Cross-RDC Impact Assessment Program: Guidelines

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Australia's 15 Rural Research and Development Corporations are a partnership between rural industries and the Australian Government to invest strategically in research, development, technology transfer and adoption, and in some cases, market access, market development and promotion. For more information visit www.ruralrdc.com.au

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Foreword and Overview

This document comprises impact assessment *Guidelines* for R&D projects undertaken by Australia's rural Research and Development Corporations (RDCs).

The project to develop these *Guidelines* was initiated by the Council of Rural Research and Development Corporations in 2011. At that time, questions were being raised in government and amongst other stakeholders about the existing funding model for rural R&D, the governance arrangements, and the justification for matching government support. These questions continue to be raised. Sustaining and improving Australia's rural R&D enterprise requires that the RDCs and the Cross-RDC be able to answer these questions effectively, to provide persuasive evidence on their accomplishments and the returns to the investments, and to justify the contributions made by the various stakeholder groups.

The motivation for the project to prepare these *Guidelines* was to establish a standardised and more comprehensive approach, and to generally strengthen impact assessment undertaken by the RDCs in view of these demands for evidence on impact of rural R&D. As well as improving the quality of the impact assessment work generally, and thus enhancing the value and usefulness of the information from individual impact assessments, the idea was to be better able to combine the results from individual RDCs into a meaningful meta-picture of the returns to the portfolio as a whole. This requires a more standardised approach. Another key point was the increased interest in evidence on returns beyond the rural industry stakeholders.

Levy-based funding is the core of Australia's rural R&D system. Matching government funding can be justified because it encourages producers to vote to support a levy-based system within which the benefits are diffuse and uncertain and are achieved only after a very long lag; producers otherwise would underfund the activity from society's point of view. However, increasingly over time the RDCs have been asked to provide evidence of spillover benefits to the broader community to help justify matching government support.

Some spillovers could go from one group of rural producers to another, and these impacts could be evaluated using conventional approaches to R&D impact assessment. But some spillovers are in the nature of environmental externalities that entail non-market goods and services (such as clean air and water or wild species preservation). Both types of spillovers are likely to be second-order forms of benefits compared with the benefits accruing to the primary stakeholders, which are first-order forms for most types of RDC R&D. These *Guidelines* discuss, in some depth, approaches to model and measure non-market spillover benefits because this is an area that is relatively new and on which relatively little is available in the published literature. The proportion of space devoted to the topic is not meant to be taken as an indication of the relative importance of spillovers relative to direct benefits.

These *Guidelines* are written for two types of audiences. The first audience is the stakeholders and their representatives who are interested in understanding how the RDCs go about assessing the returns to their investments both for reporting purposes and for resource management, and how to interpret the resulting measures. The second audience is the analysts employed by the RDCs—either on staff or as consultants—to undertake impact assessments on their behalf. Since the first audience is not expected to be conversant with the technical aspects of the work, the *Guideline*s are written intentionally using a minimum of technical language and jargon - though some is inevitable. The second audience will comprise technical specialists, typically with training to the master's level or equivalent in the relevant economics and accounting concepts. Having been written to serve the two types of audiences, the *Guidelines* may be seen as short on some desired technical detail by some members of the second group. A companion set of *Procedures* was written to provide some of that desired detail.

Neither these *Guidelines* nor those *Procedures* is intended to serve as a complete manual for impact assessment practitioners. Other sources that provide much of the relevant detail are documented in the references to the *Guidelines*. In addition, it must be understood that impact assessment, is to some extent, an art. Each individual case calls for some variation in approach to suit its circumstances. The *Guidelines* are intended to provide a common framework and a core set of principles and concepts to be applied across the portfolio to make the resulting measures more directly comparable and agreeable such that the whole set of impact assessments can be greater than the simple sum of its parts.

Executive Summary

The following lists the section headings in these *Guidelines* with a brief outline of the content of each section.

Research and Development Corporations – A brief outline of the history, structure and function of the RDCs.

Why Evaluating RDC Projects is Important – Discussion of the purpose of assessing the impact of RDC R&D and the benefits obtainable from the assessments.

Background to these Guidelines – An outline of the history of the CROSS-RDC impact assessment program, why these guidelines were created and the sources to which the authors referred.

Impact Assessment Methodology

1. The Research Project Life Cycle – A conceptualisation of a research project and its progression from problem definition to producing outputs, outcomes and impacts.

2. Using Cost-Benefit Analysis

- **2.1** – A discussion of why cost-benefit analysis is used to assess the impact of R&D and its advantages as a methodology.
- **2.2** – An outline of the core concepts underlying cost-benefits analysis.
- **2.3** – A description of the stages in the life cycle of an R&D project at which impact assessment is undertaken.
- **2.4** – Determining the breadth of the R&D to be assessed.
- **2.5** – A discussion of the reasons for discounting and compounding monetary values. Stipulation of the time frames over which costs and benefits should be assessed and the compounding and discount rates to be used in calculations.
- **2.6** – An outline of the types of the impacts that RDC R&D produces and which should subject to assessment.
- **2.7** – A note on exercising professional judgement in the impact assessment process.

3. The Impact Assessment Process

- **3.1** – An outline of the types of inputs to R&D that analysts should identify and assess.
- **3.2** – An outline of the types of outputs that R&D is likely to produce, and which should be identified by analysts.
- **3.3** – Guidance on defining the scenario that would likely have occurred if the research had not been undertaken, which is used as the basis for deducing the impacts which the research is assessed to have produced.

3.4 – An outline of the types of outcomes for producers that are likely to come from the research outputs, their variability and how they should be valued for the purposes of impact assessment.

3.5 – Guidance on estimating the rate of and extent of adoption of the outcomes from R&D and the regional variability of adoption.

3.6 – An outline of the types of impacts on the community that arise as a result of the aggregation of producer-level outcomes, spillovers and externalities and how these should be assessed by the analyst.

3.7 – Guidance on determining the extent to which the impacts can reasonably be attributed to the R&D project and other sources including expenditures on prior research, and subsequent development, extension and adoption, and the extent to which the impacts should be attributed to investment by RDCs.

4. Assessment of Non-market Impacts

4.1 – A discussion of the rising interest in non-market (environmental and other social) impacts and the emphasis on assessment by RDCs.

4.2 – Guidance on developing a narrative description of non-market benefits, as a minimum requirement for impact assessment.

4.3 – Identification of types of non-market impacts.

4.4 – A note on the complexities of identifying and measuring non-market benefits and costs arising from R&D and attributing them to R&D.

4.5 – An outline of revealed preference methods (hedonic pricing, substitute cost, compensation payment, avoidance cost) and stated preference methods (contingent valuation, choice modelling) for valuing non-market benefits, and circumstances where each might be employed.

5. Sensitivity Analysis and Reporting

5.1 – A discussion of the level of precision to which the analysis should be taken and approach analysts should take to reporting the results of the analysis of outcomes and impacts of R&D.

5.2 – Guidance on determining the key aspects of the analysis on which the results are most sensitive, and how sensitivity should be tested and reported.

5.3 – An overview of how impact assessment reports should be constructed, the importance of a clear narrative description of the R&D and its benefits, the key ratios and summary statistics to be reported. The use of Modified Internal Rate of Return is introduced.

Research and Development Corporations

Australia's Rural Research and Development Corporations (RDCs) were established in 1989 by Federal Government legislation to commission research and development (R&D) relating to primary industries.[1] The RDCs replaced the pre-existing research councils and committees, which had administered R&D programs and funds for a range of agricultural industries. Primary producers contribute to paying for the cost of the R&D and the administrative overheads of the RDCs through levies (mostly statutorily mandated) on the sale of rural products. Taxpayers, through the Federal Government also contribute funds to the RDCs, mostly by matching the industry levies up to a statutory limit of 0.5% of the gross value of industry production. The RDCs are important participants in rural R&D in Australia. In 2008/9 the 15 RDCs invested about $490 million in R&D and related extension, out of Australia's estimated $1.5 billion annual investment in rural research, development and extension, by the public and private sectors (Keogh and Potard 2011, Productivity Commission 2011).

The structure of the RDCs has many strengths and the model is highly regarded in Australia and overseas. The RDCs have specific statutory objectives to:

- fund and administer R&D that will deliver economic, social and environmental benefits,
- achieve sustainable resource use,
- make more effective use of community and scientific resources and skills, and
- improve accountability for their expenditure on R&D.

RDCs are corporations, directed by boards that draw expertise from research providers, academics, industry, and the broader community. The RDCs generally do not own research facilities or conduct research, but they have considerable independence and flexibility to seek out and contract for the skills and resources needed to achieve the best research outcomes.

[1] Throughout this document the term R&D is used to include 'extension' and other activities that contribute to the transfer of knowledge and the adoption of new technology and innovation. It is acknowledged that the relationships between research, development and knowledge/ technology transfer in all its forms vary widely, and that the responsibility of RDCs for knowledge/ technology transfer differs among RDCs and among individual projects. These functions are often inextricably intertwined with other elements of R&D projects and it is often difficult to distinguish separately their roles in generating benefits from new knowledge, technology and innovation in the context of impact assessment studies.

RDCs operate collaboratively with a wide array of research providers in Australia and overseas. Most RDC R&D projects are jointly funded by industry and government, reflecting shared interests and a joint commitment to the research and the ultimate adoption of the resulting innovations. The breadth of engagement of RDCs with industry, government and research providers, the value of their stake in rural R&D in Australia, and their collaborative approach to funding and execution of R&D, places RDCs in a central and strategic position in directing and administering rural R&D in Australia.

The joint funding from industry and the community is a crucial pillar of the Australian RDC structure. The nature of the benefits from much rural research is such that the private sector has insufficient incentive to invest in the research, even with the RDC structure that substantially overcomes free-riding within an industry. Without a community contribution, investment in rural research in Australia would be far below the national optimum, and the Australian community as a whole would be less well off, with a less-resilient, less-productive, and less-diverse food and fibre production sector; rural industries would be more likely both to under-utilise and place at greater risk the country's considerable land and water resources. Nevertheless, experience has shown that sustaining the support of all stakeholders in the RDC structure will require a sustained effort in providing persuasive evidence to show that the funds have been well managed and that the investments have earned a satisfactory return.

Why Evaluating RDC Projects is Important

Investment in rural R&D is linked strongly and directly to growth in productivity in agriculture, fishing, and forestry industries. The relationships between R&D, productivity and the flow of benefits from rural R&D to the wider community are not always readily apparent. Partly, this is because the lags between the initial investment in research and the realisation of the benefits frequently extend over decades. It is also partly because the role played by knowledge derived from science is usually not immediately obvious to the users of the technology that is developed based on that knowledge, and sometimes it is not at all possible to distinguish the contribution of particular research investments even when we know that science has played a crucial role. It is challenging to manage and sustain the investment in rural R&D that will maintain economically valuable productivity growth in rural industries when the benefits accrue at such a distance from the initial investment.

Against this background, impact assessment of RDC R&D projects through rigorous cost-benefit analyses plays several crucial roles:

- The results inform the principal funders of the RDC projects—industry, the community and Government—about the net benefits derived from their investments.
- Detailed assessment of the returns to investment in R&D provides valuable information for R&D decision-makers.
- The impact assessment process signals to researchers and collaborators how research proposals and performance are to be judged by RDCs.
- Rigorous impact assessment is central to ensuring good governance and transparency in the administration of RDC projects.

Information for stakeholders

The RDC research model is a collaborative research system in which R&D projects may have several financial supporters and participants and produce benefits which accrue widely across the community and extend for decades after the R&D has been completed. In what is a relatively complex administrative structure, careful, credible, and transparent assessment of the costs and benefits provides important information for participants. Careful assessment of the outcomes from rural research projects and their impacts on industry and the community provide the sound evidence that is increasingly sought to support the on-going investment needed to sustain the community and industry benefits associated with efficient food and fibre production.

Careful impact assessment also reduces the risk that benefits will be underestimated or that important public benefits and spillovers will not be recognised.

Ex post feedback to management

Ex post impact assessment of R&D projects, after the initial research phase has been completed but before the benefits have been fully realised, provides timely feedback to RDC boards and management on the value that is generated by their investments in research. As well as appraising individual investment decisions, impact assessments also provide an input to the rural research strategies formulated by RDCs, government agencies and research providers. Estimation of the future benefits from the research may also help guide the design of the adoption program so as to maximise the net benefits to industry and the community.

Ex ante input to investment decisions

The Council's involvement in research evaluation has been to coordinate ex post analysis of R&D projects to provide a largely retrospective view of the economic returns from earlier investment decisions. RDCs also use the same methodology to evaluate investment options prior to making a decision to invest (ex ante analysis).

RDCs make research investment decisions within a complex matrix of problem parameters, stakeholder interests and possible outcomes. The decisions are made by boards, selected to bring a diverse range of backgrounds and skills to these decisions. These boards have evolved structured project selection and investment decision processes that involve long-term strategic and annual operating plans, and that draw on input from industry, research disciplines and the community.

The RDCs have increased their use of cost–benefit analysis as part of this decision process where the proposed project lends itself to such analysis. In the main, these ex ante analyses are undertaken internally and may serve to test the claims made by a project's proponents, rigorously explore the possible outcomes and impacts of a project or provide a benchmark against which to conduct subsequent ex post assessments. Such analysis does not replace or diminish strategic considerations that should be taken into account when determining whether to embark on a research project but does assist in comparing alternative investments that may have very different benefit profiles.

Promote a focus on project outcomes and benefits

Routine impact assessment of R&D projects also signals to researchers that RDCs consider the realised value of the outcomes from the research they fund as well as the initial claims made when the research is proposed. These signals contribute to good project design by clearly identifying the attributes of the research and its adoption that generate value and that need to be measured. This helps to ensure that the research objectives are also clearly defined and remain the central focus of project management. An economic way of thinking about R&D can become inculcated throughout the system, an outcome which will help ensure that within and among projects, decisions are made that work in the direction of maximising net benefits to the community from the investment. Thorough impact assessment should also bring to the attention of stakeholders the environmental, human and social benefits from rural R&D that are typically relatively difficult to assess and measure, and which may otherwise be overlooked.

Background to these Guidelines

Each RDC separately administers its own R&D projects, responding to the priorities of the industry (or group of industries) to which it is responsible and to broadly-defined rural R&D priorities elucidated from time to time by the Government. The RDCs are also individually responsible for reporting to stakeholders on their performance, administrative processes, and governance.

An evolving effort

Until 2006, individual RDCs evaluated their R&D independently, setting their own evaluation criteria, using separate processes for selecting projects for evaluation, and using their own templates for presentation of results. In 2007, the RDCs agreed to coordinate their evaluation procedures. Through the Council of Rural Research and Development Corporations (the Council), they developed a cross-RDC evaluation program to select a sample of R&D projects, use a consistent methodology to evaluate the projects, and pool the results for further analysis.

The objectives of the evaluation program were to:

- report on the overall returns to industry from R&D funded by the RDCs;
- report on the public and spillover benefits from the R&D funded by RDCs; and
- assist in informing the community about the industry, public and spillover benefits that justify public contributions to the RDCs.

In 2008, a sample of 36 highly successful projects (or clusters of like projects) and 32 randomly selected projects (or clusters of like projects) underwent cost-benefit analysis within the evaluation program. In subsequent years, the program was expanded to include a broad cross-section of RDC projects, in order to obtain statistically significant estimates of the returns achieved across the RDCs' portfolio of investments in rural R&D. By the end of 2010, 160 projects had been subjected to cost-benefit analysis to identify industry and public benefits arising from the research and to produce estimates of the benefit-cost ratios, internal rates of return, and other performance measures.

The Council oversees the evaluation program on behalf of its 15 RDC members. The program has both strengthened and integrated the impact assessment processes of individual RDCs, establishing a common methodological footing, pooling results and providing estimates of the outcomes from the RDC portfolio as a whole that were beyond the scope of individual RDC evaluations. The RDCs set down guidelines for the evaluation program and established the procedures, governance and methodology by which RDC R&D projects were analysed. The methodology for analysis of R&D projects drew principally on official Australian Government guidance for the conduct of evaluations of government programs published as the *Handbook of Cost Benefit Analysis* (Department of Finance, 2006a), supplemented by brief instructions to evaluators addressing matters specific to the assessment of RDC R&D projects. Those guidelines, instructions, and methodology have provided a sound foundation for the cross-RDC evaluation to date.

Since the evaluation program was first envisaged, the need to substantiate the nature and the value of the benefits derived from rural R&D has, in the Council's view, assumed greater importance. Governments also increasingly require evidence that expenditure of public funds is achieving stated policy objectives, and that organisations receiving public funds follow sound governance procedures. The Council has determined that cross-RDC evaluation should continue and should be underpinned by procedures that will withstand critical review and an analytical methodology that is specific to the demands of reviewing rural R&D.

Meeting these enhanced expectations and requirements calls for revised guidelines, instructions, and methodology, as contained in this document. This revised *Guidelines* document provides the RDCs with a foundation document that sets out a standard methodology for assessing the impacts of RDC R&D projects. A separate publication by the *Cross-RDC Impact Assessment Program: Management Procedures*, sets out the role and administration of the Program under the new title of the *Cross-RDC Impact Assessment Program*.

From evaluation to impact assessment

Cost-benefit studies conducted on rural research projects supported by the RDCs have to date been referred to as 'evaluations' and the Council's involvement in coordinating these studies has been referred to as the 'Evaluation Program'. An evaluation can be directed at examining a variety of aspects of performance, value, quality or importance, whether at an intermediate or final stage, and does not necessarily imply an objective of assessing changes that occur as a result of a research project.

