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An economic evaluation of the research benefits and returns on investment in the Invasive Plants Cooperative Research Centre

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CRC Weed management

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Front cover: *The paddock on the left has been strategically cut to control Patterson's curse*
Photo: Deidre Lemerle

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Glossary

ABARE	Australian Bureau of Agricultural and Resource Economics
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
CRC	Cooperative Research Centre
CRCAWM	Cooperative Research Centre for Australian Weed Management
CRCWMS	Cooperative Research Centre for Weed Management Systems
DREAM	Dynamic Research EvAluation Model
IPCRC	Invasive Plants Cooperative Research Centre
PV	Present value
NPV	Net present value
TFP	Total factor productivity growth

Executive summary

The CRC for Australian Weed Management (CRCAWM) was initiated in 2001 as the second phase of the successful CRC for Weed Management Systems (CRCWMS) and completes its current term in June 2008. Both CRCs are commonly referred to as the Weeds CRC. A new Invasive Plants Cooperative Research Centre (IPCRC) has been proposed to continue the work of weeds research and development at a national level.

The proposed IPCRC is an agricultural and environmental research agency that comprises universities, governments and private industry. The main research areas are proposed under three Business Units, each with a set of identified programs.

- Business Unit 1: Integrating people, products and delivery
  - Regional capacity
  - Skills building
  - Communication
  - Landscape integration
- Business Unit 2: Production systems
  - Cropping systems
  - Perennial pasture and forestry systems
- Business Unit 3: Protection
  - Protection and restoration of natural assets
  - Prevention

There are four assessment criteria by which any renewal proposal for a Cooperative Research Centre (CRC) are judged (www.crc.gov.au/):

1. The outcomes will contribute substantially to Australia's industrial, commercial and economic growth.
2. The path to adoption (commercialisation/utilisation) will achieve the identified outcomes.
3. The collaboration has the capability to achieve the intended results.
4. The funding sought will generate a return and represents good value for the taxpayer.

A rigorous economic evaluation is required to meet these assessment criteria, particularly pertaining to criteria #1 and #4.

An economic analysis of the proposed IPCRC was undertaken following the 'top-down' method of quantifying research benefits. This method was used to estimate the impact of Australian Research Council-funded research on productivity growth in the Australian economy (Allen Consulting Group 2003) and has been used to value other CRC rebid proposals. The use of this approach depends on being able to identify an underlying rate of productivity growth in a particular industry and to then assess the role of research-generated technological change in promoting that growth (Griffith et al 2004). In this evaluation, the main focus has been to evaluate the IPCRC research as an overall investment package.

It was assumed that the IPCRC represents a continuation of a longstanding research investment in weed management (as evidenced by the research programs of CRCAWM and CRCWMS (see CRCAWM and CRCWMS Annual reports 1995-2006)) and that some proportion of the proposed research would have been undertaken in the future without the IPCRC. This assumption enabled the assessment scenarios to be defined as follows: the with-CRC scenario to represent an expansion of the research investment; and the without-CRC scenario to represent a continuation of the research investment but at a lower level of funding. Hence, the main effect of the IPCRC research investment will be to increase the scale and intensity of weeds research and to expedite the delivery of the research outcomes to the relevant industries. These industries were defined to be grains, beef, wool and lamb (ie sheep-meat).

The potential benefits to the research programs of the IPCRC were estimated using the standard partial equilibrium measures of economic welfare change that result from shifts in an industry's supply or demand schedules. These benefits include the potential welfare gains to producers from adopting the technology and the gains to consumers from reduced product prices. Australia was separated into a northern region (Queensland and the Northern Territory), a southern region (New South Wales, Victoria, Tasmania and South Australia) and a western region (Western Australia). These regions correspond to the survey cropping regions defined by the Grains Research and Development Corporation, the beef producing regions defined by Griffith et al (2004), and the main sheep producing regions. International regions were included to represent Australia's main export markets and competitors in grains and livestock products. These international regions that were modelled, varied by industry. Thus different estimates of the benefits from the IPCRC were generated for each industry, each region and each IPCRC subprogram.

These measures of potential benefits were then evaluated in an ex-ante benefit-cost analysis (BCA) context. Benefits were assumed to commence after the time of the combined research and development (R&D) and adoption lags and were converted to net present values (NPVs) and benefit-cost ratios (BCRs) using a discount rate of 4%.

The marginal benefit from investment in the IPCRC over a 25-year evaluation period is $2,092 million. This represents the difference between the estimated with-CRC benefits ($2,845 million) and the estimated without-CRC benefits ($753 million).

The investment in the proposed IPCRC is shown to provide a high return on public expenditure. Investing $30 million of taxpayer funds into the IPCRC will leverage a further $64 million of in-kind and cash contributions from research providers. These costs combined will generate an additional $2,092 million in discounted benefits to the broader Australian grains, beef, wool and lamb industries.

For those benefits achieved by domestic producers and consumers (some 96% of the total benefits), there will be additional economy-wide benefits as measured by macroeconomic models such as the general equilibrium MONASH model. For agricultural industries, these multipliers are typically in the range of 40% to 60% of the relevant industry benefits (Griffith 2006). Therefore, these results satisfy criteria 1, as the IPCRC can confidently claim that it can contribute substantially to Australia's economic growth through the generation of benefits to the grains, beef, wool and lamb industries, and to the wider economy.

The estimated marginal benefit-cost ratio of 55:1 from the IPCRC investment represents a high return thus representing good value for the taxpayer and, consequently, satisfies criteria 4. Almost all of the potential benefits of the IPCRC would accrue to Australian producers and consumers, further justifying the investment.

1. Introduction

The CRC for Australian Weed Management (CRCAWM) was initiated in 2001 as the second phase of the successful CRC for Weed Management Systems (CRCWMS) and completes its current term in June 2008. A new Invasive Plants Cooperative Research Centre (IPCRC) has been proposed to continue the work of weeds research and development at a national level.

Similar to its predecessors, the proposed IPCRC is an agricultural and environmental research agency that comprises universities, governments and private industry. The main research areas are proposed under three Business Units, each with a set of identified programs.

- Business Unit 1: Integrating people, products and delivery
  - Regional capacity
  - Skills building
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There are four assessment criteria by which any renewal proposal for a Cooperative Research Centre (CRC) are judged (www.crc.gov.au/):

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4. The funding sought will generate a return and represents good value for the taxpayer.

A rigorous economic evaluation is required to meet these assessment criteria, particularly pertaining to criteria #1 and #4.

The purpose of this analysis is to provide an economic evaluation of the economic benefits to agricultural industries from the proposed IPCRC and to estimate the potential returns on that investment. The study principally focuses on the benefits of productivity changes to the grains, beef, wool and lamb industries. This study does not attempt to quantify any environmental benefits from improved weed management or measure any gains to natural resources from the IPCRC.

The research problem that is addressed is the measurement of the long-term net economic benefits from the research proposed in the IPCRC. The main emphasis is to measure the economic benefits to public and industry stakeholders that could result from this research. The estimated benefits are marginal or incremental because of the long history of weeds research in Australian agriculture, some of which has been in areas that are similar to the IPCRC proposed programs. Hence, there have been past and will be future benefits from these other programs.

The benefits from the IPCRC research programs are therefore estimated to be net of the expected benefits from other research that would continue to be funded in the absence of the IPCRC. This measure of economic benefit represents the marginal return to all participants in the weed-affected Australian industries, both domestically and internationally, from the additional investment attributable to the IPCRC funding proposal.

There are two alternative approaches to such an economic analysis: the traditional 'bottom-up' approach whereby evaluations of selected projects are undertaken and then aggregated to provide an approximation of CRC impact, and a 'top-down' approach which is based on expected changes to industry productivity and measures the benefits of CRC research programs rather than individual projects.

In reviews of the Australian Research Council grant system and the Cooperative Research Centre program, the Allen Consulting Group (2003) recommended the top-down method for quantifying research benefits from integrated programs based on measuring changes to industry productivity. The following issues were identified that CRC applications should address in the forward-looking economic impact statements that accompany their applications:

- the opportunity cost associated with investment in the project
- the extent to which a final economic benefit will be attributable to a project
- the costs incurred by end users in adopting or applying research

- the time lags involved between commencement of research and achievement of a final economic benefit
- the plausible quantification of future benefits that may be delivered
- the risk that a project will not succeed in delivering some or all of its intended outcomes
- the conversion of future economic impacts to net present value terms.

To be consistent in addressing these issues, a top-down approach was used to evaluate the proposed research programs of the IPCRC. This involved specifying appropriate with- and without-CRC scenarios, to account for opportunity costs and to identify differences in the underlying rate of productivity growth in the relevant industries, adoption rates and lags and the probability of success of individual research programs.

The annual benefits from with- and without-CRC scenarios were estimated over a 25-year evaluation period using the Dynamic Research Evaluation Model (DREAM) (Wood et al 2001). This involved the use of the model's 'horizontal multi-market' model option, which allows evaluation of the economic impact of a new technology where the product is (relatively) freely traded across a number of regions (Alston et al 1995). The weed research benefits estimated by the DREAM model for with- and without-CRC scenarios were then incorporated into a benefit-cost analysis model which determined net present values (NPV) and benefit-cost ratios (BCR), as well as the marginal impact of investment in the proposed IPCRC (ie net-CRC).

2. The business units and scientific research programs of the Invasive Plants Cooperative Research Centre

The IPCRC has proposed a structure of three business units, with research and extension programs embedded within each unit. The following description of each business unit and its associated activity programs is taken from the IPCRC bid document and other supporting documents.

