, as far as possible, a control group will have similar characteristics to the active group – this means that any difference between the two can be more confidently attributed to the action being measured.

Difference over time

To estimate the change over time resulting from the introduction of a new process or product, we must compare users' historic performance data with current data – a "before" and "after."

The key point here is that, to allow a meaningful comparison and accurately measure the true impact of the action, it is important that the before and after data sets are directly comparable.

It will be very important to (if possible) develop "baseline" data – that is, to identify those aspects of the user group's output measures which are likely to be affected by the innovation, and to collect this information. Another relevant set of data will be any extra requirements or benefits associated with implementing the new process or product; for example, additional training, staffing levels, or modifications may have been necessary to put the research outputs into practical use. These should be counted in a measurement of the total impact, so that there is a clear and accurate attribution of end results to the causal factors.

We should also note that there are very few real world outcomes which can be attributed to a single source

There should also be consistency, so that these same indicators can be followed through to tell a story about the "after" situation.

Difference between groups

Similarly, in order to compare the affected group with its non-active control, there needs to be consistency in the data.

Often, a useful set of "controls" will be found in industry-wide statistics. External factors which affect the performance of a whole industry will therefore not distort our assessment of the research impact on a small subsection of the industry. Some of the main Australian databases for industry statistics include:

- ABARE (agriculture and natural resources)
- ABS
- IBIS.

To be comparable with this type of benchmark control data, it is important that the data collected from the affected user groups matches the industry standard data.

Even if it is possible to collect accurate data from users and a non-active control group or dataset, there are still some possible sources of bias in the final estimate.

In many cases, these will arise from sampling bias – that is, whose data is chosen in the active or the control groups. As discussed below, samples are often to some extent self-selected, and this can distort results.

Sampling issues

Sample size

In the case when there are many small users of a research output, it is most likely that only a sample of the total population will be able to be collected. Obviously, this sample must be large enough to be representative of the whole, but small enough to be practical and time/cost effective.

There is no fixed sample size which will give a representative picture; rather, the size selected will be dependent on the population size. For any population (N), the larger the sample size (*n*) the more accurate depiction of the actual situation will be delivered.

For example, if we are looking to find the crop output levels of all farmers in the wheat sector, we would collect the crop figures from a sample of farmers (*n*). If we compared the average of this sample with the "true" average across the whole population of farmers (N), we would probably find that there was some discrepancy. However, if we were to increase the number of farmers in the sample *n*, the sample average would more closely approximate the true or population average.

So we can see that an ideal sample size would be the whole population; however, this is unlikely to be practical. It is necessary to establish how much deviation from the "true" figures we are willing to accept. The sample size is mathematically related to the precision required from the estimate. Some examples of population size and the corresponding sample size required for 95 per cent confidence in the results of the sample are shown in the table below. Categorical data is qualitative – when responses to questions are in discrete groups or categories. Continuous data, on the other hand, can take an infinite number of values. In the case of surveys, it is most likely that data will be categorical.

Table A.1 Example sample sizes for populations, for categorical or continuous data

	Sample size (*n*)	
Population size (N)	Categorical data (margin of error = 5%)	Continuous data (margin of error = 3%)
100	80	55
200	132	75
300	169	85
400	196	92
500	218	96

1,000	278	106

For discrete data, a margin of error of five per cent means that one can be 95 per cent certain that sample means are within five per cent either way of the true (population) means.

For example, if a sample of 132 was drawn from a user population of 200, this sample would answer survey questions relating to performance measures. If, for a given measure of interest – say, the level of emissions reduction in the period – the mean response was a reduction of 24 per cent, we can be 95 per cent sure that between 19 (24 minus 5) and 29 (24 plus 5) per cent of the population would have responded in this way.

Sample size calculators are available on the internet, for example http://www.surveysystem.com/sscalc.htm, http://calculators.stat.ucla.edu/, or http://www.stat.uiowa.edu/~rlenth/Power/index.html.