In much of the international literature and in practice, an examination of the changes that occur as a result of a research project is commonly referred to an 'impact assessment'. Organisations such as the Australian Centre for International

Agricultural Research (ACIAR) and the Consultative Group on International Agricultural Research (CGIAR) conduct impact assessments to identify and measure the consequences, both intended and unintended, of a project or program of research, development and extension. This terminology draws the attention of the analyst and the reader to consider the entire change pathway and the project's final consequences for the community.

In preparing these *Guidelines* we have adopted the term impact assessment in place of evaluation, to encourage stakeholders in the R&D process to think in terms of the ultimate changes that flow from research and not just the narrow research results or outcomes. The use of this terminology will help to distinguish the assessments from evaluations of other types (whether related to rural R&D or not). It will also signal that they are assessments of the benefits realised by the community from research and are not narrow measures of performance of an RDC, research provider or individual researcher.

Sources

The impact assessment methodology described in this document was developed, drawing on many sources of expertise and guidance. The methodology is based substantially on the *Introduction to Cost-Benefit Analysis and Alternative Evaluation Methodologies* (Department of Finance, 2006b) and the *Handbook of Cost-Benefit Analysis* (op. cit.), both published by the Australian Government. These sources have served as the basis of the CROSS-RDC impact assessment methodology since 2007 and, acknowledging the integral relationship between the RDCs and the Australian Government, should continue to guide the impact assessment of rural R&D.

Considerable effort has gone into developing the more specific methodology for impact assessment of rural R&D in the academic literature and in professional publications and papers produced by a range of R&D agencies, such as ACIAR. ACIAR has systematically commissioned independent impact assessment studies within its portfolio of research for more than 20 years. Over the period 2006 to mid-2008 ACIAR developed its detailed *Guidelines for assessing the impacts of ACIAR's research activities* (Davis, J. et al., 2008). Given ACIAR's experience in rural R&D and impact assessment in the context of Australian Government administration, the ACIAR guidelines are a valuable resource for CROSS-RDC to draw on, as appropriate, in developing its own impact assessment guidelines.

Through its long experience in funding, managing, and evaluating international agricultural research, the CGIAR has developed further insights into research impact assessment that are pertinent to assessment of RDC-supported research in Australia. From the mid-1990s the CGIAR has emphasised assessment of the impact of the research conducted by the international research centres that make up the group.

This was marked by the creation of what is now called the Standing Panel on Impact Assessment (SPIA), with the purposes of providing CGIAR members with information on the impact of past investments by the various CGIAR research centres and to enhance the quality of the ex post impact assessments undertaken by the centres.

This led to the publication of *Strategic Guidance for Ex Post Impact Assessment* (Walker et. al., 2008).

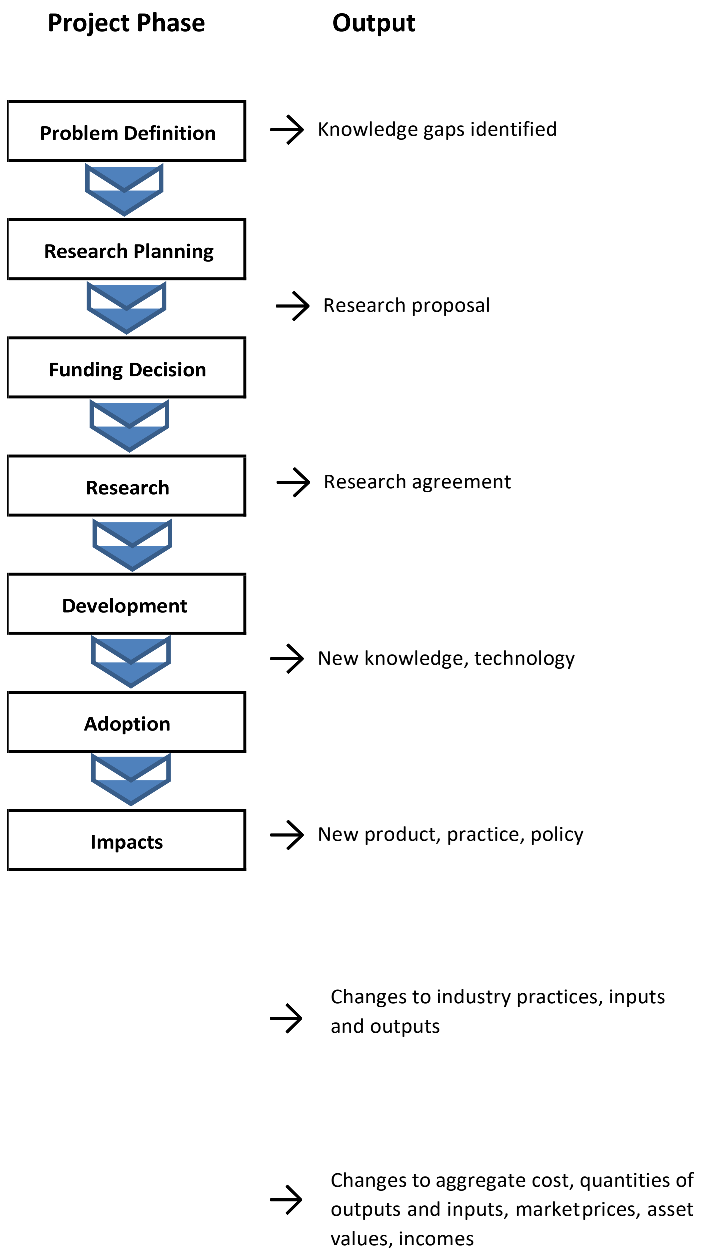
Both the ACIAR guidelines and CGIAR guidelines were developed specifically for the impact assessment of agricultural R&D and have benefited from an accumulated experience in assessment of the benefits from agricultural research around the world. The development of those two sets of guidelines has also drawn on the evolving global body of academic work that has developed the science of research impact assessment over recent years.

Impact Assessment Methodology

1. The Research Project Life Cycle

A rural R&D project can be viewed as a process in which scientific methods are applied to solving a technical problem with the objective of producing benefits to rural industries and the community. The life-cycle of a research project or group of projects has a number of discrete phases from its initial conception to final impact. Figure 1 provides a representation of the life-cycle of a single research project as a linear process in which each step has a specific output or result.

Figure 1. The research process



While projects may diverge from the pattern shown here (often the research and development are combined; the research may be halted, change direction or bring in new disciplines depending upon the results that are achieved; basic or strategic research may feed into applied research before adoption commences) the sequence of phases can be found in most projects. It is a feature of RDCs that they contribute in one form or another to most of the phases in the research project lifecycle through their links to industry, governments, and research providers.

Box 1 defines the terms we will use throughout the *Guidelines* in referring to specific phases of research projects and their consequences.

Box 1. Definitions

Research outputs	The findings from a research project which may include new scientific knowledge, new technology or new knowledge or understanding of policy, markets, or institutions. Research outputs may be ready to adopt by farmers or be inputs to further research or commercial development prior to adoption.
Research outcomes	Changes in practices, production or costs as a result of farm-level adoption of the outputs of the research and development process, or changes to market structures, institutions, laws and regulations.
Impacts	The aggregated effects of adoption of the research outcomes including changes in total production, price and quality of outputs, or market efficiency, and spillover benefits and externalities.

In the life-cycle of a project it may be many years before the research and development phases are complete and the adoption and realisation of impacts may take a further decade or more. It is useful to understand the R&D process in these terms and to acknowledge the role of RDCs in the process as a background to considering the scope of impact assessment studies and the stage at which they are undertaken within the life-cycle of the project.

2. Using Cost-Benefit Analysis

The methodology described here provides guidance on the use of social cost-benefit analysis for assessing the impact of R&D projects funded and administered by Australian RDCs. Compared with other approaches to impact assessment, cost-benefit analysis has a number of advantages in assessing these projects including:

- It is a logical process in which inputs and outputs are measured and benefits and costs are expressed in monetary terms in order to provide a consistent basis for comparison with other projects and investments.
- The value of costs and benefits can be discounted to appropriately address the changing value of money over time in projects that have a long life-span.
- Techniques for valuing non-market costs and benefits can be assimilated into the analysis.
- The analysis can be supplemented by qualitative assessment of elements for which benefits and costs are difficult to quantify.

Appropriate application of cost-benefit analysis provides a more robust and more comprehensive description and evaluation of an R&D project than can be obtained using other techniques such as commercial investment analysis, producing a 'return on investment' (ROI), or cost-effectiveness analysis.

2.1 Purpose and objectives of cost-benefit analysis

The purpose of impact assessment of R&D is to estimate the costs of the research and the costs and benefits for industry and the broader community generated by the use of the research outputs. The assessment recognises that research is inherently uncertain, sometimes producing unexpected results or unforeseen outcomes, positive and negative. These assessment *Guidelines* were developed to assist impact assessment practitioners and research managers to evaluate R&D funded by RDCs, using methods that are thorough, consistent and technically sound. It is intended that setting out clear guidelines will assist researchers, research managers and assessment practitioners in their respective roles, and will lead to improvements in the consistency of impact assessments and in the quality of the estimates of the net benefits from the RDC R&D portfolio.

The methodology for conducting cost-benefit analyses, outlined below, provides a framework for assessment of R&D, offering general guidance rather than specific, binding instructions. There is no rigid formula for research impact assessment; practitioners need to understand the context of the research they are evaluating and the purpose of the assessment, and exercise professional judgment accordingly. The *Guidelines* document is primarily directed at practitioners in rural R&D impact assessment who have an understanding of the core concepts of financial and economic analysis and of the pertinent economic and technological features of the industries in question. The *Guidelines* are also directed at RDC staff who manage research portfolios, commission impact assessments or interpret their results, or undertake in-house, ex ante impact assessments. Care has been taken to avoid technical language and to explain underlying concepts such that the *Guidelines* will be accessible to participants in the rural research process who may be less conversant with cost-benefit analysis.

The *Guidelines* document is not written as a text book or a ‘beginner’s guide’ on cost-benefit analysis. Other publications such as the *Handbook of Cost-Benefit Analysis* (op. cit.) provide a more detailed description of the underlying concepts and calculations used in cost-benefit analysis. In *Science under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*, Alston, Norton and Pardey (1998) discuss specific issues that arise and approaches to address them in conducting cost-benefit analysis applied to agricultural R&D investments.

The *Guidelines* highlights aspects of the analysis that are important to obtaining sound, robust estimates of the net benefits from R&D that will withstand critical review and facilitate comparison of research projects. It addresses a range of matters that are likely to influence estimates, including: the specification of a ‘baseline’ or ‘counterfactual’ scenario against which to assess benefits, the treatment of the administrative costs of managing R&D projects, the attribution of costs and benefits, the consideration of environmental and other social benefits, and the form in which results are to be reported.

The *Guidelines* also provides pointers for improving the presentation of results of impact assessments. This includes summarising the research and its consequences to encapsulate the resulting industry and social benefits, both to provide the information in a form that is useful to stakeholders and to facilitate better analysis and comparison of results across the RDC portfolio.

2.2 Conceptual basis of cost-benefit analysis

Cost-benefit analysis is a logical framework for examining a project or undertaking to identify, measure and value its costs and benefits. A social cost-benefit analysis (as distinct from a business or personal cost-benefit analysis), considers the project's impact on the whole community even though the costs and benefits may (in fact, usually) fall unevenly on its members. The rigor of cost-benefit analysis stems from making links between a project's costs and benefits and explicitly identifying assumptions made about those relationships. In economics it is usual to express the measures of costs and benefits in monetary terms such that a project's worth can be expressed in net terms, and to facilitate comparison of projects.

Social cost-benefit analysis is a tool used widely in the public sector to assess, from a community perspective, the impact of policy options and resource allocation decisions that involve costs or benefits in the form of goods or services that are not routinely traded in competitive markets. In the case of rural R&D, the market between research providers and those who benefit from their research is often weak or non-existent for a variety of reasons. It is the role of RDCs in these circumstances to invest in worthwhile R&D projects that would otherwise fail to attract adequate investment, and thereby to produce net benefits for industry and the community.

A cost-benefit analysis is, at its simplest, a careful evaluation of the expression:

Social Benefits – Social Costs = Net Social Benefits,

where each element is evaluated from the perspective of the community as a whole. Thus, the pertinent benefits from research-induced innovation in an industry can include direct and indirect improvements in producer's financial returns and benefits to consumers of the industry's products, as well as spillover benefits to other industries and others in the community. Costs identified in a cost-benefit analysis will include the direct costs of the R&D, the costs of extension and promotion of the innovation, the costs incurred by producers in adopting the resulting innovation, and externalities that arise from the use of the innovation. Different types of costs may be treated in different ways in a cost-benefit analysis. The treatment of different types of costs for RDC impact assessments is discussed in Section 3 of these Guidelines. Benefits and costs must be estimated over the entire life of the project and the effective life of the project's outcomes. This can be challenging because the processes of research, development, and initial adoption can take years (or decades) after which the life cycle of the outcomes from the research can extend for many decades more.

In a perfectly competitive world, free from market distortions, any research project that has positive net social benefits would result in a more efficient allocation of resources, would make society better off as a whole in that sense, and should proceed if the objective is to maximise benefits for the society as a whole. That is, an investment is justified if:

Net Social Benefits > 0;

or, alternatively, if the ratio of benefits to costs (Social Benefits / Social Cost = BCR) exceeds one. That is:

BCR > 1

In reality, however, markets are not perfectly competitive, markets for some goods are non-existent, financial and budget constraints exist, and objectives other than pure economic efficiency may apply. These considerations make the manager's task more complicated than simply identifying projects with a BCR greater than one. In particular, financial budget constraints typically apply such that the task of selecting projects involves considering the relative returns from alternative investments, and ranking projects according to their BCRs, or the Net Social Benefits per unit of constrained resource. A consistent methodology and approach to valuing benefits is clearly important if the measures are to be used for guiding priorities.

Benefits and costs must also be assessed in comparison to what the industry and the community would have experienced had the research not taken place.

Defining the baseline or counterfactual is obviously crucial to the outcome of the analysis, and usually will entail more than simply projecting current industry trends indefinitely into the future.

Another aspect of the analysis that requires careful consideration and judgement is the valuation of cost and benefits. In relation to rural R&D, many costs and benefits may be readily valued in monetary terms, such as the direct cost of a research project, the cost of adopting new technology, the value of improvements in industry productivity, or the consequences of a reduction in food prices. Other aspects, such as certain environmental benefits, or benefits from reduced public risks or wider product choice, will be more difficult to value and may require use of indirect valuation methods. Quantitative assessment of impacts let alone valuation of benefits may be impossible for some potential research outcomes, such as capacity building, increased resilience in rural communities, or social diversity. Impact assessment practitioners should, nevertheless, be able to document qualitatively the likely nature of such benefits and their potential importance.

2.3 Timing of the assessment of RDC R&D projects

The economic literature on assessment of agricultural R&D projects reports results from both 'ex ante' and 'ex post' impact assessments, but it is not always made clear what these terms mean. Here we use 'ex ante' to refer to assessments undertaken before the research phase of a project has begun (or after it has begun but before it has yielded any scientific results let alone had any economic impacts), and 'ex post' to refer to assessments undertaken after the scientific outcomes from the research are known but possibly (and in fact, usually) before the full consequences of adoption of the resulting technology or innovation have been realised. Such ex post assessments are still forward-looking in the sense that it is necessary to estimate the future impact, which will depend on the path of adoption and its consequences over potentially many years into the future.

The stage of research at which impact assessment is undertaken can have a significant bearing on the results and the extent of uncertainty surrounding the estimates of benefits. When an impact assessment is conducted earlier in the life cycle of the research project, the results will have greater contemporary relevance and will be more useful for informing decisions by RDCs, managers and researchers. On the other hand, with the passage of time, more of the benefits are realised and can be measured as actual rather than expected benefits, such that the measures become more reliable. Decisions on when to commence an impact assessment always have to balance these two aspects.

To provide consistency in the Cross-RDC Impact Assessment Program, assessments are conducted after the research has reached a significant 'milestone', or it has yielded a scientific output from which progress and future benefits can be assessed. Projects are selected for assessment from among those that have reached a significant milestone within the past five years. Practitioners will, predominantly, be working within a time frame in which the research costs will be substantially known, but the costs and benefits relating to adoption of the technology or innovations arising from the research outputs will largely be unrealised and will require speculation.

The primary focus of the Cross-RDC Impact Assessment Program is on ex post evaluation of R&D investments by RDCs, undertaken to provide a contemporary overview of the outcomes and benefits from the RDC portfolio. However, the same cost-benefit analysis techniques are also applicable in ex ante assessments to contribute to the project selection process or subsequent project management. In this section we discuss both types of impact assessment and their potential uses. Ex ante impact assessments are not included in the Cross-RDC estimates of the benefits from RDC research investments but are discussed in these *Guidelines* to assist those RDCs that wish to undertake such assessments on a basis that is consistent with subsequent ex post impact assessments.

2.3.1 Ex post impact assessment

The primary purpose of the Cross-RDC Impact Assessment Program is to estimate the benefits derived from R&D funded and managed by the RDCs. This information is relevant to stakeholders in the RDC model, especially:

- levy-payers who need to be assured that the funds obtained by deducting levies from the sale of their products are invested effectively;
- taxpayers who, through the Australian Government, co-fund RDCs up to 0.5% of GVP of levied commodities;
- research providers who, in most cases, also contribute to the cost of the R&D projects.