2.1 Business Unit 1: Integrating people, products and delivery

The main focus of this business unit is on the extension and adoption of research to be derived from the IPCRC and research and knowledge from the previous CRCWMS and CRCAWM, as well as from other sources.

The outcomes of this business unit are:

(i) to overcome the current shortage of invasive plant management skills, within industry, research and the community at local and regional level

(ii) increase the awareness of invasive plant problems.

There are four programs within Business Unit 1.

Program 1.1 Regional capacity

Achieving adoption of research results in the rural sector requires significant investments in delivery mechanisms, which also need to take into account the socio-economic drivers for on-farm change. The IPCRC will therefore carry out or commission research to determine how best to overcome the barriers to adoption on-farm.

The research theme is:

- Determining the barriers to adoption of best practice weed management.

Program 1.2 Skill building

An integral part of the delivery system will address the critical shortage of staff skilled in weed management at local and regional levels. This will require the development of the VET module in the Skill building program and its integration with delivery and adoption. Other parts of the program will ensure the provision of skilled university graduates and researchers to provide the basis for the future development of weed management and enable the IPCRC to keep abreast of and reduce the problem of invasive plants in Australia.

The research theme is:

- Targeted development of skills and capacity for future weed management.

Program 1.3 Communication

The IPCRC will also build on the existing communication and education programs of the CRCAWM to ensure that actual and potential weed issues are well understood across the community not only as a local or individual issue, but at the influential policy and decision making level. School programs will also be an important element in ensuring that the next generation of land managers and decision makers will be aware of weed issues.

The research theme is:

- Effective communication of weeds issues.

Program 1.4 Landscape integration

The recent emphasis on regional natural resource management and the formation of catchment management authorities also reflects the realisation that invasive plants do not stop at the farm gate and land managers cannot operate in isolation from the surrounding ecosystems, whether other farms or grazing properties, conservation reserves or forests. Only a regionally integrated approach will deliver the optimal management strategies for increased productivity and the IPCRC will invest in, and develop, the science of integration to lift productivity more broadly. This, in turn, will dovetail with the increased emphasis on delivery across regions.

The research theme is:

- Integration of weed management across properties, ecosystems and landscapes.

2.2 Business Unit 2: Production systems

This is the main science and research unit within the IPCRC and is strongly focussed on two programs; cropping systems and perennial pasture and forestry systems.

The primary outcomes of Production systems are:

(i) an increase in the profitability of sustainable crop and livestock production

(ii) an increase in the productivity of agricultural industries that protect the natural resource base.

Program 2.1 Cropping systems

Invasive plants are the most persistent impediment to increased production in the cropping industry across Australia (Jones et al 2000; Sinden et al 2004). A changing weed spectrum, new weed species, the development of herbicide resistance in existing weeds and lack of new herbicides have ensured an ongoing problem despite improvements in crop management, no-till farming and rotation systems. Management of herbicide resistance must continue to be improved and coordinated, but new thinking, new approaches and new technologies need to be applied.

The research themes are:
- new technologies to control weeds in crops
- systems approach to weeds in cropping
- herbicide resistance management.

Program 2.2 Perennial pasture and forestry systems

Research on weed management in pasture and extensive grazing systems will be enhanced significantly, covering both southern and northern Australian livestock industries. Biological control programs will also include a focus on weeds that are both problems in production and the environment (eg Cape tulips, brooms, mistflower, gorse). An integrated research approach that combines biological agents with existing weed control practices will provide new solutions for land managers.

The ingress of unpalatable/unproductive grasses, forbs and shrubs is a persistent and often intractable problem in productive pastures, while toxic and injurious weeds present a particular problem disproportionate to any competitive capacity. The IPCRC will provide a research emphasis on these two issues in particular.

Understanding the ecology of the pasture system is always going to be integral to sustainable gains in productivity, not only to optimise the gains from biological control and the management of unpalatable and toxic species, but also to obtain the most productive interactions between plant and animal species, soils and climate.

In forestry, the weed blackberry alone costs NSW $5 million per annum in control costs to enable routine silvicultural practice. There is a foundation of knowledge of the relevant biology, biological control and herbicide impacts for many weeds and this will be developed and integrated to yield practical, cost effective and easily-adopted management packages.

The research themes are:
- enhancing biological control
- productive management of unpalatable/unproductive grasses and shrubs
- better management of toxic and injurious species in pasture
- systems research for better weed management in grazing lands
- integrated weed management in forestry systems.

2.3 Business Unit 3: Protection

The focus of this unit is on protecting natural assets and agricultural industries from weed invasion.

There are four outcomes from Protection:

(i) invasive plant threats to natural systems and resources are reduced

(ii) restoration of degraded areas is improved

(iii) spread of new invasive plants to and within Australia is reduced by 50%

(iv) market access is maintained and trade is increased for Australian commodities.

Program 3.1 Protection and restoration of natural assets

The management of weeds in production systems may not succeed without attention to neighbouring environments that can act as reservoirs for reinfestation, which emphasises the need for an integrated approach across sub-catchments and catchments.

However, some environments have their own conservation, biodiversity and often tourism values. Combating the destructive influence of invasive plants cost conservation agencies $19.6 million in 2001–02 and considerably more in 2005/06. Much of the technology developed for production systems, particularly biological control, is directly applicable to natural assets and state and private conservation interests in Australia are investing in the IPCRC to ensure the best skills can be enlisted to reduce this cost and protect Australia's unique assets.

Natural systems are often extensive and management difficult, not least because of insufficient knowledge of the occurrence, distribution and spread of invasive plants. Automated remote sensing of weed species is still in the future, but the IPCRC will invest in new research in this area, as it has enormous potential to streamline data collection both for mapping and for the analysis of patterns and rates of spread – critical information in directing management strategies.

Water is a precious natural resource, but water supply systems can be damaged by unwanted plant invasions blocking reticulation systems, changing ecological balances and decreasing water quality. Weed management in water systems lacks coordination and critical mass in both research and delivery.

Australia has large areas of severely degraded land, partly as a result of inappropriate land use and management, or of poor management when providing mineral resources. Restoration of this land requires knowledge of revegetation principles and more particularly, weed risks and dynamics. The return of land to a weed-free condition or semi-natural state benefits productivity as well as the natural environment.

The research themes are:

- better weed management and enhanced biological control for natural areas including aquatic systems
- better mapping and prediction of weed impact and spread
- rehabilitation of degraded land.

Program 3.2 Prevention

The most effective method of weed management is to prevent their occurrence in the first place, particularly as Australia is continually subject to the risk of invasion by new species. There is also the risk of species, already present in small numbers or in confined areas, escaping their local constraints and increasing in abundance and distribution to become a major problem. The IPCRC will build on the successful previous work of the CRCAWM and CRCWMS to broaden and improve the barriers to establishment and colonisation by invasive plants in Australia.

While the principles of weed risk assessment are similar pre- and post-border, the implementation of appropriate prevention procedures differs. The Weed Risk Assessment Procedure for new imports has greatly diminished the flow of new species with invasive potential into Australia, but some of the principles need refining. More particularly, there is a need for a broader application to post-border situations. Increased effectiveness will result from a quantitative analysis of the different pathways for both entry and spread and risk assessment will benefit from an improved ability to predict impact.

A critical factor in dealing with incursions is the ability to either detect propagules before entering Australia or the first occurrence of established plants. Subsequent manage-ment of an incursion is highly dependent on accurate distribution and spread information. This has parallels with the mapping and environmental analysis required for protection of extensive natural systems.

There are a number of existing invasive species present in Australia, having been imported as ornamental plants. The nursery industry is active in cooperative initiatives to prevent such occurrences in the future. Apart from better weed risk assessment procedures, the incorporation of sterility into future new cultivars is one way to reduce this risk. The financial investment in eg molecular biology for any one species might well be prohibitive, but the IPCRC will establish the framework and possibilities for future work in this area.

The research themes are:

- understanding the invasion and establishment process
- new technologies to detect incursions and prevent spread
- refinement and broader application of weed risk assessment procedures.

3. Evaluation methods and scenarios

In an assessment of the funding proposal for the CRC for Beef Genetic Technologies (Beef CRC), Griffith et al (2004) and Griffith (2006) identified three types of economic benefits that could result from new research programs.

1. Benefits that result from completely new research that has not previously been undertaken and would not have been undertaken without the proposed CRC. *Ie new technologies that would not have otherwise been generated.*
2. Benefits that result from enhanced research outputs that have a greater impact on the industries than those that come from other research programs that may be undertaken by the same agencies independently of the proposed CRC. *Ie better technologies that come out of the proposed CRC's research programs that improve on the outputs of other programs in similar areas.*
3. Benefits that result from the extension to the industries of improved information that can legitimately be attributed to the proposed CRC's activities. *Ie faster and/or more widespread adoption of new technologies.*

The potential benefits from the IPCRC research appear most likely to fall into either the second or third categories, or both, where this investment adds to the level of research in the weed-affected industries and the IPCRC actively promotes the research outcomes. The potential benefits from this type of CRC activity have been estimated for one of the research programs initiated by CRCWMS to reduce *Vulpia* spp. infestations in Australian temperate pastures (Vere et al 2003).