In most cases, when data is collected using surveys or other voluntary methods, it is important that allowance is made for a proportion of non-respondents. Some strategies for estimating how many people are likely to respond (or not respond) may include comparison with previous surveys, or with generally accepted levels. Generally accepted non-response rates seem to be between around 25and 45 per cent, with significantly higher non-response to mail surveys (compared to face-to-face or phone interviews).[9] There are a number of approaches to dealing with non-response. One of the most simple is oversampling, or making allowance for "lost" surveys; that is, the number of surveys sent out will exceed the minimum required sample size. The amount of oversampling required will depend on the anticipated response rate.

However, ABS researchers suggest that it is more important to increase the rate of response, rather than simply increasing the sample size.[10] Some ways of doing this may include:

- Having a clear, brief explanation of the purpose of the survey;
- Notifying potential participants in advance;
- Making call-backs (often, up to four will be needed);
- Offering to provide final results of findings.

It is likely, however, that a group which doesn't respond will differ in important ways from the group which does (for example, in being more enthusiastic about both using and answering questions about innovative processes or products).

Sample bias

Even with an appropriately sized sample, there are still some potential issues which will affect how well our estimates represent the true figures. One of the main sources of sample bias are the issues associated with selection – that is, which sub-sections of the population are included in the sample we consider.

It is likely that, for any population, there will be variation in some important characteristics which will impact on how individuals are affected by the action we are measuring.

For example, if we think of the population of wheat farmers (N), we might know that some farmers were more likely to adopt new practises than others. Based on historical experience, we could estimate that a proportion of wheat farmers are innovative, early adopters, another

[9] For example, in the US, Federal Departments collecting data are required to have a minimum 75 per cent response rate; a special waiver from the Office of Management and Budget is needed to use data for which response rates were below 50 per cent.

[10] M Fogliani, 1999, *Low Response Rates and Their Effects on Survey Results*, ABS Methodology Advisory Committee paper.

group is more cautious and will only adopt new practises once they are well proven, and a final sub-group is somewhat set in its ways and unlikely to be open to new research.

So, we could expect that the population N may contain sub-groups:

- 25 per cent (N/4) are innovative,
- 25 per cent (N/4) are "followers," and
- 50 per cent (N/2) are "conservative".

It is important, of course, that we do not just measure the impact of research on the group most likely to adopt.

Inherently, however, there is likely to be an over-representation of the innovative 25 per cent in the trial group. If access to the research output was voluntary, this will be multiplied – it is far more likely that an innovative farmer will choose to take part in a trial of some new process or product than his or her more conservative neighbour. Similarly, when it comes to responding to an information collecting survey this group is substantially more likely to choose to be involved.

It is clear that an over-represented group within a sample may skew the results and invalidate extension of the sample findings to the wider population. It is necessary to consider such sources of bias and where possible undertake steps to account for them. For example, inclusion of questions regarding respondents' past history of adoption of new processes would be a first step in identifying potential sample bias.

For further reading on control issues, sample design, and statistics:

- ABS, *Labour Statistics: Concepts, Sources and Methods*, 2001. Chapters 17 and 18 provides an excellent overview of survey methodology. It can be accessed at the ABS website, www.abs.gov.au
- The "What is a Survey" series from the American Statistical Association is available online at http://www.whatisasurvey.info
- The definitive OECD glossary is at http://stats.oecd.org/glossary/; it can be downloaded or viewed online.
- Arlene Fink, 1995, *The Survey Handbook*; *How to Ask Survey Questions*; *How to Sample in Surveys*, Sage Publications. These are volumes of a nine part series.
- FJ Fowler, 1993, *Survey research methods*, Sage Publications. A good summary of the possible research methods, with a practical focus.
- For more statistical background, a good basic text is M Linton & P S Gallo, 1975, *The practical statistician,* Brooks/Cole Pub. Co..
- A useful online text, pitched at an introductory level, is http://www.sjsu.edu/faculty/gerstman/StatPrimer/.
- For more detailed discussion of statistical methods and tests, http://faculty.vassar.edu/lowry/webtext.html is easy to navigate and has helpful links.