Ex post assessment also provides useful feedback to RDC managers, providing a check on the outcomes and benefits compared with those anticipated when decisions were made to fund R&D projects. Ex post assessments also signal to researchers how the outputs from their research will be assessed and measured by RDCs. In this way, ex post assessment provides guidance to researchers on how they can focus their research and plans for adoption in ways that will maximise the net benefits from the project.

Ex post cost-benefit analysis can also be employed in other ways and at other stages in the life-cycle of an R&D project. A retrospective re-assessment of past impact assessments can provide an important check on the accuracy of the estimation techniques used in the initial assessments. Re-assessments may also provide an indication of the expected accuracy of contemporary assessments. Re-assessment, later in the life-cycle of the adoption of research-induced technology or innovation, although more distant from when the initial investment decisions were taken, provides more reliable information about adoption of the outcomes, the net benefits from the research and any spillover benefits.

2.3.2 Ex ante impact assessment

Ex ante impact assessment can be used as a decision tool when investment in research is initially being considered, especially if the investment is oriented toward producing significant, measurable market benefits. Such assessments bring together and ascribe values to the most important assumptions about the anticipated research outputs and commercial outcomes. Compounding all this information into a single estimate provides decision-makers with a means for comparing the estimated net benefits from competing projects more rigorously than could otherwise be possible.

Within RDCs ex ante impact assessment is commonly undertaken by staff to complement the wider industry, strategic and scientific considerations in the project selection process. In this context an impact assessment conducted as part of the project selection process serves as a ‘reality check’ on the credibility and consistency of estimates of the expected innovations and outcomes from adoption that have been put forward in support of a project proposal. The assessments may also be useful for comparing competing research investments that otherwise are similarly attractive, or to clarify the extent to which time erodes the real value of the expected benefits relative to the costs of a project.

Some investment proposals will be better suited to quantitative assessment than others because their impacts are better understood or more readily observed. In some instances, strategic considerations or the prospect of important but qualitative public benefits will have substantial weight in the final investment decision. But, to the extent that quantitative factors are important, a carefully constructed estimate of net benefits will always make a sounder contribution to the decision process than intuition alone or simplistic partial estimates of the benefits.

Subjecting research proposals to ex ante impact assessment also sends a signal to researchers about the rigor that is expected in their proposals, and the yardsticks by which their research outputs will be assessed, with many potential benefits for the process of initiating and managing research projects. The process of conducting an impact assessment in conjunction with researchers identifies the factors that are critical in determining the value generated by research outputs and should lead researchers to develop and manage their research in ways that are more likely to maximise the value generated. Identifying, at the outset, the variables that need to be estimated in an impact assessment highlights the variables that should be monitored and measured during the research and adoption phases of the project, and assists research managers to develop the criteria by which they will assess and manage the progress of the research they have funded. This process is likely to enhance the quality of subsequent ex post impact assessments by highlighting the factors in the analysis that are most crucial to the estimation of net benefits such that early attention can be given to observation and measurement of those factors.

In ex ante impact assessment, where less is known about the outcomes from an investment than in an ex post impact assessment, additional attention should be paid to risk and uncertainty. Future costs and benefits are uncertain to varying degrees. It is important to acknowledge this uncertainty, in order that impact assessment results do not present a misleading picture of the project. Uncertainty surrounding the estimate of net benefits can be incorporated into the impact assessment by providing a margin for error (or variation) around the estimate.

Alternatively, a comprehensive sensitivity analysis is a preferred means of informing readers about the uncertainty around the estimates of costs and benefits.

Ex ante impact assessment, during the research phase of a project, might also be a valuable aid to decision making if an R&D project has not proceeded according to plan, or if conditions that originally justified the research have subsequently changed, and consideration is being given to whether to terminate the research. In other instances, where the research phase of a project has generated unexpected results, ex ante impact assessment may also be used as a decision tool to guide investment in further development, promotion, and adoption of new technology arising from the unforeseen outputs. In these cases, the value of a rigorous cost-benefit analysis lies in disentangling the factors affecting future outcomes, carefully considering the likely course of each of these variables, compounding their effects in a controlled manner and testing the sensitivity of the resulting estimates to the assumptions employed.

2.4 Project scope for ex post impact assessment

To allow cost-effective impact assessments of RDC R&D, the individual investments to be assessed within the RDC Impact Assessment Program should be large enough to spread the cost of the assessment over a significant amount of R&D expenditure, but such that the R&D under consideration is not so wide-ranging as to overly complicate the analysis. To achieve this purpose, it is sensible to aggregate similar projects where possible into groups or clusters.

For the purposes of the Cross-RDC Impact Assessment Program, assessment is undertaken on a project or cluster of related projects, a sub-program, or a large-scale R&D program that contributes to a specific discipline, research target or product which has been supported by a RDC or RDCs. Each RDC will have determined the sub-projects which form part of the project/project cluster prior to commencing the impact assessment. Before commencing the assessment process, practitioners should ensure that they have identified the details of all sub-projects that make up the project/project cluster and that they exhibit sufficient commonality to allow meaningful analysis to be undertaken.

2.5 Compounding and discounting monetary values

The process of discounting is based on the rational preference that a dollar now is worth more than a dollar at some time in the future. The standard approach to discounting reduces a stream of costs or benefits that occur over a period of time to an equivalent amount of today's monetary values. That single amount is known as the *present value* of the future stream of costs and benefits. Most research projects will have costs and benefits spread out over many years. To properly value a project's costs and benefits we must take account of the time when they occur. This is achieved by inflating cost and benefits from previous years to present values and discounting the project's future costs and benefits to present values. The difference between the present values of the stream of costs and the stream of benefits is the net present value (NPV).

Costs and benefits may be discounted to any year, and to the beginning or end of any year. But for the purposes of the Cross-RDC Impact Assessment Program, all costs and benefits are to be valued in Australian dollars and expressed in real terms, using as the base year the financial year ending closest to the time when the assessment is done. That is, assessments completed in the second half of a calendar year will use the financial year just completed as the base year, assessments completed in the first half of a calendar year will use the financial year about to end as the base year. All monetary values should be treated as being incurred or received at the end of the financial year in which they occur. Practitioners will need to make appropriate adjustments to historical and future values for costs and benefits to ensure all estimates are made using consistent units of monetary value.

All costs incurred, and benefits received, in financial years prior to the base year should be inflated to base year values using the compound growth formula. To maintain consistency across the cross-RDC impact assessments historical values should be inflated to base year values by using the implicit price deflator for national gross domestic product (GDP). Estimates of the implicit price deflator for Australian GDP published by the Australian Bureau of Statistics (ABS, 2012a, Table 4, series A2420916F) are listed as appendix 1.

The present value of future costs and benefits is calculated using the compound interest formula; and the rate that converts future values into present value is the *discount rate.* The discount rate is in effect an 'exchange rate' between value today and value in the future. The present value of the stream of benefits is the sum of all annual benefits, with each annual benefit discounted by the appropriate discount rate (*d*) to convert it into present value. For the purposes of the Cross-RDC Impact Assessment Program future values are discounted using a standard discount rate of 5% per annum as discussed below. This does not preclude practitioners using other discount rates in addition to the 5% rate. Indeed, this can be a useful exercise to gauge the sensitivity of the results to the discount rate used.

Certain other conventions have been adopted for the discounting process in the Cross-RDC Impact Assessment Program to ensure that the methodology is consistent across all impact assessments. In all Cross-RDC cost-benefit analyses:

- at a minimum, timeframes, measured from the last year of investment, including year 0 (last year of R&D investment), 5, 10, 15, 20, 25 and 30 year investment criteria horizons will be adopted, but additional and longer timeframes may be added if desired (natural resource management projects often have longer timeframes, which should be appropriately considered);
- where possible, forward predictions should be compared against realised outcomes, with the 5 year horizon as the minimum timeframe;

- actual and anticipated benefit streams (including the 0, 5, 10, 15, 20, 25 and 30 year horizons) should be reported as raw (undiscounted) data and as charts, in addition to the discounted benefits.

Note: The Excel financial function for net present value (=NPV(discount rate, range), where the range is, for example, cells S1:S20), assumes that the first cash flow occurs at the end of the first period, consistent with the convention for Cross-RDC impact assessments.

Box 2. Why Cross-RDC uses a 5% discount rate

To facilitate further analysis and comparison of the results of the Cross-RDC impact assessments, a common discount rate of 5% per annum is used in all cost-benefit analyses. This is a real (inflation-adjusted), risk free, pre-tax discount rate.

A real discount rate is appropriate since all costs and benefits in Cross-RDC impact assessments should be estimated in inflation-free terms. In particular, historical costs incurred prior to the year of analysis will have been inflated, by an appropriate index of inflation, to current values in the year of the analysis. Future costs and benefits should be assessed in constant, current values in the year of analysis.

In Cross-RDC assessments, the discount rate is not used as a means of adjusting the NPV for risks implicit in the research or the adoption of the research outputs.

Cross-RDC assessments estimate the costs and benefits of research projects from a social point of view and do not set out to draw conclusions about the distribution of cost and benefits among individuals or groups within the community. With this purpose in mind, taxation, which in essence redistributes the costs and benefits of the investment, is not a primary consideration.

A discount rate describes the decline of the value of a cost or benefit over time. One school of thought advocates using discount rates derived from the social time preference for money— essentially the price at which the investor is willing to trade off current consumption for future consumption opportunities, reflected in interest rates on savings. An alternative school of thought advocates using discount rates based on the opportunity cost of capital— the next-most profitable use of the funds invested, reflected in capital market interest rates. While in theory these two rates should be equal when the supply of savings for investment is equal to the demand for investment capital, observed market interest rates for savings and investments reflect many price distortions and effects of market imperfections. There is no consensus among academics or practitioners on whether a discount rate for use in cost-benefit analyses should be derived from savings rates or investment rates, or how to adjust for the distortions and market imperfections implicit in observed market rates.

Textbooks, academic literature and existing examples of cost-benefit analyses suggest differing, at times widely differing, discount rates may be used. Ultimately, the organisation undertaking the analysis must determine what discount rate it will use, guided in part by the purpose for which the analysis is undertaken, and interpret the results with an understanding of the effects of the choice of discount rate on the measures.

The observed yield on short-term government bonds is often taken as an approximation of the risk-free savings rate or consumption rate of interest. The yield on short-term government bonds fluctuates but is generally observed to be around 5% per annum, incorporating expected inflation and the risk free savings rate. Investment rates of return in capital markets are generally higher than this depending on the market and the security selected as an indicator.
Various studies report capital market investment rates of 7–10% per annum, but such rates invariably include significant, but undisclosed elements of risk or other market distortions.

Where a cost-benefit analysis is aimed at assessing a commercial investment with a short- to medium-term outlook, a strong argument can be made for using a discount rate that reflects the investor's opportunity cost of capital. For this reason, commercial investment analysis frequently uses a firm's weighted average cost of capital.

Where an analysis is undertaken to examine costs and benefits from a social perspective or over very long periods, benefits are ultimately realised and measured as consumption by individual members of the community. In these instances, a discount rate based on the consumption rate of interest is often advocated as more appropriate. Research, and in particular rural research, is an example of investment that typically gives rise to benefits that are realised over many decades and by generations that follow those who contributed to the cost of the research. Thus, a long-term discount rate is appropriate.

Guidance in the selection of a discount rate can be taken from other agencies involved in rural research since they are assessing similar types of research and their analyses may provide a benchmark against which results can be compared. The Australian Centre for International Agricultural Research (ACIAR) uses a discount rate of 5% per annum in its impact assessment of research investments. The Consultative Group on International Agricultural Research (CGIAR) notes that '*Increasingly, a real discount rate in the neighbourhood of 5% is used to evaluate the results of agricultural research*…' (Walker et al. 2008, p. 49).

The requirement for impact assessments undertaken as part of the CRRDC Impact Assessment Program to be based on a discount rate of 5% per annum, to facilitate further analysis, does not preclude RDCs, for their own purposes, from also analysing the costs and benefits using a different discount rate. Indeed, it is good practice to gauge the sensitivity of a cost-benefit analysis to the discount used, by re-calculating the NPV with a plausible alternative rate.

Walker, T., Maredia, M., Kelley, T., La Rovere, R., Templeton, D., Thiele, G., and Douthwaite, B. 2008. *Strategic Guidance for Ex Post Impact Assessment of Agricultural Research*. Report prepared for the Standing Panel on Impact Assessment, CGIAR Science Council. Science Council Secretariat: Rome, Italy.

2.6 Identifying and assessing impacts

Estimated impacts are derived by aggregating across the whole community the consequences of the farm-level outcomes from the research after estimating the extent of adoption and comparing against events that would have transpired if the research had not been undertaken. Cross-RDC impact assessments are primarily concerned with identifying the initial or 'first-round' impacts of research which may include:

- changes in total production
- changes in input use
- changes in risk, market efficiency, or supply-chain costs
- spillover benefits
- externalities
- changes in the value of human and natural capital such as skills and capabilities, and environmental benefits.

Assessments are not required to estimate knock-on or final effects, beyond the initial impacts, as prices of inputs and outputs are induced to by changes in quantities produced and consumed. In most cases the main difference between initial and final impacts will be in the distribution of the benefits, with small differences in total community benefits; wool production is an example where this may not be true. Practitioners are encouraged to identify the final impacts, especially in those cases where they have reason to expect to find significant differences between initial and final impacts but estimating the magnitude of responses by markets in Australia and overseas to changes in supply or demand, product quality or market structures is a complex and demanding task that is considered beyond the scope of most Cross-RDC Impact Assessments. This is not to diminish the importance of understanding these final impacts; indeed, these market responses are the mechanism by which what are sometimes perceived as farm-level benefits are re-distributed and become community benefits.

2.7 Professional judgement and the tenor of the assessments

Assessing the impact of R&D is not an exact science. Practitioners who assess RDC R&D projects must have significant skills and experience in economic analysis and will have to exercise careful judgement when identifying and measuring impacts and valuing costs and benefits. An understanding of primary production techniques, the R&D process, and the progress of technology and research-based innovation in the relevant industries, is a pre-requisite to assessing the impact that new knowledge and technology will have on innovation, productivity, and industry adjustment.

Where judgement must be exercised, the approach taken to assessing the future prospects for an innovation as it progresses from research to adoption—whether optimistic or pessimistic or supported by strong or weak evidence—will influence the estimates and affect the credibility of the results and the overall assessment. The CROSS-RDC Impact Assessment Program is seeking consistency among the assessments conducted and balance in those areas where judgement plays a role. The following comments are a guide to the approach consultants should take to undertaking assessments, estimating costs and benefits, and reporting their analysis.

Practitioners should take a conservative approach to the estimation of costs and benefits. They must be a counterweight to the natural optimism of researchers about the potential of their research to generate new technology and innovation that will have widespread application. Likewise, analysts must be wary of tendencies to underestimate costs, the time needed for research to generate results, and the potential for unforeseen problems or hurdles to arise in the R&D process.

Contact with researchers, commercial developers, extension staff, and producers is essential to truly understanding the research, the new technology or innovation that follows, and the ultimate adoption of the technology or innovation by producers. Good R&D impact assessment is not a desk-research exercise; it is a hands-on, practical assessment. Time spent discussing the R&D project and the research outputs with key people throughout the R&D pathway will be well rewarded in the quality of the analysis. In those discussions, the consultant should maintain a healthy scepticism about others' expectations of future developments and maintain a preparedness to question the basis of those expectations. Consultants should be prepared to avoid taking predictions about the future at face value and to subject 'rules of thumb' to closer scrutiny.

Practitioners should always be aware of the difference in performance when technology or innovation is applied in controlled, small-scale trials, compared to the performance in a commercial production environment.

The credibility and standing of an impact assessment will rest crucially on how it is documented and reported. In the reports of their impact assessments, practitioners must clearly document the processes, assumptions, techniques and values on which their estimates are based. They should clearly describe and substantiate the counterfactual or baseline scenario, against which the net benefits ascribed to the outcomes from the R&D project are measured. Particular attention should be paid to documenting the treatment of those factors that are most susceptible to error or misspecification or, for want of hard data, are substantially reliant on professional judgement or opinion.

The presentation and discussion of the results of cost-benefit analyses should acknowledge the margins for error around point estimates of net benefits and returns, supported by sensitivity analysis that quantifies the relationships between key variables and the estimated results. And, while cost-benefit analysis is substantially a quantitative assessment, care should be taken to provide a succinct narrative description of the research and its outcomes, especially non-market, environmental and other social costs and benefits that cannot reasonably be measured or valued.

3. The Impact Assessment Process

The objective of CROSS-RDC impact assessment is to gauge the changes in the economy that are attributable to a research project. This entails identifying what the research accomplished and what actions have been and are likely to be taken in the future based on the resulting new knowledge, technology or discovery, compared to what would have occurred if the research had not taken place.

The process followed in a typical impact assessment can be represented as a series of steps in which the research inputs and the resulting outputs, outcomes and impacts are identified, quantified and valued. Figure 2 represents the steps in the impact assessment process.