3.1 Evaluation perspective

Economic approaches to assessing the accountability of the CRCWMS were described by the Centre for International Economics (2001). One approach was based on evaluating a random selection of projects from the research portfolio and extrapolating the estimated benefits to other research areas to determine a net overall benefit. This method relied on a large sample size and its validity depended on how representative the selected projects were of the full research program. It was difficult to apply when only some projects were amenable to quantitative evaluation. An alternate approach was based on the selection of a set of completed projects and evaluating the extent to which their estimated returns covered the full research costs. This approach was seen to be more tractable than the first and it allowed the programs and the component projects to be evaluated as being parts of an integrated research program, rather than as being stand alone entities.

The second approach described by the Centre for International Economics (2001) to evaluating programs is consistent with the methods adopted to evaluate the benefits of research funded by the Australian Research Council (ARC). This evaluation of ARC research funding followed a top-down method for quantifying research benefits that was designed to provide a benchmark or a conservative estimate of the impact of ARC-funded research on productivity growth in the Australian economy (Allen Consulting Group 2003).

The three parts of this top-down process were to:

1. determine the extent to which all research in the economy (both public and private) contributed to productivity growth
2. determine the contribution to productivity growth made by publicly-funded research in Australia
3. determine the share of the impacts of that contribution that could be attributed to the ARC-funded research.

The purpose of using this method was to provide 'a plausible order of magnitude' of the impact of ARC research funding, rather than a precise estimate of the value of that impact.

Following this reasoning, the top-down approach was used to evaluate the proposed research programs of the IPCRC. The use of this approach depends on being able to identify an underlying rate of productivity growth in a particular industry and to then assess the role of research-generated technological change in promoting that growth (Griffith et al 2004). In this evaluation, the main focus has been to evaluate the IPCRC research as an overall investment package. This procedure also provides estimates of the potential benefits of the separate research programs according to the evaluation scenarios that are described in the next section.

3.2 Evaluation scenarios

The clear definition of appropriate evaluation scenarios is an essential consideration in assessing potential research benefits. Such definitions are not straightforward because most research processes are typically on-going rather than new. It was assumed that the IPCRC represents a continuation of a longstanding research investment in weed management (as evidenced by the research programs of CRCAWM and CRCWMS) and that some proportion of the proposed research would have been undertaken in the future without the IPCRC.

This assumption enabled the assessment scenarios to be defined as:

- the with-CRC scenario to represent an expansion of the research investment
- the without-CRC scenario to represent a continuation of the research investment but at a lower level of funding.

Hence, the main effect of the IPCRC research investment will be to increase the scale and intensity of weeds research and to expedite the delivery of the research outcomes to the relevant industries. This outcome will be achieved through the IPCRC providing additional research funding and by reinforcing and expanding the strong collaboration that currently exists between researchers and the resources of the research institutions (Griffith et al 2004). Based on these scenario definitions, the evaluation task was to measure the marginal or incremental benefits that could result from the IPCRC.

3.3 Economic models used in evaluations

Alston et al (1995) considered that the objectives of agricultural research are mainly to increase the economic welfare of societies. Economic welfare is improved if the adoption of new production technologies, such as improved weed management, generates increases in the productivity of the relevant industries. In relation to a particular industry, productivity improvements can result from either an increase in production from an existing level of resources, or from maintaining production using fewer resources. The widespread adoption of a new technology that results in a productivity improvement generates an outward shift of the industry supply curve in proportion to the reduction in production costs that is achieved. Evaluation of agricultural research investments also concerns the distribution of economic welfare between social groups. As markets adjust to new levels of output, consumption and prices, various groups in the market receive benefits or suffer losses. Who gains and who loses from research (the incidence of costs and benefits) is an important issue for the funding of this research.

The potential benefits to the research programs of the IPCRC were estimated on the basis of these propositions using the partial equilibrium measures of economic surplus or welfare change that result from shifts in an industry's supply or demand schedules. The benefits that are measured using this method include the potential welfare gains to producers from adopting the technology and the gains to consumers from reduced product prices. Following the top-down method described above, the potential benefits to each of the IPCRC research programs were evaluated in terms of the annual changes in economic welfare that could result from the industry-wide adoption of the weed management technologies that will be developed under these programs. Because much of the IPCRC research is expected to impact on the supply sides of the grains and livestock industries, these benefits were estimated in terms of the annual changes in economic welfare that result, where improved weed management in crops and pastures increase the production and reduce the production costs of the weed-affected commodities.

The estimates of change in economic welfare provide the measures of potential benefits that were then evaluated in an ex-ante benefit-cost analysis (BCA) context. Benefits were assumed to commence after the time of the combined R&D and adoption lags (at the end of the IPCRC's funding). They were converted to net present values (NPVs) and benefit-cost ratios (BCRs) at a 4% real discount rate over a 25-year evaluation period.

Research program costs for the with-CRC scenario were derived from the CRCAWM administration and included all direct grants and in-kind contributions from the collaborating agencies. The costs of the non-research programs were treated as scientific overheads and were allocated proportionally across the various research program areas. Costs for the without-CRC scenario were held to be 80% of the total value of the in-kind contributions made by the IPCRC partners, less the value of Commonwealth government and partner grants. After the approach of Griffith et al (2004), the 80% scaling of the in-kind contributions was considered to be a reasonable approximation of the value of the research funding that was likely to have continued in the absence of the IPCRC. For the without-CRC scenario a Commonwealth commitment to weed research will continue through the part Commonwealth funding of rural industry research organisations (ie Grains Research and Development Corporation, Meat and Livestock Australia and Australian Wool Innovations).

The economic welfare change and BCA calculations were made using the DREAM model developed by Wood et al (2001) that is based on the economic principles for research evaluation that are detailed in Alston et al (1995). DREAM is an internationally respected model that has been refined and promoted for use by major world and Australian agricultural research funding agencies. The model has a rigorous theoretical base and requires well defined parameter values that include equilibrium prices and quantities, supply and demand elasticities, commodity supply shifts, adoption rates and lags and probabilities of success. One market specification option in the DREAM model is the horizontally-disaggregated multi-region option, which allows evaluation of the economic impact of a new technology where the product is (relatively) freely traded across a number of regions (Alston et al 1995). This option was used to evaluate the IPCRC program benefits. An advantage of this option is that it captures the multi-regional and international trade status of the weed-affected industries. The main disadvantage is that the potential impacts of the programs on the vertical market segments of the industry, such as processors and retailers, cannot be evaluated. The estimated benefits therefore relate to farm-level as the point of exchange and the price, quantity and elasticity values chosen reflect this part of the relevant industries.

Because DREAM operates in an equilibrium displacement context, it uses equilibrium values for the input prices and quantities that define the size and structure of the market in each region. It also uses elasticities of supply and demand to predict how producers and consumers in each region will react to new prices generated by the simulated shocks to the market from the impact of the programs and estimates how the programs' technologies would change producers' cost structures or consumers' willingness to pay for different quality products in the region where the technology will be adopted (ie the supply and demand shifts).

For the DREAM modelling, Australia was separated into a northern region (Queensland and the Northern Territory), a southern region (New South Wales, Victoria, Tasmania and South Australia) and a western region (Western Australia). These regions correspond to the survey cropping regions defined by the Grains Research and Development Corporation, the beef producing regions defined by Griffith et al (2004) and the main sheep producing regions. International regions were included to represent Australia's main export markets and competitors in grains and livestock products. These varied by industry, as different DREAM models were specified for each industry.

The economic surplus method

This method considers that weed control results in an outward shift in the supply curve for a particular product such as wool or wheat, with the demand curve remaining stationary. With information about the slopes (elasticities) of the supply and demand curves for that product, the type of the supply shift following weed control, the relationship between producer and consumer prices and the impact of widespread weed control on a particular industry can be evaluated. This situation is illustrated in Figure 3.1.

Initial production is Q_0 for which consumers pay a price of P_0. Producers have an economic surplus equivalent to P_0AC while consumers' surplus is the area P_0AF. The main economic effect of weed control is to reduce per unit production costs and shift the commodity's supply curve outwards to S_1, resulting in more output at a lower price. Here, the demand curve D_0 remains stationary, as there are no anticipated demand shifts. The area of economic surplus is now FBD comprising consumers' and producers' surpluses of P_1BF and P_1BD, respectively.

These areas of total economic surplus change represent the impact of weed control on both consumers and producers. The net change in economic surplus is equivalent to the benefits of control and this is given by the area $CABD$, the difference between the areas FAC and FBD. The incremental benefit area $(CABD)$ incorporates the production cost reductions for the initial output Q_0 (the area $CAED$) and the value to consumers of the extra production at S_1, net of production costs (the area ABE). Where the supply curve shift is parallel so that the vertical distance between the two supply curves is constant, and following Alston (1991), the changes in the economic surplus areas from weed control can be estimated as:

change in consumers' surplus;
$\Delta CS = P_0Q_0Z(1 + 0.5\eta)$

change in producers' surplus;
$\Delta PS = P_0Q_0(K - Z)(1 + 0.5\eta)$

change in total surplus;
$$\Delta TS = P_0Q_0K(1 + 0.5\eta) = \Delta CS + \Delta PS$$

where, P_0 and Q_0 are the initial equilibrium market-clearing price and quantity for the commodity, Z is the percentage reduction in price arising from the supply shift defined as $Z = K\varepsilon/(\varepsilon+\eta)$, K is the initial vertical supply shift expressed as the percentage reduction in production costs from the adoption of the new technology and ε and η are the product's price elasticities of supply and demand. With estimates of these parameters, the economic surplus equations can then be solved.