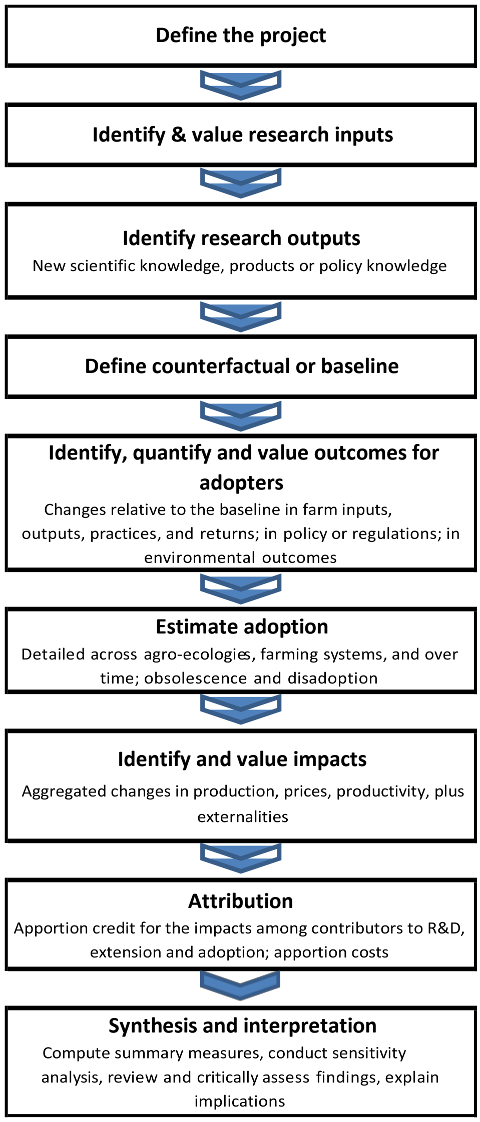
The impact assessment process should trace a causal relationship from the research project, through the research outputs, development processes and adoption, to ultimate impacts. This can be a complex chain of events with a range of variables affecting each link in the chain, especially if the project includes early-stage, strategic research.

Analysts have to both understand and describe this process from research to impacts because different benefits can emerge over time from each of the steps.

Developing a flow chart that identifies the steps in this research-to-impact pathway, the role of external third parties and other inputs, and exogenous factors such as economic settings, weather and commodity market conditions, will help to depict the process and place the research outputs in context. A flow chart will also help to crystallise the importance of issues, such as attribution and adoption rates, that bear critically on the impact assessment results.

The flow chart represents both a logical sequence in the development and organisation of information and a sequence in practice, as each step uses and builds on information developed in the previous one. It is important for analysts to identify and document clearly in their reports the detailed procedures adopted at each stage of this process in a form such that readers can fully understand what was done, and why, and if necessary replicate the computations.

Figure 2. The impact assessment process



3.1 Identifying and valuing project inputs

In cost-benefit analysis, costs and benefits are valued on the basis of willingness to pay or opportunity cost. Costs are valued on the basis of what other users would be willing to pay for the resources employed or what would otherwise be the best (highest value) alternative use for the resource owner—the opportunity cost. In situations where inputs to an R&D project cannot be valued by reference directly to market prices, practitioners will have to impute ‘shadow prices’ either by adjusting the observed market prices or imputing values from other evidence.

All inputs to the R&D project, as well as additional adoption and supply-chain costs, that contribute in a substantive way to final research impacts should be included. Initially, it is useful to list the types of costs associated with the R&D, without necessarily quantifying or valuing each item.

Inputs to the R&D process will generally include:

- financial outlays by collaborators and participants in the R&D project;
- financial outlays on development of the research outputs separate from the research project;
- in-kind contributions to the research project;
- extension and technology transfer; and
- administrative costs borne by the RDC and by research providers;

Additional costs that contribute to final research impacts may include:

- extension costs incurred by third parties (e.g. commercialising agents) to encourage adoption beyond the extension costs incurred within the R&D investment;
- adoption costs incurred by producers or initial users of the research outputs; and
- additional supply-chain costs.

In most cases these inputs will be financial flows or contributions that can be measured directly, or tradable goods and services that can be valued at their market prices or their best (highest value) alternative use by their owner. The following sub-sections address considerations that may arise in quantifying the costs of the inputs listed above.

3.1.1 Costs of R&D

The impact assessment should include the costs of all the research that contributed in a substantive way to the research outputs and should record the year in which the costs were incurred. Direct financial costs of R&D borne within a project will usually have been documented during the project. At the time of the assessment, data may be required on both historical expenditures and forecast outlays. Care should be taken to obtain data on actual historical outlays rather than budgeted estimates and to review estimated future costs in the light of historical performance against budget.

RDC projects may exist as stand-alone R&D projects with discrete outputs, ready for adoption. But mostly RDCs contribute to R&D projects that are part of a larger set of investments in R&D and extension within a research institution or across a research discipline, that together deliver multiple outputs that may be ready for adoption or may, in turn, feed into other projects where further investment and development will occur. For the purposes of impact assessment, all the R&D costs involved in delivering the final research output should be considered together and may include costs incurred in related R&D projects, or parts of projects, and in other institutions, where the research or activity is integral to the outcomes from the R&D project being assessed. Impact assessments that fail to include all of the intermediate research costs will understate the investment required to deliver the outputs and outcomes and overstate the net benefits and BCR.

R&D projects often include in-kind contributions from collaborators and participants including commercial partners, public institutions and producers. For example, plot trials and demonstrations of new pasture and field crop varieties are regularly performed on land provided by growers; and food processors such as millers, maltsters and brewers collaborating with plant breeders provide commercial processing trials on new grain varieties.

If more than a few projects or institutions contributed to the final output, a flow chart as suggested above can assist the reader to understand the relationships among the contributing components of the research as well as assisting the practitioner to define the elements to be quantified and their relationships to one another.

Care should be taken to capture these costs at a market rate or opportunity cost, remembering that the analysis is evaluating community costs and benefits, and even resources that are donated, free of charge, have an opportunity cost. Both the total overall magnitude of investment and the relative shares of the costs contributed by RDCs and by other participants in the project are important and should be recorded. These data are essential for the CROSS-RDC analysis of the results of the impact assessments.

3.1.2 Costs of extension

Costs of extension, promotion and technology transfer can, in some instances, exceed costs of research. The assessment results, especially for smaller projects may be sensitive to assumptions on how the costs of extension are calculated.

Costs associated with promotion and extension of the research outputs need to be estimated for all outputs. Researchers are often involved in promoting new technology and developments to producers, other researchers, extension staff or the community. However, extension and promotion will frequently involve other staff from the research institution, as well as RDC staff, and staff and resources from government agencies and private providers, whose time and costs for this activity may not always be accounted for as part of the research project. Practitioners should explore with researchers the adoption path for the research outputs and how the costs of this aspect of their work are accounted for by the institutions concerned.

It is important for the analyst to identify whether the extension costs were part of the investment being assessed or incurred after the investment as part of the adoption and implementation phase. For CROSS-RDC impact assessments, it is preferred that any costs of extension that were not incurred as part of the RD&E investment being evaluated are incorporated into the assessment by deducting them from estimated gross benefits (e.g. gross benefits – additional third party extension/adoption costs = net benefits) to ensure that the investment criteria reported (e.g. present value of costs, benefit-cost ratio, and internal rate of return) relate directly to the costs of the R&D project(s) being evaluated (e.g. benefit-cost ratio = PV of net benefits / PV of RD&E costs).

In assigning the cost of government extension staff involved in development and adoption of a selected technology or innovation, a common practice is to estimate the share of their time devoted to the specific technology or innovation and assign a share of their total employment cost (salaries plus on-costs) pro rata, according to the proportion of their total time attributed to the project. This approach may also be used in relation to other staff or resources that contribute to the extension or promotion of a technology or innovation, for which the full cost is not charged to the R&D project. An assumption that the cost of extension services, public or private, is a sunk cost, and has zero opportunity cost, is not a valid assumption.

In cases where the adoption process has not been completed, this element of the process will have to be projected forward in the analysis. Some research projects will have well-documented extension plans developed at the time when the research proposal was formulated; in others the extension and promotion may be less well planned. In either case, consideration should be given to whether, as the research has progressed, the original plans are still appropriate to the research outputs and what resources will be required to achieve an optimal time-path of adoption of the new technology. If extension plans have not been adequately documented, the practitioner will need to devise and cost a plan that is appropriate to the concomitant assumptions made about the adoption potential of the research outputs.

In cases where technology is licenced to a private firm that assumes responsibility for promotion and earns a return from sale of the technology or complementary products, that firm's net return and any licence fees or royalties paid to the research provider or the RDC will form part of the total economic benefits, along with the benefits from productivity gains realised by producers.

Some RDCs are assuming a larger role in promoting the outputs of the research projects they support through field days, industry events, sponsorship and, print and electronic media articles. Costs associated with this promotion should be included in the analysis. If these costs have not been specifically allocated to the research project by the RDC, the total cost of promoting a project during the research phase and promoting the resulting research outputs, technologies and innovations should be estimated. One method is to assign a portion of the RDC's total promotion expenditure (on all media forms and activities) pro rata according to the RDC's investment in the R&D project being assessed, expressed as a share of the RDC's total R&D investment over the same time period.

In relation to all extension and promotion cost items, practitioners should satisfy themselves that the allocation procedure is reasonable, and the method used to identify and allocate the costs is documented in their impact assessment reports. Estimates of the costs of the transfer of research outputs into a new technology or innovation and achieving commercial adoption are likely to be less precise than estimates of research costs, much of which will already have been expended. Analysts will need to consider whether assumptions about the cost of technology transfer and extension should be a candidate for sensitivity analysis when presenting their results.

3.1.3 Administrative costs

R&D costs should also include the administrative costs associated with managing and supporting the project, including the administrative costs of the research provider, whether public or private, and of the RDC. An assumption that the cost of administration, whether incurred by an RDC or by a public or private research provider, are sunk costs and that the resources have zero opportunity cost is not a reasonable assumption. Estimating and apportioning administrative costs attributable to a particular project can be complicated in a large research institution combining diverse projects and disciplines. A common procedure for charging these costs is to assume that they are proportional to the scientist years involved in the R&D project of interest relative to the total number of scientist years in the institution over the relevant time period. An alternative is to allocate administrative costs among projects in proportion to their shares of total research costs of all the projects operating within the institution.

Similarly, an RDC's administrative costs should be allocated across the projects it supports. One approach is to allocate the RDC's overheads pro rata, in proportion to the value of its financial contributions to research projects that it supports. In industry-owned corporations that have functions other than research administration, administrative overheads applied to R&D projects should be limited to those associated with research funding and management. In statutory RDCs, the administrative costs should include a pro rata share of all overhead and administrative costs. This share could be equal to the amount the RDC has invested in the R&D project under assessment, throughout its life, as a share of the total R&D investment by the RDC in all projects over the same time period. Analysts should satisfy themselves that the allocation procedure is reasonable, and the method used to identify and allocate administrative costs is documented in their impact assessment report.

3.1.4 Costs of adoption

Estimating adoption costs necessarily requires assumptions about adoption rates over time and across regions. These assumptions are usually crucial to the results of the assessment and should normally be subjected to deep scrutiny and careful sensitivity analysis. Assumptions about adoption are dealt with in more detail below in the discussion on estimating benefits.

For CROSS-RDC impact assessments, it is preferred that the costs of adopting or implementing a new technology or other innovation are incorporated into the assessment by deducting them from estimated gross benefits (e.g. gross benefits – additional adoption/implementation costs = net benefits) to ensure that the investment criteria reported (e.g. present value of costs, benefit-cost ratio, and internal rate of return) relate directly to the costs of the R&D project(s) being evaluated (e.g. benefit-cost ratio = PV of net benefits / PV of RD&E costs).

These adoption costs may, variously, include capital outlays by producers for new machinery or equipment, and additional labour costs, depending on the nature of the innovation. Additionally, innovations may lead to redundancy and premature depreciation of existing equipment and improvements that should also to be taken into account.

An assessment of the benefits and costs realised by industry from a new technology or other innovation should take into account increases in recurrent operating costs and changes to the risk profile of production for producers who adopt the innovation. This may involve assessing, in addition to the effect on yield or net income, the effect of the innovation on the variance of yield or net income. Innovations often entail both higher income and higher variability—for example a high-yielding wheat variety that is clearly superior under ideal conditions may not be dominant when disease, drought, frost or other environmental stresses occur. Alternatively, a drought-tolerant wheat variety may produce less-variable yields over a range of different seasonal conditions but with a lower average yield. Researchers may be in a position to provide information about the effect of their technology on risk or variability that can be used to make an assessment. If it is not possible to quantify the effects accurately, a qualitative assessment of factors such as the effects on production risk may be appropriate.

Adoption costs may also be incurred along the supply chain in cases where adoption results in new products, product specifications or product segments, or new handling, storage, or marketing arrangements. The effect of new technology in these industries may include a range of capital and recurrent costs and effects on risk similar to those outlined above for the producers who adopt the new technology.

Checklist

- Costs counted in impact assessment of an R&D project should include:
  - Direct financial cost of research incurred by all contributors and participants.
  - Development cost associated with the research outputs prior to or after adoption.
  - In-kind contributions valued at market cost or opportunity cost.
  - Extension and promotion costs incurred by the research provider, government agencies, RDCs and private providers.
  - Administrative and overhead costs of research providers, RDCs, and other collaborators.
  - Adoption costs incurred by producers and the supply chain including capital recurrent costs.
- A flow chart may assist in tracing and describing the contributions and involvement in large, complex and collaborative projects.
- Input costs should be actual expenditure or contribution and likely future expenses not budgeted contributions.

3.1 *Identifying research outputs*

The outputs from a research project may comprise:

- new scientific knowledge,
- new products, processes or technologies,
- new knowledge about markets, institutions or policy,
- new or broader capacity or skills.

If a project comprises more than one sub-project, there may be multiple outputs that either feed into further research or are used in conjunction with other research outputs to deliver the outcomes from the project when they are realized on farms or by other adopters of the results.

Some outputs may be ready to adopt by producers or others in the supply chain and others may require further development or modification prior to adoption. It will be useful to identify the sequence of steps in the development of the outputs from initial scientific findings to the final, ready-to-adopt outputs.

In many projects, some outputs will be stipulated as deliverables from the research project. However, practitioners should look beyond these deliverables to identify other outputs from the project. These may be of secondary importance to the principal outputs and not identified in the original project specification. In some cases, there may be unintended outputs that were not envisaged at the commencement of the project but were discovered during the course of the research.

New research capacity or skills will often be an output of research which by its nature is breaking new ground in a scientific sense. The new capacity or skills may permit similar work to be completed in a related field more quickly or cheaply.

It will generally be sufficient for assessments to identify the nature of the research outputs with a brief description of each and where appropriate an outline of the sequence of findings or developments that lead to the final, ready-to-adopt output.

Checklist

- Identify all research outputs including new scientific knowledge, products technologies, processes, institutional or policy knowledge and new capacity or skills.
- Look for secondary outputs as well as outputs stipulated as project deliverables.
- Look for unintended outputs.
- Identify the sequence of development of outputs from initial scientific findings to ready-to-adopt outputs.

3.2 Defining the counterfactual or baseline scenario

The basis of any R&D impact assessment is the baseline—without research—scenario against which the impact of the research-induced innovation is assessed. In ex post analysis, this baseline is a hypothetical counterfactual scenario. Determining the characteristics of this counterfactual requires judgements about the course of events that would have transpired in the absence of the research outputs produced by the project under consideration. This counterfactual scenario obviously did not, and will not occur, and can only be inferred from knowledge of the industry and its markets.

The definition of an appropriate counterfactual is one of the most important elements of a cost-benefit study and should be discussed explicitly when reporting the impact assessment. The impact of industry productivity improvements should be assessed against the productivity improvements that would have occurred in the absence of the funded project. For example, yield improvement from a plant breeding program will often be assessed against a background in which yields would have been rising because of adoption of new varieties released by other breeding programs, and improvements in crop husbandry. On the other hand, the virulence of some crop diseases tends to increase over time, as new races of pathogens emerge and become endemic, which acts to reduce yields of older, as well as many new, varieties. The counterfactual needs to identify the range of factors that would influence future performance and estimate their impact.

The counterfactual should be carefully considered, and its implications explored, as there are no firm rules on how to construct a convincing alternative scenario. The practitioner needs to strike an appropriate balance between optimism and pessimism in defining an alternative course of events. In most cases the improvements in production, productivity and financial margins will be small, incremental gains rather than step changes. Wherever possible the practitioner should seek evidence to support the specified counterfactual scenario, for example, from analogous industries or other jurisdictions, or from prior experience with the industry and the program.

Caution should also be exercised in the use of simplifying assumptions. A common default assumption is that, for a particular variable or parameter, the difference between the research outcome and the counterfactual is constant over the impact assessment period. While a constant margin of difference will simplify estimation of benefits and *may* represent a feasible scenario, such assumptions should not go unchallenged by the practitioner.

Because the counterfactual has such a pervasive influence on the results of an impact assessment, it should invariably be subjected to sensitivity analysis. This analysis should test the sensitivity of the results to changes in the key characteristics of the counterfactual scenario, especially those that might be contentious or subject to great uncertainty.

A question that will arise in relation to RDC R&D projects is whether the research would have proceeded in the absence of RDC funding—would the research outcomes have arisen anyway? In most cases, RDCs are partners in research projects and provide only part of the funding, but may impose, as an explicit condition, that RDC funding is essential to the viability of the project. Where this condition has been imposed, it provides a prima facie answer on this point. In general, given the budget constraints facing research providers and funders, and the narrow range of options for funding rural research in Australia, specific evidence should be presented to support an assumption that the R&D would have occurred anyway. In relation to some larger or high-value R&D projects, the counterfactual may be that, in the absence of RDC funding, the project may well have proceeded, but on a smaller scale and with commensurately diminished immediate outputs or consequent improvements in technology. In the absence of RDC funding, specific basic or strategic research findings might be expected to come from other projects or institutions either in Australia or overseas. In this scenario the principal effect of the project would be to speed up the development of the relevant innovation or technology, its adoption and resulting benefits, and the net impact of the project derives entirely from the extent to which the benefits will be brought forward in time.

Checklist

- Determine whether the research would have proceeded in the absence of RDC funding.
- Define the relevant counterfactual scenario and its characteristics.
- Consider whether the difference between the research outcomes and the counterfactual will be constant over time.
- The counterfactual and inherent assumptions should be explicitly described in the impact assessment report.

3.3 Identifying and valuing research outcomes

The outcomes from an R&D project are the changes that occur on farms or along the supply chain for a product when producers adopt the research outputs. These changes result from the adoption of new technology, new management practices or improved skills. The first step is to identify the past or prospective changes in:

- farm outputs (increased quantity, new products, improved quality)
- farm inputs or cost,
- marketing or supply chain costs,
- other efficiency gains, or
- off-site effects or externalities

In most cases the changes as a result of adoption of the research outputs will be quantifiable and estimates should be made of the magnitude of each change that has been identified. The farm-level outcomes may not be constant over time because of variation in seasons and market conditions, and other changes, and outcomes should be assessed over an extended period, or with allowance made for variations over time.

For example, in the case of crop varietal improvement research, the relevant comparison may be between a representative field on which the new variety is planted and the (counterfactual) variety that would have been planted on that field otherwise.

In most cases adoption of the research outputs will only be in its early stages such that only limited evidence may be available on adoption and actual producer outcomes for those who adopt. Practitioners will be faced with estimating the magnitude of the outcomes, the proportional changes in price, yield, and cost per hectare relative to the baseline or counterfactual alternative) usually from research results, small-scale trials and producer experience.

At the level of an individual farm, or at a broader level of aggregation, these measures might then be aggregated up across fields according to the extent of adoption.

Even in this comparatively straightforward and familiar example, the measurement challenges facing the analyst are many. In practice, various approximations will be required—such as, perhaps, assuming the effects are constant across places and over time for those who adopt. Because these decisions and assumptions are crucial determinants of the ultimate measures of impact, analysts should take particular care to document fully and clearly in their reports what they did and why at this stage of the analysis, in ways that would allow reader to replicate the computations if they should wish to do so.

Some outcomes will be more difficult to measure (e.g. reduced soil loss from broadacre cropping land as a result of maintaining ground cover between successive crops). Practitioners will also need to estimate the extent to which measured changes will vary among regions or among individual producers as a result of factors including climate, soil conditions, operator skills and production scale.

Outcomes that occur as changes to physical outputs, inputs or reduced supply chain costs should be valued at market prices. Outcomes should be valued in net terms when both inputs and outputs are affected. The value of off-site effects and externalities will be more difficult to value. Valuation methods are discussed in more detail in later sections.

Checklist

- Identify all research outcomes in terms of changes to outputs, inputs, supply chain costs, and externalities.
- Quantify the outcomes making allowance for variation over time, and differences according to region, climate, and other conditions.
- Value outcomes at market prices wherever possible.

3.4 Estimating adoption

Assessments of the returns to investment in research rest heavily on estimates of adoption. Estimates of benefits and other summary statistics are often more sensitive to assumptions about the rate of adoption and its timing than to any other element in the estimation process, indicating that it is an aspect of the assessment process to which particular care and attention should be given.

Individuals adopt a new product, process or idea when they perceive that the benefits from adopting the innovation outweigh the costs of making the change. The adoption process involves not just a consideration of whether the technology or other innovation will function in a given production environment, but also an assessment of the impact on production, profits and financial risk.

In regard to scientific and other knowledge products that will be used in further research, especially basic or strategic research outputs, adoption may be affected by limits on technical skills or on scope to invest in new capacity, the extent of interest by researchers in the scientific field, or availability of funding for new research. Uptake of the new knowledge and further R&D may also be constrained by processes of regulatory review and approval that add to the time lags and the other costs. The progress of research using transgenic technology and animal cloning are prominent examples of these issues. Discussions with researchers and research managers may help to elucidate the prospects for adoption and development of the new technology or knowledge. Analysts may consider referring to CSIRO's ADOPT tool (https://research.csiro.au/software/adopt/) when considering assumptions about adoption.

These factors should be considered by practitioners in tracing the path of the research outputs through to their final impact. In many instances adoption will be in its early stages at the time of the assessment and estimates will have to be made of the expected progress of adoption in future years. Consideration should also be given to differences in expected adoption across different agro-ecological zones. Comparison with past adoption of similar technologies may also provide a guide to likely adoption.

In cases where adoption has progressed significantly, it may be appropriate to conduct a formal adoption study that (a) identifies the potential of the technology and the processes and resources committed to achieving adoption, (b) estimates adoption to date, and (c) assesses the outcomes that have resulted from adoption. An adoption study is a more formal process that documents the progress of the original research output along its expected development and adoption pathway and compares actual progress against estimated outcomes. An adoption study should also examine the reasons for non-adoption or dis-adoption where this is observed. Understanding the reasons why adoption did not occur, or occurred more slowly than anticipated, can be just as important a guide to future R&D and extension programs as understanding the successes.

Estimates of adoption, whether based on formal adoption studies or not, should as a minimum focus on identifying the following fundamental characteristics of a new technology or other innovation:

- What are the geographic dimensions or other defining characteristics, such as farming system type, of the parts of the industry to which the innovation is suited?
- Within each part of the industry to which the innovation is suited:
    - What technology or practices does the new technology replace and what are its relative advantages over the existing technology or practices?
    - What are the expected benefits and costs per unit (or range of expected benefits/costs per unit, both direct and indirect) from adoption relative to the benchmark technology?
    - What is the potential for subsequent dis-adoption or replacement by other technology?

These factors help to define the competitiveness and lifecycle of the innovation, which in turn provides evidence of the limits of its adoption potential and the aggregate benefits. This information underpins quantification of the expected rate of adoption of the new technology, year-by-year over the life of the innovation, for each industry segment or region to which the technology is suited.

Checklist

- Identify the key factors driving adoption of the new innovation and its competitiveness compared to existing technology or practices.
- Identify the regions to which the innovation is suited.
- Quantify the sources of variation in rates of adoption among regions.
- Estimate the expected adoption rates
- Consider the innovation's life cycle and potential to be superseded.

3.5 Identifying and estimating impacts

Previous sections have identified inputs to an R&D project, its outputs and, through adoption, how the outputs are transformed into outcomes on individual farms or for other adopters throughout the economy. The final step in the impact assessment process is to trace how these outputs and outcomes are transformed and aggregated up to the impacts that are quantified and valued across the community as a whole.

The measures of benefits used in cost-benefit analysis of R&D projects or other investments typically correspond, at least in principle, to measures of economic surplus (i.e. producer surplus and consumer surplus and the like). A great deal of economic theory and thinking underpins the use of these measures, but it is easy to get the details wrong and for various reasons impact assessment reports should make transparently clear how measures of outputs and outcomes from R&D have been transformed into measures of benefits.

Impact assessments of RDC R&D will predominantly entail measures of producer and consumer surplus (and perhaps transfers) associated with research-induced shifts of farm supply functions, where all of the benefits are market benefits. This is a relatively well-understood economic problem for which the tools of analysis are well-developed, but still the analyst is free to choose approaches to measurement that can have significant consequences for the measures. To enhance transparency, in most instances it will be appropriate to provide both a flow chart, showing the pathway by which R&D gives rise to outputs and outcomes, and a supply and demand diagram, showing how those outcomes result in market-level changes that can be translated into measures of benefits, with a clear identification of how those measures of benefits are defined. In addition, the specific mathematical formulas used to compute measures of impact and benefits should be provided, and explained, with their details fully documented.

In addition to the kinds of market benefits realised by producers and others in the community, as just discussed, the impacts of an RDC R&D project may include costs or benefits imposed on the community as externalities. This section identifies the different types of benefits and how they should be valued and how assessments should address externalities. The importance of accurately attributing benefits among sources for the purposes of impact assessment is also discussed.

3.5.1 Identifying types of benefits

In identifying the impacts of R&D and the different groups in the community who benefit from it, and considering questions of valuation, a clear understanding of the types of benefits and their attributes is helpful. All outputs from research are either 'private' or 'public' goods (or a mixture of the two types of goods). Private goods are excludable, that is the benefits accrue to an individual and access to the benefits can be controlled. Usually private goods can be valued by reference to market values.

Public goods are non-exclusive—it is impossible to limit who receives the benefits. Public goods may also be non-rival, that is, consumption by one person does not diminish availability to others—for example, maintenance of quarantine barriers against exotic agricultural pests and diseases. Typically, market economies under-produce both non-rival and non-excludable goods. Many of the outputs from rural R&D exhibit these characteristics, which is the principal reason why a public contribution is required to maintain adequate investment in certain types of R&D.

Since public goods do not have effective markets, valuation of these goods will often have to rely on shadow-pricing methods. Shadow-pricing methods are described in more detail in *Section 4 – Evaluation of non-market impacts*.

Classifying research outputs according to their private or public good attributes does not have an exact parallel when we come to classifying the benefits that arise from the final outcomes of an R&D project. The important distinction for the purposes of economic analysis and policy consideration is between market benefits (benefits for which the recipient pays a price in a market transaction) and non-market benefits (benefits received free of charge or at a price that is significantly less than their economic value).

For example, the development of zero- and minimum-tillage farming practices produced significant market benefits for producers who adopted the new farming methods. The benefits included reduced fuel and machinery maintenance costs (partially offset by increased herbicide costs) as well as reduced soil loss and longer-term improvements in soil structure, microbial activity and fertility (which would be expected to result in an increase in the value of the land asset although this may be difficult to measure). In addition to these market benefits the innovation also produced non-market benefits in the form of reduced emissions of greenhouse gases, less river turbidity as a result of reduced run-off from zero- and minimum-tilled farmed land, lower risk of toxic algal blooms in river systems, and improved air quality in towns and cities adjacent to farming land as a result of reduced soil loss by wind erosion.

A related issue concerns the distribution of market benefits, along the supply chain for a product, as a consequence of market forces (which are not, as sometimes described, spillover benefits). Consider the example of levy-funded research into improved dairy productivity. If the research results in increased production or lower milk production costs, this will initially benefit dairy producers. However, market forces will likely lead to second-round effects including increased demand for some production inputs or lower milk prices. As a result, some of the 'producer' benefits will be distributed up and down the marketing chain as benefits to suppliers of inputs and to consumers. Moreover, through cross-commodity substitution effects in production and consumption, consumers and producers of other products may gain or lose. It will generally be beyond the scope of impact assessment studies to quantify and value the extent to which market forces redistribute benefits among producers, the supply chain and consumers. However, practitioners should highlight the redistribution of the market benefits of R&D along supply chains and across commodities since this is the main mechanism by which the wider community receives benefits.

RDC investments in R&D will yield non-market benefits if the resulting new technology or innovation can be applied beyond the levy-paying industry and its supply chain. Suppose the research that led to the improved dairy productivity mentioned above was also applicable directly or with small modification in other industries (e.g. if it were improved pasture management or nutritional knowledge that could be used in beef or lamb production). In the absence of intellectual property rights whereby the dairy industry could charge others for the use of the research results, we have a spillover of benefits from levy-funded research by the dairy industry to other industries—a non-market benefit that should be added to the conventional measures of benefits within the dairy industry. Where these spillovers can be identified and are significant, efforts should be made to estimate their size and value. Depending on the nature of the spillover, this may require a separate analysis of the recipient industry or, in a mixed farming context, may require estimation of a shadow price for the benefits received by another farm enterprise, or modelling of a whole-farm production system. The extent of spillovers between rural industries and especially within a farming system will be quite variable and may be difficult to estimate with precision but should not be overlooked or dismissed merely because of the difficulty.

For the purposes of RDC-funded R&D, impact assessments should give regard to another classification of benefits. The Commonwealth *Primary Industries Research and Development Act 1989* (C'wlth), which establishes the RDCs, set out their objectives as:

(a) increasing the economic, environmental and social benefits to members of primary industries and to the community in general by improving the production, processing, storage, transport or marketing of the products of primary industries; and

(b) achieving the sustainable use and sustainable management of natural resources; and

(c) making more effective use of the resources and skills of the community in general and the scientific community in particular; and

(d) improving accountability for expenditure upon R&D activities in relation to primary industries.

To report against these objectives calls for a classification of benefits in terms of 'economic', 'environmental', and 'social', and of beneficiaries between 'primary producers' and the rest of the 'community'. This classification creates some difficulties for categorising the various types of benefits and cross-tabulating them with the more precise and more widely accepted definitions of benefits in the economic literature.

Nevertheless, the reporting requirements exist. So, when evaluating benefits from R&D funded by RDCs, it will be necessary to expand the classification to distinguish among different types of benefits and beneficiaries, including:

- market and non-market benefits that accrue to levy-payers, or to a levy-paying industry;
- non-market (spillover) benefits that accrue to other industries or consumers;
- market benefits derived by the consumers through the purchase of food and fibre products, and other consumer products derived from new, research-based rural technology; and
- non-market benefits, received by the community, encompassing what are variously referred to as social or community benefits, including broad structural and welfare effects on the community and environmental benefits arising from the production of public goods or goods that have some public-good attributes.

The following table outlines some examples of the benefits that may arise from RDC R&D projects in each of these categories:

Market and non-market benefits received by levy-paying industry: • improvements in productivity or other economic advantages from the adoption of new technology embodied in services, equipment or machinery based on RDC R&D; • improvements in productivity or other economic advantages from the adoption of PBR-protected plant varieties commercialised from RDC-funded breeding programs; • improvements in productivity and profitability through improved management and husbandry; • reduction in financial risk or in undesired income variability; • improved on-farm environmental outcomes from changed cropping and pasture systems; • improved market access; • increases in specific research capacity or ability that enables progress on particular research targets; • improved safety for producers and their employees; • reduction in damage or risk to the productive resource base.
Non-market (spillover) benefits to non-levy-payer industries: • improvements in productivity, profitability, risk profile or resource security in other rural industries that have not contributed to the cost of the R&D; • improvement in productivity, turnover, profitability or risk in non-rural industries that did not contribute to the costs of the R&D; • longer-term improvement in research capacity likely to benefit future levy-payers and upstream or downstream industries; • future benefits from incorporating the research outputs into related research fields that deliver subsequent new technologies and products.
Market benefits received by the broader community: • benefits to buyers and final consumers of food and fibre products from improved product quality, variety, reliability, food-safety, or lower cost; • availability of new or improved consumer products derived from research-based rural technology such as safer or otherwise improved household pesticides, herbicides and veterinary medicines.

Non-market benefits received by the broader community:

- general improvements in research capacity that enhance Australia's technical capabilities across a range of disciplines;
- environmental benefits, including:
  - improvements in water quality, environmental flows and salinity in both surface and groundwater;
  - improvements in natural resource management including wetlands, nature reserves and cultural values;
  - improvement in the sustainability of areas of conservation value;
  - improvements in air quality;
  - improvements in soil conservation and management;
  - preservation of endangered species;
  - sustainable management of biological resources;
  - reduction in emissions of greenhouse gases;
  - reduction in toxic waste;
  - reduced off-site and residue effects of agricultural and veterinary chemicals.
- social benefits, including:
  - occupational health and safety;
  - public health and mental health;
  - creation of resilient regional communities;
  - building innovation skills for other industries or communities;
  - building research skills;
  - animal welfare;
  - biosecurity.

After identifying the research outputs, outcomes, adoption, the counterfactual and benefits, careful consideration must be given to the issues of attribution and the valuation techniques applicable to estimating the various forms of benefits. These elements in an impact assessment are most important in determining the accuracy, robustness, and thus the plausibility and value of the assessment and the results.

Checklist

- List the initial impacts that are derived from aggregation of the producer outcomes including both market and non-market benefits.
- Identify actual or potential spillover benefits that may be realised by other industries.
- Identify the various non-market benefits that may flow to consumers and the broader community.
- Quantify all the market benefits
- Quantify non-market benefits wherever possible or provide a description of the extent and nature of the impact.
- Identify how the various impacts should be described in terms of the objective described in the *PIRD Act* of producing 'economic, environmental and social benefits'.

3.6 Attribution

Attribution may be thought of as a two-stage process. In the first stage, impacts (measured as described in the previous section) are attributed between the particular project being evaluated and other contributing factors. Often, many parties will have contributed directly or indirectly to bringing about the impacts of an R&D project. The impacts of the particular research investment being evaluated may depend on or be enhanced by prior and complementary research investments, investment in adaptation or development of the research outputs, investment in extension or promotion, costs of adoption borne by producers, and policy or regulatory changes. It would be misleading to attribute all of the impacts to any one of these contributors or their investment.[2]

In the second stage, the analyst has to estimate the proportion (of the total net benefits that are attributable to the project) that should be attributed to an RDC versus other contributors to the project. Usually, impacts will be attributed among contributors based on the value of their contributions to the project, so long as all the contributions to the project have been identified including the costs of extension and adoption by producers.

If all the contributions to the project are equally essential to producing the impacts—that is if any one of those contributions were absent there would be no outcomes or impacts—, then this calculation will be relatively simple. Consider the following simplified example,

- a research project costs $2.25 million
- extension of the research outputs costs $750,000

Using attribution based on cost shares, 75% of the benefits would be attributed to the research and 25% to the extension. Further, if an RDC contributed 50% of the cost of the research and separately 20% of the cost of the extension, it would be appropriate to attribute 42.5% (75%x50% + 25%x20%) of the net benefits to the RDC.