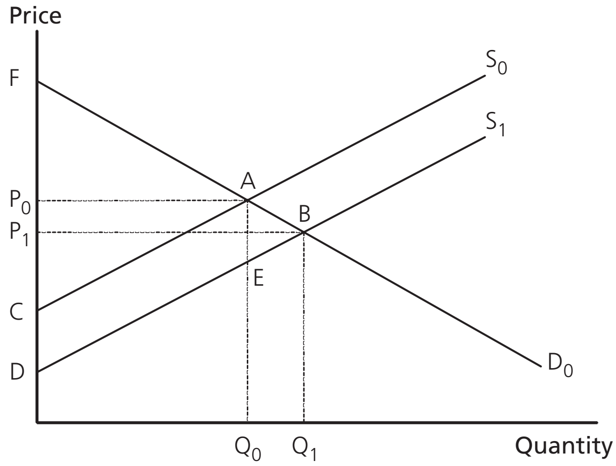

Figure 3.1 Effect of a supply shift in a commodity market
Note: In summary, this figure shows that the effect of weed research (once adopted by producers) increases the supply of a commodity (eg wheat) by reducing the cost of production, which benefits industry.

Benefit-cost analysis

The primary objective of benefit-cost analysis (BCA) is to determine the potential returns on investment from a project involving public expenditure. In BCA all the benefits and costs of a project or research program are identified and where possible, valued. BCA recognises that expenditure on the IPCRC represents an investment and that the benefits of that investment can be spread over a number of years. Thus, one of the important features of BCA is the concept of 'discounting'. Whenever the patterns of benefits and costs are distributed over time, discounting is used to convert future cash flows to a present-value monetary amount. A discount rate is used in this process, the actual rate reflecting the difference in current and future monetary values.

To estimate returns on investment, the two primary criteria used are the net present value (NPV) and the benefit-cost ratio (BCR). These two criteria are estimated as follows:

$$NPV = \sum_{t=1}^{T} \frac{B_t - C_t}{(1 + r)^t}$$

$$BCR = \sum_{t=1}^{T} \frac{B_t}{(1 + r)^t} \bigg/ \sum_{t=1}^{T} \frac{C_t}{(1 + r)^t}$$

where B_t are benefits in year t, C_t are costs in year t, r is the discount rate and T is the evaluation period. The investment with the highest NPV and BCR is generally preferred and any project with a negative NPV or BCR less than unity indicates an economically-undesirable project.

4. Data and information requirements for the economic evaluations

4.1 Data required for estimation of industry benefits

An important issue in undertaking this economic evaluation of the IPCRC was to obtain realistic information about the expected impacts of the research on the target industries. Data from published sources include annual rates of productivity growth and the required industry modelling data such as equilibrium prices, production quantities, consumption quantities and supply and demand elasticities. A workshop was held in Canberra on 20–21 February 2006 to elicit a range of data from CRCAWM senior management, IPCRC bid committee and senior weed researchers. The workshop involved 15 senior research managers and weed scientists from a range of technical backgrounds and geographic areas. The main data elicited included the contribution of IPCRC research programs to any industry productivity change, the probabilities of project success, research and development (R&D) lags, adoption lags and adoption ceiling levels for each research program. This information was derived for with- and without-CRC scenarios.

The analysis is confined to four agricultural industries that are expected to be the main beneficiaries of IPCRC research outcomes. These are grains, beef, wool and lamb (ie sheep meat). The grains industry is an amalgamation of a number of winter crop commodities, principally wheat, barley, oats, canola and the pulse crops lupins, field peas and chick peas.

The economic surplus model used is a regionally disaggregated model, thus during the data elicitation process separate Australian regions were identified as being north, south and west (see Section 3.3). The beef industry regions were slightly different as it was only split into north and south regions, including the northern and southern regions of WA.

Estimates of the rate of productivity growth in the weed-affected industries

Two essential sets of information for this evaluation were:

1. the underlying rates of productivity improvement in the Australian rural industries that are affected by the weeds research
2. the expected improvement to these rates of growth if the IPCRC received funding.

To assist in making some judgements about these inputs, a review of past studies on productivity growth and returns to research on investments in the agricultural industries was undertaken. This information enabled the annual rates of productivity growth in the relevant industries to be determined and compared to the potential rates of growth that could result from the IPCRC research programs. This information is important to the evaluation process because the effect of research and development on industry growth has typically been inadequately measured in productivity studies (Mullen 2002).

Estimates of productivity growth in the Australian grains and livestock industries were derived from published ABARE studies and are reported as annual rates of change in total factor productivity (TFP). Table 4.1 indicates that the more recent rate of productivity growth of 1.8% in the grains industries is well below the historical 30-year rate of productivity growth of 3.3%. This is likely due to a lack of new technologies (such as replacement herbicides, improved crop varieties) and an increase in environmental and pest problems

Table 4.1 Estimates of long-term total factor productivity growth in the Australian grains and livestock industries (% pa)

Industry	Period	TFP	Source
Grains	1977–78 to 1993–94	4.6	Knopke et al (1995)
Grains	1977–78 to 2001–02	3.3	ABARE (2004a)
Grains	1988–89 to 2001–02	1.8	ABARE (2004a)
Beef	1977–78 to 1993–94	1.6	Knopke et al (1995)
Beef	1977–78 to 2001–02	1.8	ABARE (2004a)
Beef	1988–89 to 2001–02	2.1	ABARE (2004a)
Sheep	1977–78 to 1993–94	1.0	Knopke et al (1995)
Sheep	1977–78 to 2001–02	0.9	ABARE (2004b)
Sheep	1988–89 to 2001–02	1.2	ABARE (2004b)

such as herbicide resistance, salinity, soil erosion and crop diseases. Beef and sheep industry TFP has increased relative to grains industries in recent decades. For example the long-term annual productivity growth of the beef industry is 1.8%, whereas annual productivity growth since 1988–89 is 2.1%.

Estimates of technology adoption in the Australian grains and livestock industries

Rates of technology adoption in the weed-affected industries are important determinants of the potential and actual rates of productivity gains. Although there have been few formal measures of technology adoption rates in Australia's rural industries, adoption is recognised as being relatively low, particularly in the livestock industries.

When used in combination with productivity growth estimates, technology adoption rates enable the potential rates of growth that could be realised by the industries to be determined. As an example, a 1% actual rate of productivity growth combined with a 25% adoption rate results in a potential (or maximum) annual productivity growth rate of 4% (ie 0.01 = 0.04 x 0.25 or 0.04 = 0.01 / 0.25). It was assumed that the IPCRC could help to move closer to the maximum potential productivity growth by expediting the release of new technologies and by promoting their adoption.

Estimates of the IPCRC contribution to productivity growth in the Australian grains and livestock industries

A research organisation such as a CRC can have several types of impacts on industry growth. The first is where the CRC does not add to the technology stock but invests in achieving a greater level of adoption of the existing technologies. Industry benefits result from increasing the technology adoption ceiling and by reducing the time required to attain that ceiling. A second type of impact is where the CRC adds new technologies to the existing stock but does not invest in increasing the level of technology adoption, so there is no change in the adoption ceiling. The main benefit provided by this option is through opportunities to reduce the costs to the group of adopters that comprise the adoption ceiling. Here, the potential for larger industry benefits cannot be realised without also improving the adoption profiles. A third option is a combination of the others whereby the CRC invests in both developing new technologies and in improving technology adoption in the target industries.

The main objective under any of these options is to reduce the differences between the potential and actual rates of productivity growth.

This objective recognises that:

1. there are large differences between the potential and actual rates of productivity growth being achieved in most of Australia's agricultural industries
2. the research activities of a CRC provide new opportunities for cost savings in addition to those that are being realised by the industry's adopter group (eg the without-CRC scenario)
3. if there is no investment in developing new technologies, there is no change in the underlying potential for productivity growth and the actual rate of growth can only be increased through higher adoption
4. increasing both the technology stock and its level of adoption has the potential to generate substantial industry benefits.

It was considered that the impact of the IPCRC would most likely relate to the fourth option by providing opportunities to increase the use of existing weed management technologies by adding new weed management technologies to the current stock and by improving the level of adoption of existing and new technologies. Economic evaluations of the CRCWMS and the Beef CRC have demonstrated that investment in new technologies and in enhancing adoption has a significant economic value (Griffith and Vere 2006).

Estimates of the contributions to industry productivity growth that were expected to result from the IPCRC research were obtained from the workshop data elicitation process. Here agreement was reached as to what the growth shares were expected to be across all programs (Table 4.2). Within each industry and each region, the shares from the relevant research programs have to sum to unity for a 1% productivity growth for the with- and without-CRC scenarios.

These estimates were the starting values for the top-down evaluations which provided the basis for calculating the expected shifts in the supply and demand schedules for these industries. For the Beef CRC evaluation, Griffith et al (2004) drew on past studies of productivity growth in the Australian beef industry and estimates of adoption levels to assume that the potential growth rate that was available to the beef industry was about 5% per annum. Based on recent economic estimates of the benefits of specific beef production technologies and on the expectations of the scientists' that future successes would be duplicated through the renewed

CRC funding, Griffith et al (2004) assumed that the aggregate impact of the proposed Beef CRC on the potential rate of growth was an additional 4% if there was maximum adoption of the research outcomes. Hence, the comparison for the Beef CRC evaluation was based on 5% potential annual growth under the without-CRC scenario, compared to 9% potential annual productivity growth under the with-CRC scenario. Relative estimates of sheep industry potential annual productivity growth for a Sheep CRC evaluation were 5 and 7.5% for the without- and with-CRC scenarios (Vere et al 2005).