[2] Pardey et al. (2006) illustrate the importance of accurate attribution among different domestic and international research agencies, and research partners in the case of Brazil's national agricultural research agency, EMBRAPA.

In many projects the task of attribution will involve more complex considerations. There may be contributions to a project that are not strictly essential to an outcome but serve to enhance the impact by, for example, further developing the initial research output or by facilitating and thus increasing the extent of adoption (either the number of farmers adopting or their intensity of adoption) beyond what would have occurred otherwise. In this type of case, if it is possible for the analyst to identify the additional benefits that arise directly because of the additional contribution, then only these additional benefits should be attributed to the 'impact-enhancing' contribution.

It is also relevant to consider the extent to which a benefit, such as productivity enhancement, is attributable to pre-existing technology on which the new technology is substantially reliant, or previous research on which the new research builds. For example, the cost savings from the development of continuously variable fertilizer application equipment for field crops are possible only because of the prior development of GPS-based yield-mapping capability on harvesting equipment. In such a case, the yield-mapping information on its own is interesting but produces an economic benefit only when it is used to increase output or reduce input costs.

Failure to reasonably apportion the benefits among substantial contributing sources of technology or knowledge can result in significant double-counting of benefits across innovations and consequent over-estimation of the benefits from the investment under consideration. The contribution of prior technology may already have been included in project costs if the use of the technology is subject to a licensing fee or other cost of acquisition. If the project has not been charged for significant prior technology, the analyst may consider it appropriate to impute a shadow cost for access to the technology for the purposes of determining a reasonable attribution of impacts. The use of a conservative approach to apportioning benefits among sources is appropriate to guard against under-valuing the contributions to the final impact made by prior investments in research that led to pre-existing technology, and consequently overestimating the share of benefits attributed to the research investments under consideration.

A case could be made for determining attribution other than by reference only to shares of project costs if some contributions to the project are not measured accurately by the expenditures. This might arise either because the quantities of inputs are not properly measured (or not measured at all) or if some inputs are inappropriately valued (or are not valued at all). In-kind contributions are often a case of inputs that are not measured or not properly priced. Another, more complex, instance is the role of management control and direction in the accomplishment of the project. Consider, for example, a project funded in equal shares by a fund that took no part in direction or management of the project and a second contributor that was active in directing and managing the project through to completion. The analyst may consider it appropriate to attribute some of the benefits to the role that management and direction played in producing the project's outputs by attributing a greater share of the benefits to the active contributor.

These attribution decisions are typically neither simple nor clear-cut, such that the practitioner will need to exercise judgement according to the circumstances. When reporting how the credit has been apportioned among a project's contributors, the practitioner should identify those activities or contributions that are deemed to be essential to producing the impacts and those that are impact-enhancing. It is essential to clearly describe the factors taken into consideration in deciding the basis on which the attribution has been determined.

Checklist

- Identify all sources of contributions to bringing about a project's impacts.
- Consider whether particular contributions are essential to deriving the impacts or are impact-enhancing.
- Attribute to impact-enhancing contributions only the additional benefits they produce.
- Attribute a project's benefits among contributors according to their shares of project costs.
- Consider the extent to which benefits are substantially reliant on investments in pre-existing technology to which a portion of the benefits should be attributed.
- Report the basis on which benefits are attributed between an RDC and other contributors to a project.

4. Assessment of Non-Market Impacts

Cost-benefit analysis of agricultural research typically focuses on costs and benefits that are reflected in market outcomes—changes in prices and quantities of agricultural inputs and outputs. Some impacts on the natural environment, on people and on social well-being are not transmitted or distributed through market transactions.

These impacts—referred to as non-market impacts—may be significant in some research projects but are rarely subject to rigorous analysis.

The basic principles of economics tell us that we are unlikely to make efficient use of natural and human assets and the services they contribute to production if we do not understand, value and incorporate them into our decision-making. Therefore, where they are thought to be important, non-market benefits ought to be incorporated in the analysis of research benefits

Efforts to analyse non-market impacts of research are beset by at least three difficulties, which largely explains why they have been neglected in past assessments:

- Because these goods have not been intensively studied, or because they are not traded, we often lack clear definitions or an accepted language with which to describe them.
- Though we may be able to observe non-market outcomes, it is difficult to define and quantify the effects of R&D on many of the non-market goods in which we are interested.
- Even if we can observe a change in a non-market outcome that is attributable to research-induced agricultural innovation, we often lack a direct basis for valuing the goods and services in question and the impacts they generate.[3]

Some advances have been made in addressing these problems and developing analytical techniques but analysis of non-market impacts remains a difficult undertaking. In this section we discuss reasons for focussing more attention on the analysis of non-market impacts and, where possible, provide advice on approaches to address the issues identified above.

[3] In practice the distinction is not quite so sharp. We discuss in other parts of the Guidelines the serious challenges posed by (a) the general attribution problem and (b) the measurement of benefits from more fundamental research or disembodied knowledge, that are not directly observable in markets for inputs or outputs, even though the consequences are ultimately reflected in markets.

4.1 Why put more emphasis on social and environmental impacts?

In economics and other disciplines, both in Australia and internationally, greater attention is being paid to the contributions to wealth and economic output made by the services derived from environmental assets. More consideration is also being given to the linkages between economic output and a range of social issues such as the development and resilience of regional economies; the structure of, and relationships among, social networks; and development of skills and knowledge.

The importance of natural and human assets that provide non-market services to producers and the broader society is perhaps more obvious in primary production than other industries because agricultural output is directly reliant on many environmental factors and on the skills and knowledge of individual owners or managers. Without a good understanding of their contribution to the economy and society and the impacts of R&D on them, we risk under- or over-utilising these natural and human factors of production, depleting these assets to the detriment of future well-being, or under-investing in their protection and enhancement.

Understanding and measuring non-market outcomes has particular relevance for RDCs. The Primary Industries and Energy Research and Development Act specifically charges RDCs with delivering 'economic, social and environmental benefits', and 'achieving the sustainable use and sustainable management of natural resources'. Other government policies and processes also express an enduring community concern about protecting the natural environment and certain resources, and providing a stable, equitable social fabric. Among other initiatives, government programs and agencies increasingly require organisations to report so-called 'triple bottom line' (economic, social, environmental) outcomes, although the methodology for assessing the social and environmental outcomes is rarely made clear. For RDCs, measurement of non-market impacts is critical for monitoring performance towards and ultimately achieving objectives of this type. It is also necessary for obtaining an accurate and unbiased assessment of the total returns to the investment in R&D in those cases where impacts on non-market outcomes are significant.

Among the RDCs, the former Land and Water Australia (LWA) focussed particular effort on evaluating non-market benefits because its objective was to invest in R&D that improved sustainable natural resource management. LWA also undertook to take the lead on behalf of all the RDCs in advancing the methods for evaluating non-market benefits. Following the winding-up of LWA, the RDCs, as a group, need to return to the task of advancing the methods of evaluating non-market benefits. The incorporation in these *Guidelines* of instructions on assessment of non-market benefits endeavours to preserve the advances made by LWA and draw on developments by other agencies and practitioners that will assist RDCs in evaluating their R&D investments.

Many RDC R&D projects address problems that constrain output or increase production costs and have outcomes that are overwhelmingly realised in productivity improvements and measured as market impacts. These may have little or no off-site consequences and little effect on natural and human factors of production. While the analyst should remain vigilant for potential unintended impacts of research, if the impacts on natural and human factors of production are minor, there is little merit in extending the impact assessment into a detailed analysis in this area.

In each impact assessment, the analyst will need to judge the analytical effort that is warranted according to the extent of the environmental and human impacts that are identified. Even where no further analysis is deemed necessary the assessment report should record this decision and acknowledge that these impacts have been considered.

4.2 A narrative approach to evaluating non-market benefits

All research assessments should, as a minimum, provide a comprehensive descriptive evaluation of non-market outcomes that have been observed or are expected to result from the investment. This narrative analysis should be no less systematic than the analysis of market outcomes and should follow a similar process.

The objective is to identify the non-market outcomes that are expected to arise as a result of the R&D and to present an incisive, analytical portrayal of the relationship between the research outputs, the innovations generated, their adoption and the resulting non-market outcomes and impacts. Any assumptions made should be identified, the contribution of other research to the outcomes should be acknowledged, an appropriate counterfactual should be constructed against which to compare the outcomes, and the question of attribution should be considered. As in the analysis of market benefits, an unbiased approach to the narrative is essential, identifying, as appropriate, both positive and negative impacts of the research. The description of impacts should discuss the relative importance of the various market and non-market impacts, or at least those that are of most significance.

In cases where important non-market impacts can be quantified, they should be estimated and reported, with appropriate details about the roles of underlying assumptions and the confidence that can be placed in the estimates. In analyses of R&D projects that involve a range of effects, only some of which can be measured, care should be taken to make sure that reporting quantitative measures for some impacts does not bias the reader's impression of the importance of the measured impacts relative to those for which measures are not available; likewise, in comparing projects, some of which have primarily non-market benefits that cannot be quantified, an appropriate balance should be struck.

4.3 Types of social and environmental benefits from R&D

Analysis of the impacts of market transactions is underpinned by defined concepts and a language that describes the nature of the traded goods and services, their value and how benefits are distributed. The discussion of non-market impacts is often hindered by a lack of consensus on language and concepts and less clarity about the goods and services under consideration. Terms used to discuss non-market impacts—such as 'triple bottom line' outcomes and 'social and environmental benefits'—often lack clear definition or are not comprehensive in delineating the range of factors that should be considered.

Work within the United Nations and the OECD has endeavoured to provide a more comprehensive language and definition of the concepts for the contribution of non-market factors to aggregate community wealth. In February 2012 the United Nations Statistical Commission formally adopted the System of Environmental–Economic Accounting (SEEA). This is an international statistical standard with the same purpose and status as the System of National Accounts (SNA), which is a standard for measuring and recording economic activity. The SEEA has its origins in the SNA and provides a standard by which to measure and record the non-market contribution of environmental assets and services to our total well-being, and their interaction with economic activity.

Following the United Nations decision, the ABS published *'Completing the Picture—Environmental Accounting in Practice'* (ABS 2012b) to inform government decision-makers, analysts, scientists and industry on how environmental accounts could be used and further developed in Australia. The publication of this document represents a recognition of growing economic and policy interest in Australia in understanding the contributions to output made by non-market assets. It provides a conceptual guide to the structure and measurement of stocks and transactions of non-market assets and the services they provide and complements earlier work by the OECD on the contribution of human and social capital to the growth and development of communities (OECD, 2001). The following discussion draws substantially on the concepts presented in this publication to establish a clearer foundation from which to identify non-market impacts and assess their interaction with the market economy.

4.3.1 Asset types

Australia's capital base can be described as comprising the following types of assets:

- Produced capital – non-financial assets that have come into existence as outputs from production processes.
- Financial Capital – all financial claims, shares or other equity in corporations plus gold bullion held by monetary authorities as a reserve asset.
- Natural Capital – comprising:
    - air
    - water (fresh, groundwater, and marine)
    - land (including soil, subsoil assets, space, and landscape) and
    - habitats (including the ecosystems, flora, and fauna, which they both comprise and support).
- Human Capital – the stock of knowledge and skills within the population as a consequence of net natural growth, net migration, education and training as well as changes in the health and physical well-being of the population.

- Social Capital – the strength and quality of relationships within and among groups across society. Also defined as the '…networks, together with shared norms, values and understandings which facilitate cooperation within or among groups' (OECD, 2001: p. 41). Network qualities include norms such as trust, reciprocity and inclusiveness, and common purposes such as social, civic and economic participation.

Produced and financial capital comprise the stock of 'economic' assets, defined as having an identifiable owner who must be able to hold, use or trade these assets for economic gain. Investment in these assets predominantly occurs through market transactions, and the services they produce contribute to output of market goods. A non-market valuation problem can arise for physical assets if the assets (or service flows from them) are not much traded on markets, except in new form. For some forms of capital used on farms—such as machinery or durable improvements such as buildings, fences, dams, and the like—the measurement of the stock of capital is conceptually straightforward but often difficult in practice because the value of used capital and true economic depreciation rates are hard to observe; likewise the measurement of flows of services from those stocks must be imputed if the transactions are all within the farm firm, and not observed in any market. Agricultural economists have developed approaches for measuring the relevant quantities and values, depending on the types of data that may be available. The problem is worse for natural capital because the assets are typically not tradeable in any form.

Natural capital is comprised predominantly of non-tradeable assets (habitats, air, public land, landscapes, oceans). Private land exhibits most of the qualities of a tradeable or economic asset, although the ownership rights are not absolute. Some natural assets that are intrinsically, or deemed legally to be, non-tradeable assets are given economic asset-like character through the creation of rights to exploit the asset (rights to mine mineral deposits, water pumping/diversion rights, fishing licences, timber harvesting licences). These licences, typically issued by government, do not constitute ownership of the asset (the mineral deposit, water in a river, a fishing ground or a timber stand) but the goods extracted become private property at the point of extraction. Thus, it is possible to establish values for the created licences, which are economic assets, and for extracted goods, but this is not the same as the value of the underlying asset, which is more difficult to establish. It is also possible to invest in definable improvements to the quality or quantity of natural assets although, with the exception of private land, it is often difficult to put a value on the improvement.

Human capital is a non-tradable asset, although many of the services that derive from human capital—labour, skills and knowledge—are traded through market transactions. Like other non-tradable assets, the value of human capital is difficult to measure since it embodies diverse attributes such as health, knowledge, and ability that do not have natural quantitative measures. Investment can be made in improving the quality of human capital, through education, training, safety regulations, health services, and improved nutrition, which may result in a measurable increase in the value of the services contributed to economic output, but measurement of these services does not provide a measure of the total value of the underlying asset. Humancapital and social capital, discussed below, do not form part of the SEEA concepts discussed above, but methods of measuring and accounting for these types of capital have been considered elsewhere and in an international context by the United Nations. The ABS (2008) discussed the core concepts and human capital estimation methods and produced experimental estimates of Australia's human capital.

Social capital is even less easily defined and measured. Like other non-traded assets, it is possible to observe, and in some instances measure (and possibly assign a value to improvements, or investments in improvements in) social capital. But, even the services social capital provides are mostly not traded in competitive markets and are themselves difficult to measure and value. ABS (2009) discusses some of the concepts underlying social capital and its measurement.

4.3.2 Relationships between non-tradeable and economic assets

The linkages between economic assets and the market economy on one hand, and non-tradable natural, human and social assets on the other hand, are diverse.

Investments can be made in increasing the value and stock of non-tradeable assets (for example by improving water quality in streams or repairing degraded landscapes). Opportunities exist to substitute between tradable and non-tradable assets in economic production (farmed fish stocks can be substituted for wild fish stocks) and among non-tradable assets (water can be used to increase agricultural output as a substitute for using more land). Non-market assets provide a range of services to economic production (native ecosystems provide pollination services to open-pollinating crops, microbial/invertebrate ecosystems maintain and revitalise soils, water extractions support plant and animal production) that come at no charge or at less than their economic value. The regulation of CO_2 emissions in some countries, together with taxation, carbon credits and emissions trading systems, constitute an attempt to create a market for the services the atmosphere provides as a sink for CO_2 emissions. However, the carbon stocks in the air or sequestrated in land or forests have no market value at present.

Analysis of non-market costs and benefits must acknowledge the distinction between transactions of a capital nature that either add to or deplete the stock of non-tradable assets, and the services provided by these assets. The former is an investment (or disinvestment) that may yield future benefits or returns. The services derived from these assets are unpriced inputs to current production.

Better understanding of the nature of non-tradable assets, how and at what cost the stocks can be increased, the services non-tradable assets provide to economic output, and the value the services add, are keys to the better management and more efficient use of non-tradable assets. Assessment of the contribution of research outputs to investment in these assets or to more efficient use of their services can make an important contribution to this understanding.

4.3.3 The non-market impacts of rural R&D

The consequences of rural R&D may include a wide range of environmental impacts on land, habitat, air and water systems. These include soil loss or improvement, reparation of past land degradation, emission and sequestration of carbon, minimising or controlling off-site effects of salt, nitrates, phosphates, and by-products from agricultural production, the proliferation or control of weeds and other pest species, improved animal welfare, and impacts on the aesthetic and amenity values of rural landscapes and improvements to habitat and species diversity.

Rural R&D may also induce a range of impacts on human capital by improving the skills and knowledge of producers, scientists, participants in product supply chains, and consumers. R&D may contribute to the safety of rural workers as well as to a safer and more nutritious food supply for the wider community and foreign consumers.

The impacts of rural R&D on social capital include effects on the structure of regional communities, the spatial distribution of the population and the size of regional and rural towns and cities. R&D also affects business confidence and willingness to invest, and certainty about lifestyle and financial security among producers and others in regional communities. At a higher level, confidence in the food supply chain substantially adds to confidence in the community about having a reliable supply of safe, high quality, and affordable food. Less tangibly, the growth of rural industry has contributed to the country's civic identity, and its exports of food and agricultural technology play a part in the county's relationships with international neighbours and trading partners.