The IPCRC can contribute to ameliorating the problems of weeds by lifting productivity in four agricultural industries; grains (comprising wheat, barley, oats, canola, pulses), beef, wool and lamb. Considerable effort was made to be conservative in the estimates of potential annual productivity growth improvements due to an IPCRC and for the assumptions to be explicit and defensible. The derived with- and without-CRC productivity changes are given in Table 4.3 for the livestock industry and Table 4.4 for the grains industries. For each industry the without-CRC potential annual productivity growth rate is obtained by dividing the actual productivity growth rate by the industry adoption rate.

The rationale for the derivation of with-CRC productivity growth differed for the grains and livestock industries. It was assumed that the IPCRC could increase total livestock industry productivity growth by around 12%. Using this figure for each livestock industry would likely result in a double counting of benefits given the integrated nature of weeds and grazing systems, thus the simplifying assumption was made to share the productivity gains equally across the beef, lamb and wool industries at a rate of 4%.

There has been a decline in the annual productivity growth of the grains industry from a long-term average of 3.3% to 1.8% over the past decade. Using the long-term annual productivity growth rate, the potential rate of future annual productivity growth is 6.6%. This potential rate would occur if a range of production and resource management problems were addressed. Given the scale and diversity of such issues, it is assumed that the IPCRC could only account for 25% of any such gain in future productivity growth, which results in an estimated with-CRC annual productivity growth of 4.35%.

Table 4.2 Proportional contributions of individual IPCRC research programs to a 1% increase in productivity growth by industry for with- and without-CRC scenarios

Programs	Northern zone	Southern zone	Western zone
Grains industry			
With-CRC			
– better herbicide resistance management	0.20	0.30	0.40
– crop systems research	0.50	0.30	0.20
– new technologies	0.30	0.40	0.40
Without-CRC			
– better herbicide resistance management	0.40	0.40	0.40
– crop systems research	0.50	0.40	0.40
– new technologies	0.10	0.20	0.20
Beef industry			
With-CRC			
– biological control	0.15	0.10	na
– unpalatable grasses and shrubs	0.30	0.25	na
– toxic and injurious plants	0.05	0.15	na
– grazing systems research	0.50	0.50	na
Without-CRC			
– biological control	0.10	0.05	na
– unpalatable grasses and shrubs	0.25	0.20	na
– toxic and injurious plants	0.05	0.10	na
– grazing systems research	0.60	0.65	na

Programs	Northern zone	Southern zone	Western zone
Wool industry			
With-CRC			
– biological control	0.00	0.10	0.10
– unpalatable grasses and shrubs	0.10	0.25	0.10
– toxic and injurious plants	0.20	0.15	0.20
– grazing systems research	0.70	0.50	0.60
Without-CRC			
– biological control	0.00	0.00	0.00
– unpalatable grasses and shrubs	0.00	0.20	0.00
– toxic and injurious plants	0.10	0.10	0.10
– grazing systems research	0.90	0.70	0.90
Lamb industry			
With-CRC			
– biological control	0.00	0.10	0.10
– unpalatable grasses and shrubs	0.10	0.25	0.10
– toxic and injurious plants	0.20	0.15	0.20
– grazing systems research	0.70	0.50	0.60
Without-CRC			
– biological control	0.00	0.00	0.00
– unpalatable grasses and shrubs	0.00	0.20	0.00
– toxic and injurious plants	0.10	0.10	0.10
– grazing systems research	0.90	0.70	0.90

na – not applicable

Table 4.3 Derivation of the potential rates of annual productivity growth of the livestock industries for the with- and without-CRC scenarios (%)

		Beef industry	Lamb industry	Wool industry
C	Current actual productivity growth	2.10	1.60	1.20
A	Historical adoption rate	25.00	20.00	20.00
P_1	Without-CRC potential productivity growth	8.40	8.00	6.00
R	Potential productivity increase attributable to IPCRC	4.00	4.00	4.00
P_2	With-CRC potential productivity growth	8.74	8.32	6.24

Note: $P_1 = C/A$; $P_2 = P_1 \times (1+R)$

Table 4.4 Derivation of the potential rates of annual productivity growth of the grains industry for the with- and without-CRC scenarios (%)

		Grains industry
C	Current productivity growth	1.80
A	Historical adoption rate	50.00
P_1	Without-CRC potential productivity growth	3.60
P	Potential productivity growth	6.60
R	Potential productivity increase attributable to IPCRC	25.00
P_2	With-CRC potential productivity growth	4.35

Note: $P_1 = C/A$; $P_2 = P_1 + (P-P_1)xR$

The supply shift values (Table 4.5) were estimated as a function of the with- and without-CRC productivity growth rates in Tables 4.3 and 4.4 and the contributions to productivity growth data in Table 4.2. For example, in the case of the grains industry northern region the with-CRC supply shift value of 0.87% for the better herbicide resistance management program was derived by multiplying the grains industry productivity growth of 4.35% (Table 4.4) by a contribution value of 0.2 (Table 4.2) from this research program.

For most industry/region/research program combinations the with-CRC supply shift exceeds the without-CRC supply shift. However, for some industry/region/research combinations the with-CRC supply shift is lower. This results from a reduced emphasis of the individual research program for the with-CRC scenario, despite the total industry supply shift being higher than the without-CRC scenario. An example is the northern zone grains industry, where the supply shift for the better herbicide resistance management program for the with-CRC scenario (0.87%) is lower than the without-CRC scenario (1.44%). This is due to a reduction in the individual contribution to productivity growth from 0.4 to 0.2 (see Table 4.2), which is not compensated for by the overall gain in annual potential productivity growth from 3.60% to 4.35% (see Table 4.4). However, despite differences across the research programs the total supply shift for the with-CRC scenario for each industry/region combination is always greater than the without-CRC scenario.

Estimates of the expected adoption profiles for the IPCRC research outcomes

The extent and time profiles for the adoption of a new technology are also critical factors in determining the research benefit levels. The components of these profiles are the delivery time for the technology (the R&D lag), the time taken to achieve the expected level of adoption of the technology in the industry following its release (the adoption lag) and the eventual level of the technology's adoption in the industry (the adoption ceiling). The first two components define the total technology lag from the commencement of the research and the adoption of its outcomes by the industry, while the third defines the maximum number of operators who make up the size of the market that will potentially benefit from the research outcomes. Each component is a central issue in the economic evaluation of a new technology.

Table 4.5 Estimated commodity supply shifts from IPCRC research programs (%)

Programs	Northern zone	Southern zone	Western zone
Grains industry			
With-CRC			
– better herbicide resistance management	0.87	1.31	1.74
– crop systems research	2.18	1.31	0.87
– new technologies	1.31	1.74	1.74
Without-CRC			
– better herbicide resistance management	1.44	1.44	1.44
– crop systems research	1.80	1.44	1.44
– new technologies	0.36	0.72	0.72
Beef industry			
With-CRC			
– biological control	1.31	0.87	na
– unpalatable grasses and shrubs	2.62	2.18	na
– toxic and injurious plants	0.44	1.31	na
– grazing systems research	4.37	4.37	na
Without-CRC			
– biological control	0.84	0.42	na
– unpalatable grasses and shrubs	2.10	1.88	na
– toxic and injurious plants	0.42	0.84	na
– grazing systems research	5.04	5.46	na

Programs	Northern zone	Southern zone	Western zone
Wool industry			
With-CRC			
– biological control	0.00	0.62	0.62
– unpalatable grasses and shrubs	0.62	1.56	0.62
– toxic and injurious plants	1.25	0.94	1.25
– grazing systems research	4.37	3.12	3.74
Without-CRC			
– biological control	0.00	0.00	0.00
– unpalatable grasses and shrubs	0.00	1.20	0.00
– toxic and injurious plants	0.60	0.60	0.60
– grazing systems research	5.40	4.20	5.40
Lamb industry			
With-CRC			
– biological control	0.00	0.83	0.83
– unpalatable grasses and shrubs	0.83	2.08	0.83
– toxic and injurious plants	1.66	1.25	1.66
– grazing systems research	5.82	4.16	4.99
Without-CRC			
– biological control	0.00	0.00	0.00
– unpalatable grasses and shrubs	0.00	1.60	0.00
– toxic and injurious plants	0.80	0.80	0.80
– grazing systems research	7.20	5.60	7.20

na – not applicable

The data regarding research impacts, research time lags, adoption ceilings and adoption lags used in research programs that were elicited from the workshop are given in Tables 4.6 and 4.7. For the with-CRC scenario, the main effect of the IPCRC research on the adoption profile was to expedite the delivery of the programs' technology areas and to shorten both the adoption lags and the R&D lags. This data was subjectively determined from the workshop. The probability of success for each research program was also defined for each region and each industry for the with- and without-CRC scenarios, respectively. Note that in the case of some technologies, such as the adoption ceiling for biological control, there may be no difference between the with- and without-CRC scenarios. In the case of this technology, the effect of the CRC is to enhance the rate of R&D and adoption and to improve the probability of project success.

Industry (DREAM) modelling data

The industry structure data required by the DREAM model are equilibrium prices, production quantities, consumption quantities, supply and demand elasticities and price linkages. For each commodity (grains, beef, wool, lamb) the model was disaggregated into Australian regions (mostly by state) and where appropriate, into international regions. The data is reported for each industry in Table 4.8.

4.2 Data required for estimation of natural asset protection benefits

The analysis of the protection benefits from the IPCRC investment were aggregated into three areas:

1. pre-border benefits
2. post-border benefits
3. benefits from reduced price discounts due to contamination.

Many of the benefits of the IPCRC activities in this area are likely to accrue to natural ecosystems, which are not valued here. However, a number of examples of industry benefits from protection activities were identified in the workshop process and are described as follows.

Table 4.6 Adoption ceiling and lag estimates for with- and without-CRC scenarios by industry

	Adoption ceiling (%)			Adoption lags (years)		
Programs	**North**	**South**	**West**	**North**	**South**	**West**
Grains industry						
With-CRC						
– better herbicide resistance management	25	35	50	5	5	5
– crop systems research	40	50	70	10	10	10
– new technologies	50	50	50	5	5	5
Without-CRC						
– better herbicide resistance management	25	35	50	8	8	8
– crop systems research	30	40	60	15	15	15
– new technologies	50	50	50	5	5	5
Beef industry						
With-CRC						
– biological control	90	90	na	10	10	na
– unpalatable grasses and shrubs	40	25	na	10	10	na
– toxic and injurious plants	40	20	na	10	10	na
– grazing systems research	30	25	na	10	10	na
Without-CRC						
– biological control	90	90	na	30	30	na
– unpalatable grasses and shrubs	20	15	na	15	15	na
– toxic and injurious plants	20	15	na	15	15	na
– grazing systems research	20	15	na	15	15	na
Wool industry						
With-CRC						
– biological control	90	90	90	10	10	10
– unpalatable grasses and shrubs	20	20	40	10	10	5
– toxic and injurious plants	20	20	40	10	10	10
– grazing systems research	25	30	35	10	7	10
Without-CRC						
– biological control	90	90	90	30	30	30
– unpalatable grasses and shrubs	20	15	20	15	15	20
– toxic and injurious plants	20	20	20	15	15	15
– grazing systems research	20	25	25	20	10	15
Lamb industry						
With-CRC						
– biological control	90	90	90	10	10	10
– unpalatable grasses and shrubs	20	20	40	10	10	5
– toxic and injurious plants	20	20	40	10	10	10
– grazing systems research	25	30	35	10	7	10
Without-CRC						
– biological control	90	90	90	30	30	30
– unpalatable grasses and shrubs	20	15	20	15	15	20
– toxic and injurious plants	20	20	20	15	15	15
– grazing systems research	20	25	25	20	10	15

na – not applicable

Table 4.7 Research and development lag and probability of program success estimates, for with- and without-CRC scenarios, by industry

	R&D lag (years)			Probability of success (%)		
Programs	**North**	**South**	**West**	**North**	**South**	**West**
Grains industry						
With-CRC						
– better herbicide resistance management	5	5	5	80	70	70
– crop systems research	5	5	5	70	75	75
– new technologies	10	10	10	25	25	25
Without-CRC						
– better herbicide resistance management	10	10	10	80	70	70
– crop systems research	10	15	10	50	55	55
– new technologies	20	20	20	10	10	10
Beef industry						
With-CRC						
– biological control	4	4	na	70	70	na
– unpalatable grasses and shrubs	5	5	na	70	70	na
– toxic and injurious plants	5	4	na	70	70	na
– grazing systems research	5	5	na	60	70	na
Without-CRC						
– biological control	10	10	na	50	50	na
– unpalatable grasses and shrubs	6	6	na	50	60	na
– toxic and injurious plants	6	5	na	50	60	na
– grazing systems research	10	10	na	50	70	na
Wool industry						
With-CRC						
– biological control	4	4	4	70	70	70
– unpalatable grasses and shrubs	5	5	5	70	70	70
– toxic and injurious plants	5	4	5	70	70	70
– grazing systems research	5	5	5	60	70	70
Without-CRC						
– biological control	10	10	10	50	50	50
– unpalatable grasses and shrubs	6	6	10	50	60	50
– toxic and injurious plants	6	5	10	50	60	50
– grazing systems research	10	10	10	50	70	70
Lamb industry						
With-CRC						
– biological control	4	4	4	70	70	70
– unpalatable grasses and shrubs	5	5	5	70	70	70
– toxic and injurious plants	5	4	5	70	70	70
– grazing systems research	5	5	5	60	70	70
Without-CRC						
– biological control	10	10	10	50	50	50
– unpalatable grasses and shrubs	6	6	10	50	50	50
– toxic and injurious plants	6	5	10	50	50	50
– grazing systems research	10	10	10	50	50	50

na – not applicable

Pre-border benefits

It is anticipated that IPCRC activities will lead to a similar case as occurred at the CRCWMS for the weed Mexican feather grass, where this invasive plant was identified in gardens and nurseries and action was taken to eliminate the potential for spread from these sources. For this analysis it was assumed that the IPCRC would lead to an elimination of the threat of one new weed invasion that costs the grains industries and livestock industries, individually, $30 million per annum at full invasion. This was considered a conservative estimate given the number of invasive plants controlled and that the industry costs of minor weeds such as serrated tussock can be greater than $40 million per annum. The time taken to achieve steady state infestations are 20 years for cropping systems and 40 years for livestock. The workshop process defined that in the absence of the IPCRC there is a 20% probability of eliminating this exotic invasion, while with the IPCRC there is an 80% probability of success.

Post-border benefits

The benefits from control of post-border spread from sleeper weeds already present in Australia are likely to be considerably less than reducing spread from exotic invasive plants. In this case the assumed steady state infestation costs of spread of an existing weed are $5 million per annum (eg *Vulpia* spp.) for both the grains and livestock industries. The time paths to achieve this steady state are 10 years for grains and 20 years for livestock. The probability of success of eliminating spread are: grains industry – 60 and 30% (with- and without-CRC respectively) and livestock industries – 40 and 10% (with- and without-CRC respectively).

Reduced price discounts

Jones et al (2000) identified price discounts due to weeds in the grains industry of $25 million per annum. It was assumed that with-CRC such annual losses could be reduced by 2%, while in the without-CRC case these losses could be reduced by 1% annually. No benefits were attributed to reduced price discounts from IPCRC activities to reduce wool contamination.

Table 4.8 DREAM model parameters by region for grains, beef, wool and lamb industries

Region[a]	Price ($/t)	Price links[b]	Production quantity(kt)[c]	Consumption quantity (kt)[c]	Supply elasticity	Demand elasticity
Grains						
NSW	232	0.80	9,984	4,041	0.36	-2.20
Qld	232	0.80	1,755	375	0.36	-2.20
Vic	232	0.80	3,863	1,533	0.36	-2.20
SA	232	0.80	5,546	1,899	0.36	-2.20
WA	232	0.80	11,617	1,575	0.36	-2.20
ROW	232	0.80	827,388	850,734	0.50	-5.00
Beef						
NSW	3,130	0.80	475	296	1.00	-0.33
Qld	2,634	0.80	1,007	129	0.75	-0.27
Vic	3,223	0.80	363	171	1.00	-0.33
Tas	2,773	0.80	45	17	1.00	-0.33
SA	2,714	0.80	91	54	1.00	-0.33
WA south	2,550	0.80	50	50	1.00	-0.33
WA north	2,550	0.50	111	18	0.75	-0.27
NT	2,592	0.50	51	7	0.75	-0.27
Japan	5,110	0.70	457	1,207	0.70	-2.00
Korea	4,295	0.70	190	580	0.70	-2.00
US	4,016	0.80	11,762	12,268	1.00	-3.00
ROW	4,016	0.50	35,753	35,556	1.00	-5.00

Region[a]	Price ($/t)	Price links[b]	Production quantity(kt)[c]	Consumption quantity (kt)[c]	Supply elasticity	Demand elasticity
Wool						
NSW	6,500	0.80	232	3	0.80	-0.50
Qld	6,500	0.80	52	3	0.50	-0.50
Vic	6,500	0.80	123	3	0.50	-0.50
SA	6,500	0.80	82	3	0.50	-0.50
WA	6,500	0.80	147	3	0.50	-0.50
EU	6,500	0.80	177	346	0.50	-0.24
NZ	6,500	0.80	256	23	0.33	-0.47
USA	6,500	0.80	22	44	0.50	-0.50
China	6,500	0.80	281	329	0.80	-0.59
ROW	6,500	0.80	912	1,527	0.80	-0.35
Lamb						
NSW	3,489	0.80	90	58	1.38	-0.66
Qld	3,489	0.80	19	12	1.38	-0.66
Vic	3,489	0.80	142	90	1.38	-0.66
SA	3,489	0.80	45	21	1.38	-0.66
WA	3,489	0.80	46	29	1.38	-0.66
EU	3,489	0.80	826	1,105	0.67	-0.92
NZ	3,489	0.80	422	46	0.50	-0.25
USA	3,489	0.80	108	138	0.50	-0.50
China	3,489	0.80	1,339	1,425	0.30	-0.19
ROW	3,489	0.80	2,073	2,186	0.50	-0.26

[a] ROW – rest of world.

[b] adjustment factor to account for price linkages between regions.

[c] kilotonne.

4.3 Cost data

The costs associated for the with- and without-CRC scenarios are given in Table 4.9. The cash costs represent the commitments made by a number of organisations over the life of the IPCRC (as committed at the Stage 1 Business Case). It is assumed that in the absence of the IPCRC a number of these organisations would still fund weed research at some level, assumed to be 80% of the with-CRC level of funding. However, there are some organisations that would not fund Australian weed research without the Commonwealth grant contribution, hence in some cases the cash costs are zero for the without-CRC scenario.