The nature of the impacts of rural R&D on non-traded capital and assets will vary among projects. In some cases, the impact will be in the nature of an investment in the quality or size of the asset. In other cases, the impact may be on the availability, quality or value of the services produced from non-traded assets, and in some instances the R&D will affect both the stock and the flow. R&D that leads to a reduction in quantities of salt released into a river improves the quality and capital value of the river asset. Reduced salinity in the river has additional benefits for riverine habitats and their capital value. However, these are non-tradable assets and establishing the value of the improvement in quality is difficult. The reduced salinity also affects the services derived from the river water and its habitats. Water extracted from the river may have a wider range of uses or be more productive, such that the value of the extracted water and of the extraction licence is increased and, since these are traded assets, the value can be measured. The quality and amount of recreational fishing may also improve because of the reduced salinity, but since this service is not traded, its value will be more difficult to establish.

R&D projects will vary in the types, quantities and value of the non-market goods they generate, and evaluators will need to identify those environmental assets and their services that are to be considered in an impact assessment. This judgement will need to be guided by the objectives of the project combined with a consideration of the outputs from the research and their likely impacts, as well as the importance the community or government places on particular environmental or social attributes.

4.3.4 Negative externalities

In the present context, a negative externality is a cost imposed on members of the community, other than those who adopt the technology, for which they are not properly compensated through market transactions. Negative externalities are non-market costs that arise when there is no (or an imperfect) market between those who benefit from a new technology or other innovation and those who bear the costs as spillovers. Examples may include the effects of increased river turbidity or pollution as a result of increased cropping intensity, increased road damage from a rise in heavy vehicle traffic related to increased production of certain products, off-site effects of spray drift as a result of adoption of crop types that require more frequent treatments, or depletion in quality or quantity of water resources available to others as a result of increased extraction of river- or ground-water for agricultural production.

Since negative externalities are non-market costs, measurement and valuation can often be problematic. Practitioners will need to choose among alternative valuation techniques. Some options for pollution-type externalities include pricing based on estimates of ‘willingness to pay’ or ‘willingness to accept’. Alternatively, in some cases externalities may be valued by reference to related or similar markets, and others may be valued by estimating avoidable costs, such as in the case of vehicle damage to roads. Many negative externalities are not solely attributable to a single new technology or other innovation. Hence, the task of the practitioner will frequently be to assess the incremental contribution of the innovation and the cost of that increment. Thus, by reference to the counterfactual, the valuation of, for example, increased river turbidity and pollution from a change in land use, is not the difference between a polluted and a pristine river, but between more or less river pollution compared with the status quo. These are complex estimation tasks, often with no clear right or wrong procedure or valuation technique. Practitioners will need to consider and make choices among accepted estimation and valuation techniques, depending on the nature of the costs under consideration.

Practitioners should document the assumptions made about the extent of negative externalities and the valuation techniques used. Where appropriate, estimates should be subject to sensitivity analysis to determine whether the results from the assessment are critically dependent on the estimation techniques and assumptions used. Here also, analysts should ensure that the techniques and valuations employed do not routinely exclude, under-estimate, or place an unduly conservative bias on their estimates of these costs.

4.4 Analysis of non-market impacts

A cost-benefit analysis of non-market impacts follows the same process as is applied to market impacts—identify R&D costs and R&D outputs, determine the appropriate counterfactual, identify R&D outcomes (positive and negative) attributable to the outputs, and compare outcomes to the counterfactual or baseline scenario.

It will rarely be desirable or possible to analyse all the non-market impacts of a research project, so the analyst's first task is to identify those non-market impacts or non-market goods to be considered. Typically, the choice should reflect the magnitude of the various non-market impacts from the R&D but may also be influenced by the priorities of the RDC (and the interests of levy-payers and government), the R&D project objectives and the amenability of the non-market impacts to analysis. The impact assessment report should briefly indicate the reasons why each non-market good was included in the assessment.

Analysis of non-market impacts will often face data limitations, either because precise measurement is not possible, or because suitable data were not collected.

Quantitative measures are always to be preferred, but objective qualitative criteria may be the only available measures for some non-market goods. R&D projects for which non-market benefits are a significant objective—whether in the form of social, human or environmental benefits—should address the measurement of the benefits in question during the design and approval processes. Care should be taken to avoid unduly emphasising those impacts that can be measured at the expense of those that do not lend themselves to measurement or for which data are not available.

An impact assessment should describe the relationship between the research outputs, innovations developed from those outputs, their adoption by producers and the eventual outcomes in terms of the benefits realised by the community. For example, consider research that identifies a plant gene that induces resistance to a particular insect pest of field crops. Subsequent plant breeding may incorporate the newly identified gene into new crop varieties that are resistant to the pest which, when adopted by farmers, reduces or eliminates pesticide applications to the crops.

Adoption of the new technology by farmers offers a productivity benefit to growers from either reduced pesticide costs or higher yields, or both. The market benefits from this research will include a combination of higher returns for growers, increased supplies of product to consumers and potential for lower consumer prices.

The reduction in pesticide use may also result in reduced incidence of both pesticide run-off into streams and rivers, and pesticide drift onto adjacent areas of natural vegetation, neighbouring farms and nearby communities. The non-market benefits from these outcomes might include reduced pesticide load in streams and rivers with consequent effects on wild fish stocks, greater biodiversity in the surrounding natural bushland, and reduced community concern about pesticide drift. These non-market benefits can be readily identified and can be measured with varying degrees of accuracy but are difficult to value.

These relationships and estimates of non-market impacts will have their own set of risks and uncertainties that may be quite different from those surrounding estimates of market outcomes and impacts. The risks and uncertainties associated with the non-market outcomes should be identified and discussed as part of the sensitivity analysis conducted on the impact assessment results.

4.5 Valuation of non-market benefits and costs

To completely integrate the evaluation of non-market impacts into the evaluation of the economic impacts of R&D requires the use of a single metric—money values—across all costs and benefits. In order to monetise non-market impacts, values must be estimated using a shadow price—the price that would be paid for a given quantity of the good if a market existed for it. The principal methods for estimating shadow prices are outlined below. This list is not exhaustive and other methods or variants of those listed can be found in the literature.

- Revealed preference methods use actual market or behaviour data to impute a price for a non-traded good.
    - Hedonic pricing method – by which market price differences are analysed to indicate the value placed on the presence or absence of a non-market good. For example, the value to a farm of river frontage can be estimated by comparison of prices of farms that do or do not have river frontage; or the value to home owners of a particular view can be estimated by comparison of prices of houses that do, and do not, have the view in question.

- Substitute cost method – by which values are inferred from expenditure required to obtain a good or service by an alternative means. For example, the value of pollination services from the natural environment could be estimated by reference to the cost of obtaining a similar service from an apiarist, or the value of a road between two points may be estimated from the cost to travel between those points by another route or travel mode (the travel cost method).
- Compensation payment method – by which actual compensation payments accepted are used to value a non-market good. For example, payments made to landholders, in excess of the rental value of the land, for the right to locate wind turbines on their property compensate for the visual, noise and other impacts of the structure other than loss of production potential, or compensation payments for pain and suffering (but not for economic loss) to persons injured in farm or industrial accidents.
- Repair or avoidance cost method – by which values are inferred from expenditure required to offset or avoid a negative impact. For example, the cost of herbicide resistance in weed species could be estimated from the additional cost of controlling those species by other methods; or the cost associated with road noise can be estimated by reference to the cost of erecting noise barriers next to a busy road to alleviate the effect of the road noise on adjacent households.

- Stated preference methods use survey-based techniques to elicit values for non-market goods.
  - Contingent valuation – in which respondents are asked to indicate their willingness to pay (WTP) for a specified non-market good or willingness to accept compensation (WAC) for removal of a good or enduring a specified nuisance. For example, respondents could be asked what they would be prepared to pay for access to a travelling stock route, or the payment they would accept as compensation for the effects of granting approval for a new mine in a nearby location, or loss of access to a particular road route.
  - Choice modelling – in which respondents are asked to choose between or rank a number of alternatives with a range of attributes or levels of attributes of interest. Values are inferred from the choices made and monetary values implicit in or among the choices.

Each of these methods has limitations and difficulties. A particular problem with stated preference methods is that respondents may not take the question seriously, because in contrast to an actual market they may believe that they will not suffer a cost if they get their valuation 'wrong'. Moreover, respondents may have an incentive to 'free ride'. They may exaggerate their true preferences in the desire to encourage provision of a public good in the expectation that it will be provided from consolidated revenue at no cost to the respondent. Also, even if respondents mean to answer honestly, in many instances respondents may not be able to estimate accurately their true willingness to pay for a good or outcome described in hypothetical terms. Economists have been improving stated preference methods for eliciting information about willingness to pay, but some of the problems are persistent, and research evaluators should be aware of the limitations and pitfalls of the procedures when using the results to value research benefits and costs.

Shadow-pricing methods that rely on surveys or analysis of large volumes of market data may be costly to undertake. Where consideration is being given to employing these shadow-pricing methods in an evaluation of non-market benefits RDCs and Practitioners will need to weigh-up the cost against the reliability of the price estimates that will be generated. Alternatively, estimates of shadow prices for particular goods that have been reported in published articles could be used in CROSS-RDC assessments where the non-market goods concerned and the circumstances are comparable. It should be noted that many non-market values are very specific to the location or population concerned and estimates should be extrapolated to other circumstances only with great caution. Databases of published articles that have reported estimated shadow prices are accessible through the internet and may be of assistance to RDCs and analysts searching for valuations. These include the NSW '*Envalue*' database (NSW Department of Environment and Climate Change, 2004) and the Canadian Environmental Valuation Reference Inventory (EVRI) (Environment Canada, 2011).

Checklist

- Identify impacts on natural (land, water, air, habitat), human and social assets and services provided by these assets.
- Consider the magnitude of the impacts and the depth of analysis that is warranted.
- Quantify the impacts where data and measurement systems permit.
- Review literature to identify appropriate valuations of assets and services, or identify appropriate valuation methodologies where impacts warrant detailed analysis.
- As a minimum, include a narrative assessment of non-market impacts in each assessment report.

5. Sensitivity Analysis and Reporting

5.1 Estimation techniques and precision

The precision with which assessment results are reported and discussed must acknowledge the limits of the techniques underlying cost-benefit analysis. While efforts should be made to monetise costs and benefits wherever reasonably possible, some less-tangible, private and public benefits and costs are difficult to value in monetary terms—for example, attributes such as ‘quality of life’, research capability, food security, food safety, or retention of natural habitat. However, decisions by government and research managers implicitly place values on these attributes, so the valuation problem is not so easily avoided. In cases where the total benefits are expected to be sensitive to the value of such attributes, evaluators need to report on this aspect and the implications for the results.

A good assessment should acknowledge that the benefit-cost ratio does not constitute the entire assessment of a project, and that in some cases quantitative assessment is difficult. The extent and value of non-market costs and benefits can be crucial in some cases, but at the same time, the limits to the accuracy of the estimation techniques must be acknowledged, especially where indirect valuation methods have been employed to ascribe values to non-market costs and benefits.

Practitioners should clearly state what can and cannot be reliably quantified, and valued, within the resources available to their analysis. Intangible factors that cannot be satisfactorily valued should be listed and described as fully as possible. On the one hand, it is necessary to avoid imparting a false accuracy to the estimates.

However, it is also essential that analysts accept their responsibility to quantify and value as many elements of costs and benefits as they reasonably can.

Cost-benefit analyses of large research projects can be complex and convey a lot of information. Judgement is needed on the level of detail or the range of variables analysed, which entails a trade-off between the cost of the analysis and the precision that is appropriate. Evaluators should consider the potential sensitivity of the results to individual variables, when determining the effort that is to be committed to analysing the effect of the research on particular outcomes or the sensitivity of outcomes to particular variables.

Analysts should also guard against the ‘black box’ effect that can often accompany complex assessments. If the estimation processes and underlying assumptions are visible only to those involved in the analysis, the results might be presented or interpreted as though they were estimated with a greater certainty than is warranted and may be open to criticism for overstated accuracy or bias in favour of the RDC. These problems can be minimised by clearly explaining the valuation processes used, giving prominent and explicit exposure of key assumptions, and making enlightened use of sensitivity analysis.

5.2 Sensitivity analysis

The first phase of a sensitivity analysis will normally be to substitute plausible pessimistic estimates for each important variable simultaneously and calculate a revised NPV. If the estimated NPV is still positive, we can say that even with pessimistic assumptions the project is likely to yield positive net social benefits, and further sensitivity analysis may not be needed. If, however, the pessimistic net present value falls below zero, it confirms that the benefits are significantly uncertain and further sensitivity analysis should be considered. Within this broad approach, one option is to adjust all of the relevant variables by a fixed percentage of the difference between the best estimate and the pessimistic values, to determine the effect on the estimated NPV. A variant of this option is to solve for the proportional shift toward the pessimistic value for the key variables that yields an estimated NPV of zero.

In many instances, it will be appropriate to undertake a more-detailed but partial analysis, to assess which variables most influence the estimated the net present value and evaluate its sensitivity to changes in each variable. This will require making incremental change to each variable, one at a time, across a range commensurate with what is known about the issues, holding every other variable at its best estimate and recalculating the estimated NPV. If some of the variables are correlated, it may be more informative to alter the values of those variables together. This analysis can proceed by calculating the change in the estimated NPV for a proportionate change in the variable under consideration, or by solving for the change in each variable that causes the estimated NPV to fall to zero. This detailed partial sensitivity analysis determines the variables to which the estimated NPV is most sensitive.

Depending on the results from the partial analysis of the sensitivity of the analysis to individual variables, analysts should consider whether further testing, by changing the values of multiple variables, or groups of variables, simultaneously would be informative in describing the sensitivity and risk that is implicit in the initial estimate of NPV.

In addition, some further partial sensitivity analysis could focus on particular variables for which the analyst is less confident about the best estimates or which are likely in a priori grounds to have important implications for the results. This is a matter for individual judgment based on specifics of the case. However, a separate sensitivity analysis should normally be conducted on the counterfactual. Using a similar process to that described above, the key variables in the counterfactual scenario should be varied to plausible pessimistic values (i.e. alternative values that reduce the estimated NPV) to determine the sensitivity of the estimated NPV to the chosen counterfactual. If the estimated NPV remains positive under the pessimistic scenario, further testing is probably unwarranted. Conversely, if the pessimistic counterfactual gives rise to a negative estimated NPV, further analysis should be considered.

5.3 Impact assessment results and reports

The report of an impact assessment of an RDC R&D project is primarily a report to the RDC concerned, but it should also serve other audiences and objectives. The assessment will have special relevance for the R&D provider(s) and the scientists who have contributed to the project (and to the assessment). The assessment will also contain information of interest to the RDC's key stakeholders—producers in the relevant industry and the Government. Every individual assessment, as a part of the CROSS-RDC Impact Assessment Program, will contribute to the pooled results of assessments from all RDCs from which estimates will be made of the total net impact of the RDC R&D portfolio as a whole. In addition, all assessments within the CROSS-RDC Impact Assessment Program are made available to the general public through publication on the CROSS-RDC web site.

The primary purpose of an impact assessment report is to inform RDCs about the impacts generated by their investment in the R&D projects. Reports should present the results of the assessment, balanced by an explanation of the underlying assumptions and robustness of the results, in language that is accessible to essentially lay readers. This is not a simple endeavour, as the assessment of an R&D project often entails a complex and lengthy analysis. The information conveyed in the reports will be more accessible to readers if a common template is followed, such that readers from the various stakeholder groups can learn, over time, where to go in a report to find the various parts of the picture that the assessment report presents. For this purpose, a template for assessment reports is included as appendix 2 to these *Guidelines*.

The results of CROSS-RDC impact assessments also need to be presented in a common format to facilitate the pooling and aggregation of results from the assessments by all RDCs, and analysis of the performance of the RDC R&D portfolio. For this purpose, an electronic spreadsheet template will also be provided to practitioners as the basis for reporting results, in addition to the written format contained in these *Guidelines*. A representation of the format of the spreadsheet is included as appendix 3.

The following sections provide guidance on the formulation of results and the key matters that should be addressed in the content of impact assessment reports.

5.3.1 Results

The assessment should provide estimates of costs and benefits for the life of the project, expressed in real dollars, as at the end of the year in which the assessment was undertaken. The elements estimated for a particular R&D project should include:

Costs

- the total cost of the R&D project, over the life of the project, borne by the RDC and its collaborators, including costs of promotion, extension, and administration;
- where appropriate, the cost of any specific external technology or R&D on which the research outputs are dependent;
- the share of the total R&D and promotion expenditure in the project contributed by the RDC(s) participating in the project;
- expenditure on the project by the RDC(s) participating in the project as a share of their total expenditure on all the projects they funded over the relevant period.

Net Benefits

- private benefits received by levy-paying producers from adoption of the innovation, net of their private costs of adoption[4];
- spillover benefits to other producers and supply chain industries;
- market benefits received by consumers;
- non-market public benefits accruing to the community from changes in environmental impacts; and
- non-market public benefits accruing to the community from other social impacts.

In addition, the assessment should consider:

- the distribution of benefits between levy-paying producers and other industries; and
- the distribution of non-market benefits among various groups in the community (which may be based on location, consumption patterns, income, occupation recreational activity etc.).

Year-by-year measures of benefits and costs as accruing to and borne by different interest groups as well as in total should be presented in both tables and graphs, in both raw, nominal currency values and, separately, in discounted/inflated current-year currency values. Summary measures of total project results should presented, expressed as net present value (NPV), benefit-cost ratio (BCR), modified internal rate of return (MIRR) and internal rate of return (IRR). The reasons for employing MIRR as a measure of project returns are discussed in the box below. In order to calculate an MIRR the evaluator will need to specify a re-investment rate (r in the box below) to reflect the rate of return that could be earned by the beneficiaries on benefits derived from the project.