The in-kind contribution costs are derived from an estimate of 40 full-time equivalent research officers at an average cost of $125,000 per annum and an overhead factor of 2.1 (data provided by the CRCAWM). For the without-CRC scenario it is assumed that 80% of these researchers would continue in weeds research. The costs in Table 4.9 are further disaggregated by the business unit for the with- and without-CRC scenarios.

4.4 Benefit-cost analysis data

The main data for the benefit-cost analysis (Table 4.10) include a discount rate of 4% and a 25-year time horizon commencing in the year 2008.

Table 4.9 Costs associated for the with- and without-CRC scenarios ($ million)

	With-CRC	Without-CRC
Cash costs		
Department of Education, Science and Training	30.000	0.000
Grains Research and Development Corporation	5.250	4.200
Australian Wool Innovation	0.700	0.560
Department of Primary Industries and Fisheries, Queensland	1.050	0.840
Meat and Livestock Australia	4.200	3.360
S. Kidman and Co.	0.030	0.000
Forests NSW	0.140	0.000
Department of Environment and Conservation, NSW	0.210	0.000
Department of Conservation, NZ	0.350	0.000
Corangamite Catchment Management Authority	0.010	0.000
Department of Environment and Conservation, WA	0.700	0.000
Charles Sturt University	0.350	0.000
Subtotal	43.020	8.960
In-kind contribution costs	**51.044**	**40.835**
Total cost	**94.064**	**49.795**
Breakdown of costs by business unit		
Business Unit 1	30.101	15.935
Business Unit 2	40.448	21.412
Business Unit 3	23.516	12.449

Table 4.10 Benefit-costs analysis parameters

Variable	Unit	Value
Base year for onset of benefits		2008
Period of BCA simulation	years	25
Real discount rate	%	4

5. Results of evaluations

5.1 Benefits from weed research

Measurement of total weed research benefits

The benefits from weed research were derived for each industry and research program (Table 5.1). These benefits comprise the gains in industry productivity and the effects of the R&D lag, adoption lag and adoption ceiling and the probability of success. The results were derived by discounting (at a rate of 4%) the annual stream of benefits over the 25-year period into a present day value.

The extra industry benefit attributable to the additional investment in the IPCRC has a present value (PV) of $1,830 million over the 25-year period (ie the net-CRC scenario). This represents the difference between the with-CRC scenario ($2,500 million) and the without-CRC scenario ($669 million) and is equivalent to the net social welfare gains that could result from funding the IPCRC. The main contributors to the marginal IPCRC industry benefit were the beef industry with $869 million, followed by the grains industry ($497 million) and the wool industry ($340 million).

The contributions of each research program to the industry benefit are given in Table 5.1. In the case of the grains industry the crop systems research program made the greatest net contribution to net-CRC industry benefit. For the livestock industries, the largest benefits were associated with the biological control and grazing systems research programs.

Table 5.1 Discounted industry benefits from weed research (PV $ million)

Industry	Without-CRC	With-CRC	Net-CRC
Grains			
– better herbicide resistance management	160.4	299.5	139.1
– crop systems research	35.9	294.3	258.5
– new technologies	0.3	99.4	99.1
Subtotal	196.5	693.3	496.7
Beef			
– biological control	29.0	368.2	339.2
– unpalatable grasses and shrubs	65.1	274.5	209.5
– toxic and injurious plants	22.6	79.7	57.1
– grazing systems research	120.5	383.4	262.9
Subtotal	237.1	1,105.8	868.7
Wool			
– biological control	0.0	126.5	126.5
– unpalatable grasses and shrubs	17.2	66.8	49.6
– toxic and injurious plants	15.8	62.7	46.9
– grazing systems research	134.9	251.3	116.4
Subtotal	167.8	507.3	339.5
Lamb			
– biological control	0.0	50.3	50.3
– unpalatable grasses and shrubs	7.8	26.2	18.4
– toxic and injurious plants	6.5	21.5	15.0
– grazing systems research	53.4	95.1	41.7
Subtotal	67.7	193.1	125.4
Industry benefit from weed research	669.2	2,499.5	1,830.3

The marginal benefits associated with the IPCRC Protection business unit activities were estimated to be $262 million (Table 5.2). This benefit value was comprised of pre-border activities ($230.2 million), post-border activities ($28.9 million) and price discounts ($2.6 million).

The total discounted marginal benefit from investment in the IPCRC is therefore $2,092 million, being the sum of $1,830 million (from Table 5.1) and $262 million (from Table 5.2). Without investment in the IPCRC, on-going weed research would yield a benefit of $753 million, however funding of the IPCRC would increase the discounted benefit from weed research to $2,845 million.

Disaggregation of marginal industry benefits by region, producers and consumers

The industry benefits given in Table 5.1 were disaggregated into the benefits to each Australian state and territory (Table 5.3). The largest beneficiary of the IPCRC investment is Queensland ($467 million), closely followed by New South Wales ($435 million) and Western Australia ($389 million). The international spill-over benefits are relatively small ($67 million), representing 3.6% of the total industry benefit. Therefore, most of the benefits from the IPCRC will accrue to Australian producers and consumers.

The impact of weeds research across producer and consumer groups in Australia and overseas is further explored in the results of Table 5.4. The marginal change in producer surplus from the investment in the IPCRC is a total gain of $1,213 million, comprised of a gain of $1,751 million to Australian producers and a loss of $537 million to international producers. The IPCRC is estimated to result in a gain in consumer surplus of $617 million, comprised of $13 million to Australian consumers and $604 million to international consumers.

The total gain in economic surplus (or industry benefit) was $1,830. The breakdown in the share of this benefit was 66% to producers and 34% to consumers.

Table 5.2 Discounted protection benefits from weed research (PV $ million)

	Without-CRC	With-CRC	Net-CRC
Pre-border			
– grains industries	47.8	191.3	143.5
– livestock industries	12.4	99.1	86.7
Post-border			
– grains industries	16.9	33.8	16.9
– livestock industries	4.0	15.9	12.0
Price discounts			
– grains industries	2.6	5.1	2.6
– livestock industries	0.0	0.0	0.0
Protection benefit from weed research	**83.7**	**345.2**	**261.6**

Table 5.3 Regional disaggregation of weed research benefits (PV $ million)

Region	Without-CRC	With-CRC	Net-CRC
New South Wales	179.2	614.5	435.3
Queensland	118.9	585.7	466.8
Victoria	125.6	410.5	284.9
South Australia	69.3	221.7	152.4
Western Australia	133.9	522.5	388.5
Tasmania	4.7	19.1	14.4
Northern Territory	5.2	26.6	21.3
Rest of world	32.4	98.9	66.5
Total	**669.2**	**2,499.5**	**1,830.3**

Table 5.4 Disaggregation of weed research benefits between producers and consumers (PV $ million)

Region	Without-CRC	With-CRC	Net-CRC
Producers' surplus			
– Australian	630.8	2,381.3	1,750.5
– international	-230.6	-767.9	-537.3
Subtotal	400.3	1,613.4	1,213.1
Consumers' surplus			
– Australian	6.0	19.3	13.3
– international	262.9	866.8	603.9
Subtotal	268.9	886.1	617.1
Economic surplus	**669.2**	**2,499.5**	**1,830.3**

Disaggregation of industry benefits into adoption and research components

The total industry benefit value of $1,830 million represents the benefit attributable to the combined Business Units 1 and 2 and is based on the gains in productivity and the effects of the reduced R&D lag, enhanced adoption (shorter lag and higher adoption ceiling) and greater probability of project success. By disaggregating the benefits into higher productivity, R&D lag and enhanced adoption it is then possible to allocate these benefits specifically to either Business Unit 1 (enhanced adoption) or Business unit 2 (increased productivity, reduced R&D lag). The benefits from Business Unit 3 ($262 million) are already separately identified in Table 5.2.

The benefits were disaggregated by re-solving the DREAM model for specific enhanced adoption (the combined effects of adoption lag and adoption ceiling) and R&D lag scenarios. To measure enhanced adoption the model was solved for the without-CRC adoption lag and adoption ceiling parameter values, with all other model parameters held at the with-CRC values. The difference in the benefit value between this scenario and the base with-CRC simulation represented the benefit of improved adoption. This process was repeated for each industry and each research program. The benefits of a reduced R&D lag were estimated in a similar manner, where the without-CRC R&D lag values were simulated with all other parameter values held at the with-CRC levels. The increased productivity benefit (including the higher probability of success) was calculated as the residual between the with-CRC scenario and the benefits from enhanced adoption and reduced R&D lag.

The resulting disaggregated benefits (Table 5.5) were enhanced adoption $1,036 million, reduced R&D lag $640 million and increased productivity ($154 million). The enhanced adoption benefit was associated with Business Unit 1, while the combined values of the increased productivity and reduced R&D lag ($794 million) were associated with Business Unit 2.

It is likely that the IPCRC Production systems business unit also has some share of the estimated adoption benefits, due to the nature of the proposed participatory research resulting in more targeted research and greater awareness by industry of the problems and solutions – hence higher ceiling rates of adoption and reduced adoption lag.

There were significant differences between the industries in terms of the contribution of enhanced adoption, reduced R&D lag and increased productivity towards

Table 5.5 Economic benefit of IPCRC disaggregated into enhanced adoption, reduced research and development lag and increased productivity (PV $ million)

Industry	Enhanced adoption	Reduced R&D lag	Increased productivity	Total
Grains	133.3	303.3	60.1	496.7
Beef	595.4	185.7	87.6	868.7
Wool	225.1	109.6	4.8	339.5
Lamb	82.1	41.7	1.6	125.4
Total	**1,035.9**	**640.3**	**154.1**	**1,830.3**

the total industry IPCRC benefits. Improved adoption accounted for $133 million (27%) of the grains industry benefit, whereas for the livestock industries the contribution of this factor was $595 million (69%) for beef, $225 million (66%) for wool and $82 million (65%) for lamb. The small productivity gains for the livestock industries from the IPCRC investment in Table 5.5 reflect the conservative assumptions made in the analysis whereby the improved livestock productivity from improved weed management was equally shared across the three industries.