For the purposes of standardising the procedures and ensuring that results are comparable for CROSS-RDC assessments the re-investment rate used in MIRR calculations should be a real rate and the same as the rate used to compute NPVs and benefit-cost ratios (i.e. $r = d = 5\%$ per annum). Setting the rate for re-investment of the stream of benefits the same as the discount rate for funds employed will provide a

[4] Care should be taken regarding the identification and treatment of direct and indirect costs of adoption for cost-benefit analyses. Costs of adoption also should be clearly defined and documented during the cost-benefit process. See section 3.1.4 for further information with regard to the CRRDC impact assessment approach.

conservative estimate of the project's real rate of return (*m* in the box below) compared to calculations that assume a higher re-investment rate. Also, when the re-investment rate equals the discount rate on funds employed, the calculated MIRRs will rank alternative projects in the same order as the ranking based on NPV, whereas the projects may be ranked in a different order based on IRR. Of course, any RDC is free to compute alternative MIRRs using alternative values for *r* for its own purposes but, for purposes of comparison across assessments, and for consistency with measures of BCRs, RDCs should compute and report the MIRRs based on the standard value of *r* = 5% per annum.

A description of the sensitivity analysis should discuss those aspects of the estimation of costs and benefits to which the results are most sensitive. The results of the sensitivity analysis should be reported, to provide an appreciation of the boundaries within which the actual outcomes are likely to fall and, if possible, the probabilities associated with these bounds. The range of values reported does not need to extend to the 'worst case scenario' since the probability of this occurring may be very small. The range of results should include courses of events that are plausibly probable.

Modified Internal Rate of Return

The preponderance of studies of agricultural research investments report internal rates of return (IRRs). However, benefit-cost ratios (BCRs) or modified internal rates of return (MIRRs) are to be preferred as summary measures of project performance, especially when the computed IRRs are large.

All capital budgeting algorithms entail discounting streams of benefits and costs, and typically the calculation involves a single discount rate. In computing BCRs this rate is the investor's opportunity cost of funds. An IRR calculation solves the discounting equation for the discount rate at which the NPV = 0. This conventional IRR can be interpreted as the maximum rate at which the investor could afford to borrow to finance the project, assuming that the stream of benefits from the investment being evaluated can be reinvested and earn the same rate of return.

The reinvestment assumption is implicit in the use of compounding in the discounting procedure, as is demonstrated mathematically below, but its importance is not always understood or appreciated. This feature of the IRR calculation is problematic unless the beneficiary from the investment is able to reinvest the stream of benefits from the project at the computed IRR, which is implausible for public projects earning high returns. For example, if a public agricultural research investment has a conventionally computed IRR of 50 percent per annum, the underlying calculation will be correct only if the farmers and consumers to whom the streams of benefits accrue can (and do) invest their net benefits at the same 50 percent rate of return. Clearly that is an implausible rate of return for farmer investments, yet many studies report IRRs of 50 percent per annum or more for agricultural R&D projects.

Kierulff (2008) provides a discussion of conventional measures of internal rates of return, their shortcomings, and why a 'modified' version is preferred for financial analysis. Consider an investment of I_t dollars in time t that will yield a flow of benefits, B_{t+n} over the following N years. The conventional internal rate of return, i, solves the equation:

$$\text{(B-1)} \quad \sum_{n=0}^{N} B_{t+n}(1+i)^{N-n} - I(1+i)^{N} = 0.$$

Alternatively, suppose the stream of benefits would be reinvested by the beneficiaries (say, farmers or food consumers) at some external rate of return, r, which could be different from the rate for the project being evaluated. Then we would want to solve for the modified internal rate of return, m which solves the problem:

$$\text{(B-2)} \quad \sum_{n=0}^{N} B_{t+n}(1+r)^{N-n} - I(1+m)^{N} = 0.$$

Intuitively, m is the rate at which one could afford to borrow the amount to be invested, I_t, given that it would generate the flow of benefits, B_{t+n}, which would be reinvested at the external rate, r. It can be seen that the conventional internal rate of return calculation (B-1) is a special case of equation (B-2) which assumes $r = i$ (= m), which is implausible for public projects yielding flows of benefits that imply very large conventional internal rates of return.

Alston, Andersen, James, and Pardey (2011) demonstrated that, in their examples, research investments which yielded flows of benefits over 50 years that implied quite large benefit-cost ratios (BCRs), in the range of 20:1 or more, had implausibly large conventional IRRs, in the range of 20 percent per annum or more but much more modest albeit economically satisfactory MIRRs, in the range of 10 percent per annum.

Calculating an MIRR necessitates selecting an appropriate value for *m*, but relaxes the unrealistic constraint implicit in IRR that *m* must equal *r*. As a result, compared with the IRR, the MIRR provides a more realistic and more meaningful indicator of the rate of return to the investment. If rates of return are to be reported, they should be MIRRs, not IRRs. It may take some time for practitioners to become accustomed to the use of these measures and to develop an empirical sense of the much lower rates of return that will be observed for successful projects, when MIRRs are used rather than the conventional IRRs. Conventional IRRs should only be reported as a basis for comparison with other projects that have been evaluated using conventional IRRs, and even then, only as a supplement to an analysis that has included measures of BCRs and MIRRs, never in isolation.

Alston, J.M., Andersen, M.A., James, J.S., and Pardey, P.G. 2011. 'The Economic Returns to U.S. Public Agricultural Research.' *American Journal of Agricultural Economics* 93 (5), 1257-1277.

Kierulff, H. 2008. 'MIRR: A Better Measure.' *Business Horizons* 51(4), 321-329

5.3.2 Description of the project and benefits

The 'bottom-line' summary statistics (i.e. NPV, BCR, IRR, and MIRR) outlined in the previous section, estimated as part of the assessment, cannot convey the full story of either the costs or, especially, the benefits from the outcomes of many research projects. The numerical results from the analysis of costs and benefits and the derived summary statistics for an R&D project should be complemented by a concise narrative description of the project, its outputs, and outcomes. The discussion should outline:

- the research phase of the project;
- the outputs of the project;
- the development stages that convert the research outputs into new technology or other innovation which in turn, when adopted, generates outcomes;
- the adoption process;
- the array of benefits that result from the project.

A more detailed discussion of the benefits from the project should also be provided, addressing:

- the expected time path and extent of adoption of the new technology or other innovation among different geographic regions and producing systems, and in total, and factors influencing the adoption decision;
- costs associated with adoption;
- benefits to the levy-paying industry and the spillovers to other industries in terms of enhanced productivity and farm profitability;
- other (e.g. non-financial) factors influencing adoption decisions;
- the range of non-market public benefits that will be produced and the groups in the community who will receive the benefits.

The reporting of results must not overstate the accuracy or certainty of the results. Reports should be written so as to help readers to appreciate that the assessment is an estimate of the outcomes of the research project, and to understand the range of factors that will impinge on the actual outcomes, the value of the benefits, and the time period over which the benefits will accrue. The report should provide information on:

- assumptions made in estimating adoption, how these were arrived at and evidence that supports them;
- the methods used to determine the value of benefits, especially non-market benefits;
- assumptions about future costs, especially those relating to further development and related research that will contribute to final outcomes;
- assumptions about attribution of benefits and the roles of other factors that contribute to final outcomes;
- the structure of the counterfactual and the reasons supporting the likelihood of the specified course of events.

Considerable care should be devoted to discussion of non-market benefits, since these are very difficult to quantify accurately. Quantitative measures of non-market outcomes from the research should be included wherever possible, even though valuing these effects may be difficult or subject to uncertainty. If quantitative measures are not possible, then incisive qualitative description that conveys the impact of the R&D is essential.

5.3.3 Assessment summary and summary statistics

Assessments of RDC R&D projects have a range of uses, but among the most important are to provide an estimate of the net benefits from the broad portfolio of rural R&D undertaken with the support of the RDCs, and to provide those who contribute funds to the RDCs (i.e. levy-payers and the Australian Government) with a characterisation of the research projects in which the funds have been invested and their consequences.

All impact assessment reports should include a succinct, interpretive summary to characterise the benefits from the R&D to stakeholders, who are mostly not technically trained in either science or economics. This is a crucial element in the assessment that facilitates publication of the findings to stakeholders and enables a lay audience to appreciate the value of the research and the benefits produced. The summary should capture the essence of the research outputs and outcomes, and the estimates of the net benefits. The summary should acknowledge that uncertainty surrounds the individual estimates of benefits but should also convey the rigour and robustness that the methodology and sensitivity analysis impart to the estimates.

Summary statistics can be produced pertaining to individual projects and for the broader portfolio representing all RDCs.

Each assessment completed as part of the CROSS-RDC Impact Assessment Program, whether for a project, cluster of projects or a program, should report the following summary data in both nominal currency values, and discounted/inflated (current year) values in a format similar to that in the table shown below:

	Historical				Current	Future					
	Yr-x	…..	Yr-2	Yr -1	Year 0	Yr+1	Yr+2	Yr+3	…..	Yr+30	
ESTIMATED COSTS											
Total research program costs											
RDC contribution to program costs											
Contributions by other collaborators											
Additional, non-program costs - technology development											
promotion and extension											
Non-market costs - environmental externalities											
other social externalities											
Total cost of outcomes											
ESTIMATED NET BENEFITS											
Benefits to levy-paying industry											
market benefits											
non-market benefits											
Spillover benefits to non levy-payers											
Non-market benefits											
technology/ capacity building											
environmental benefits											
other social benefits											
Adoption and implementation costs											
producer costs, down-stream costs (direct and indirect)											
Total net benefits											
ESTIMATED TOTAL NET BENEFITS											

The derived estimates of the investment performance of the R&D project should also be presented in tabular form similar to the following:

	Result
Project estimated present value of nrt benefits (PVB) ($)	
Project estimated present value of costs (PVC) ($)	
Project estimated net present value (NPV) ($)	
Project estimated benefit-cost ratio (BCR)	
Project estimated MIRR (%)	
Estimated NPV of RDC contribution ($)	
Estimated BCR of RDC contribution	
Estimated MIRR of RDC contribution (%)	

These results will be pooled by the CROSS-RDC and used to develop a profile of the R&D undertaken within the RDC portfolio and to calculate the following estimates of costs and benefits and returns generated by the portfolio:

- lower-bound estimate of NPV, BCR, MIRR, and IRR for the RDC portfolio;
- estimated average NPV, BCR, MIRR, and IRR for the RDC portfolio;
- estimated distribution of NPV, BCR, MIRR and IRR for the RDC portfolio;
- total annual investment in R&D projects, average project size.

A summary of all assessments and results will be published by CROSS-RDC on its web site along with the statistical estimates of the RDC portfolio calculated from the pooled results. CROSS-RDC will, each year publish an Impact Assessment Program Annual Summary Report incorporating these results and an overview of the R&D conducted within the RDC portfolio and the benefits expected to be produced from adoption of the new technologies or other innovations generated from the research outputs.

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Appendix 1 – Implicit Price Deflator for GDP

The table below contains an example of the annual values for the implicit price deflator for Australia's GDP from June 1980 to June 2017 to be used to inflate historical costs of R&D to current values. The index numbers are published by Australian Bureau of Statistics (ABS) in publication 5204.0, Australian National Accounts (Table 4, series id A2420916F).

Date	Index Number
June 1980	24.9
June 1981	27.2
June 1982	30.4
June 1983	33.5
June 1984	36.1
June 1985	37.8
June 1986	40.2
June 1987	43.1
June 1988	46.2
June 1989	50.5
June 1990	53.6
June 1991	55.2
June 1992	56.0
June 1993	56.5
June 1994	57.1
June 1995	58.4
June 1996	60.0
June 1997	60.7
June 1998	61.5
June 1999	61.7
June 2000	63.3
June 2001	66.2
June 2002	68.1
June 2003	70.2
June 2004	72.6
June 2005	75.3
June 2006	79.2
June 2007	83.1
June 2008	86.9
June 2009	91.2
June 2010	92.3
June 2011	98.1
June 2012	99.9
June 2013	99.8
June 2014	101.2
June 2015	100.5
June 2016	100.0
June 2017	103.7

Appendix 2 – CROSS-RDC Impact Assessment Report Template

Note: content to be further developed to provide brief outline of the content of each item

Summary (Should be no more than two pages, aimed at an audience comprising RDC staff, directors and levy payers.)

- Overview of the research project, its outputs to-date and expected outcomes
- Summary of the investments in the project
- Summary of the principal benefits evaluated
- Overview of the impact assessment results and key sensitivities

Description of project R&D

- A concise, narrative description, in layman's language, that 'tells the story' of the project, describing the problem or opportunity it addresses, the research objectives, methodology, and intended outcomes.

Financial and in-kind investments in R&D project

- Identify participating institutions, collaborators, and other investors.
- Detail the year-on-year, cash and in-kind, contributions by each participant in nominal dollars and show adjustment to current-year (of impact assessment) values.
- If other than market values have been used for in-kind contributions, adjust those amounts to market values and show the basis for the adjustments.

Research outputs

- Describe the research outputs, intended and unintended, in terms of new knowledge, intellectual property and other findings.
- Describe the steps taken to publish and disseminate the research outputs.
- Describe the actual past or planned future pathway for development of the research outputs into adoption-ready innovations or new technology, and the parties that did or will participate in the development.

Costs of further development

- Year-on-year actual or estimated additional investment (not part of the cost of the research project per se) by project participants, public or commercial developers, extension and advisory services, and producers to convert research outputs to adoption-ready innovations or technology.
- Detail development costs in current-year values.

Description of the adoption-ready innovation or new technology

- Describe the intended, final, adoption-ready innovations or new technologies, whether these have altered from those identified in the initial proposal, and how the new technology or other innovation addresses a problem or opportunity.
- Describe the potential and expected adoption of the new technology or other innovation, its industry and geographic range, and the expected timeline for adoption.
- Detail costs of adoption of the new technology or other innovation by producers and relevant supply chains.

Description of outcomes and benefits

- Describe the market induced and transmitted changes that are expected to result from adoption of the innovation or new technology for producers, supply chains, and consumers.
- Describe the non-market changes that are expected to result from adoption of the innovation or new technology, including:
    - Costs or benefits to consumers,
    - Impacts on rural and urban communities,
    - Impacts on the environment and the agricultural resource base,
    - Impacts on human skills and capabilities in science and other disciplines,
    - Spillover costs or benefits to other industries.
- Discuss attribution and linkages between research outputs, development and outcomes

Estimation of benefits

- Describe underlying assumptions
- Describe estimation techniques
- Describe valuation methods
- Describe the counterfactual

Results and discussion

- Present the estimates of the physical measures of research outputs and outcomes with a discussion of distribution of benefits, timelines, and reliability of estimates.
- Present the estimates of the total costs and benefits, the components of each, and discuss the reliability of the estimates.
- Present estimates of NPV, BCR, MIRR, IRR and other summary statistics

Sensitivity analysis and discussion

- Identify the key parameters in the impact assessment, to which the results are most sensitive and discuss the boundaries of probable alternative values for those parameters.
- Present the results of the sensitivity analysis and discuss.

Conclusions on readiness of R&D project for impact assessment

- Discuss the conclusions reached by the impact assessment on the social and economic value of the research project.
- Discuss the extent to which the research project managers had documented plans, processes and anticipated outputs and outcomes, had quantified the likely development and adoption of resulting technology or other innovation, and had prepared for measuring and valuing the economic impacts.

References

Acknowledgements

Appendix 3 – Spreadsheet Format for Reporting Impact Assessment Metrics

Project Identification					Project parameters							Evaluaton metrics of costs and benefits realised at 5 year inte						
												NPV - total project						
Name of RDC	RDC contact responsible for evaluation	Name of cluster/sub program	Consultant used	Evaluation year	Total cluster/sub program cost for period	RDC contribution	Total cluster/sub program cost for period	RDC contribution	Period of cluster/sub program evaluated		Discount rate used	At 'Final year'	After 5 years	After 10 years	After 15 years	After 20 years	After 25 years	After 30 years
					Quoted in nominal $		Quoted in real $ of evaluation year		Start year	Final year								
RIRDC		Worms	Worm Master Economic Consulting	2010	$900,000	$90,000	$1,000,000	$100,000	2001	2005	5%							

cont.

rvals from 'final year' (col I)																				
BCR - total project							**MIRR - total project**							**IRR - total project**						
At 'Final year'	**After 5 years**	**After 10 years**	**After 15 years**	**After 20 years**	**After 25 years**	**After 30 years**	**At 'Final year'**	**After 5 years**	**After 10 years**	**After 15 years**	**After 20 years**	**After 25 years**	**After 30 years**	**At 'Final year'**	**After 5 years**	**After 10 years**	**After 15 years**	**After 20 years**	**After 25 years**	**After 30 years**

cont.

NPV - RDC investment							BCR - RDC investment							MIRR - RDC investment							IRR - RDC investment						
At 'Final year'	**After 5 years**	**After 10 years**	**After 15 years**	**After 20 years**	**After 25 years**	**After 30 years**	**At 'Final year'**	**After 5 years**	**After 10 years**	**After 15 years**	**After 20 years**	**After 25 years**	**After 30 years**	**At 'Final year'**	**After 5 years**	**After 10 years**	**After 15 years**	**After 20 years**	**After 25 years**	**After 30 years**	**At 'Final year'**	**After 5 years**	**After 10 years**	**After 15 years**	**After 20 years**	**After 25 years**	**After 30 years**