A more detailed disaggregation of the adoption, research and productivity benefit components is presented in Table 5.6, where the contributions of each research program are estimated.

Changes to the adoption and research lag matters in the analysis of IPCRC benefits because the benefits are discounted over time. Thus time, as measured by the lags, has a major effect on the benefit levels. Speeding up both the research lag and adoption lag process means that the benefits and costs in the short term have a greater value than benefits and costs in the long term. The level of adoption also matters because the benefits from a technology are directly related to the size of the market that takes it up. Therefore, raising the adoption ceiling will result in greater economic benefits.

Industry benefit streams over time

The annual research program benefit streams derived from the DREAM model simulations over the 25-year evaluation period for the with- and without-CRC scenarios were aggregated for each industry (Figure 5.1). This illustrates that for each industry considered there was a positive impact by the IPCRC on both the ceiling level of industry benefit and the speed of achieving these benefits. Using the wool industry as an example, the ceiling level of weed research benefits were increased from around $35 million per annum to around $60 million per annum. In the case of the without-CRC scenario the maximum wool industry benefit was achieved in the year 2027 (a 19 year lag) whereas the with-CRC scenario resulted in the maximum industry benefit occurring in

Table 5.6 Economic benefit of IPCRC disaggregated into enhanced adoption, reduced research and development lag and increased productivity for each research program (PV $ million)

Industry	Enhanced adoption	Reduced R&D lag	Increased productivity	Total
Grains				
– better herbicide resistance management	32.4	99.5	7.2	139.1
– crop systems R&D	101.0	122.9	34.6	258.5
– new technologies	0.0	80.8	18.3	99.1
Subtotal	133.3	303.3	60.1	496.7
Beef				
– biological control	214.6	84.6	40.0	339.2
– unpalatable grasses/shrubs	156.0	11.2	42.3	209.5
– toxic/injurious plants	37.3	3.9	15.9	57.1
– systems research for grazing	187.4	86.0	-10.5	262.9
Subtotal	595.4	185.7	87.6	868.7
Wool				
– biological control	87.3	27.9	11.3	126.5
– unpalatable grasses/shrubs	32.2	5.0	12.4	49.6
– toxic/injurious plants	23.2	7.3	16.5	46.9
– systems research for grazing	82.4	69.4	-35.4	116.4
Subtotal	225.1	109.6	4.8	339.5
Lamb				
– biological control	34.8	11.1	4.5	50.3
– unpalatable grasses/shrubs	11.8	1.8	4.9	18.4
– toxic/injurious plants	6.6	2.2	6.1	15.0
– systems research for grazing	28.9	26.7	-13.9	41.7
Subtotal	82.1	41.7	1.6	125.4
Total	**1,035.9**	**640.3**	**154.1**	**1,830.3**

the year 2020 (a 12 year lag). Due to the effects of discounting, bringing forward the benefits from weeds research along with increasing the benefit level, results in a significant economic benefit.

The total weed research benefit streams from all business unit activities (including protection) are illustrated in Figure 5.2. The inclusion of the protection research program benefit streams results in an increase in the annual benefits after 2020 for the with-CRC scenario, whereas the industry benefits are relatively constant after this period for this scenario.

The annual benefit streams for the net-CRC scenario illustrate two key features of the investment in the IPCRC:

(i) it brings forward in time the benefits from weed research

(ii) it results in an increase in the industry ceiling benefits.

The decline in annual benefits after 2020 for the net-CRC scenario reflects the situation that benefits from the without-CRC are still increasing (because they are delayed over time) and that the annual benefits from the with-CRC scenario have approached an equilibrium.

The temporal weed research benefits given in Figures 5.1 and 5.2 allow the derivation of discounted benefits for shorter periods than the 25-year evaluation period. For instance, over the 7- year life of the CRC (2008 to 2014) the discounted benefits were calculated as follows:

- with-CRC $101.1 million
- without-CRC $10.5 million
- net-CRC $90.6 million.

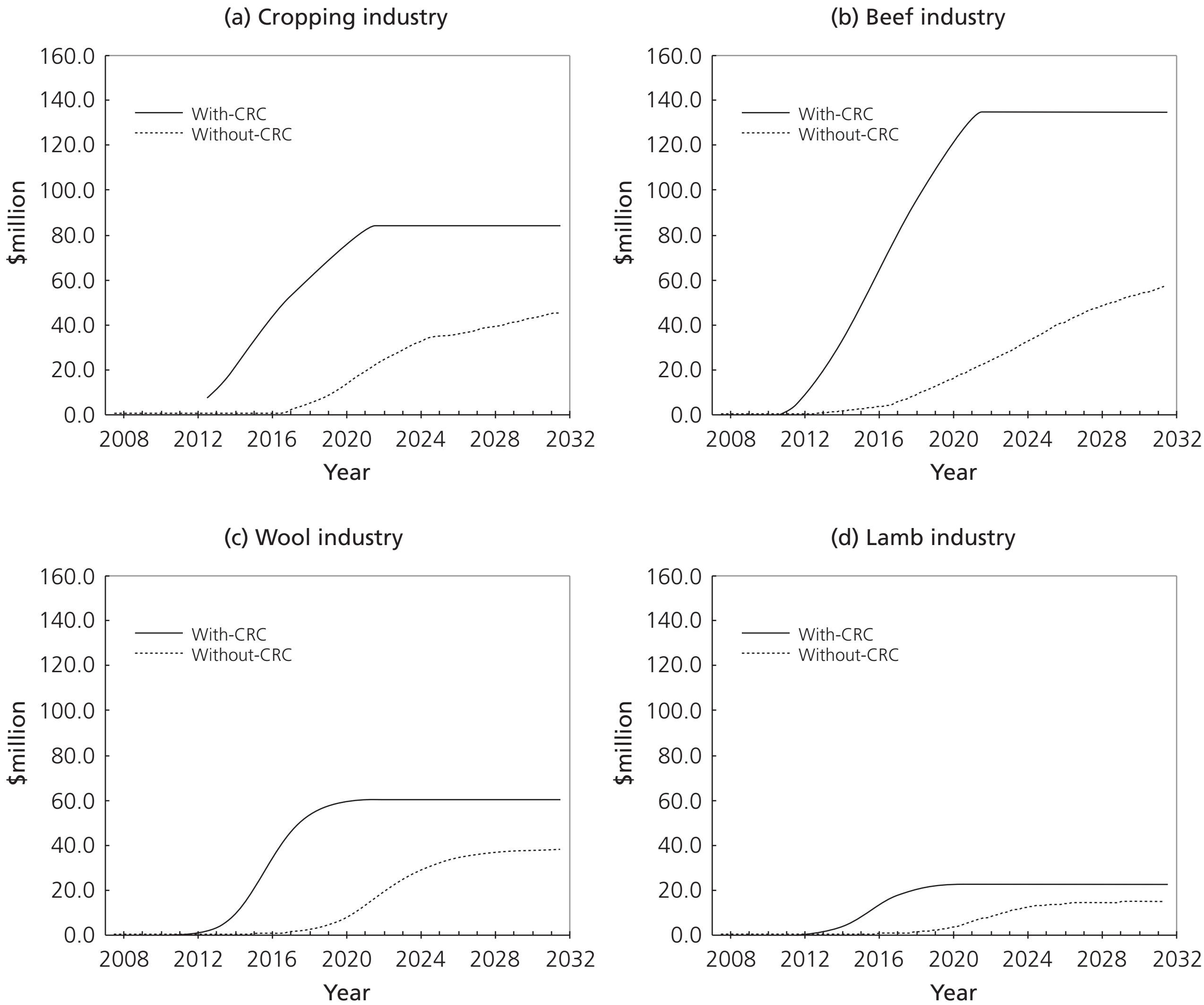

Figure 5.1 Annual benefits by industry for with- and without-CRC scenarios

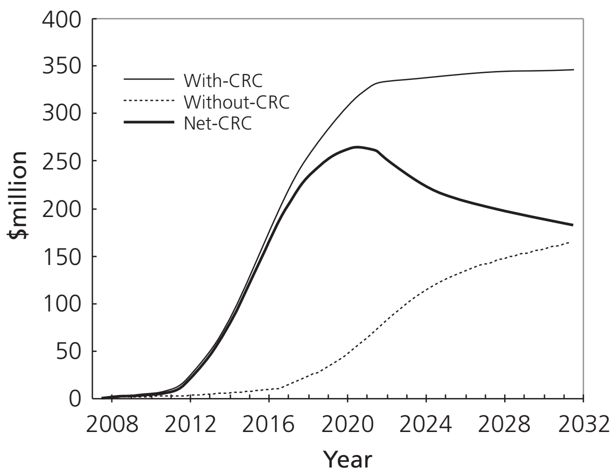

Figure 5.2 Annual total industry benefits for with-, without- and net-CRC scenarios

5.2 Benefit-cost analysis of weed research

The benefit-cost analysis is undertaken for the full IPCRC activities (Table 5.7). This analysis considers all costs and benefits of the with- and without-CRC scenarios and determines the marginal return on the IPCRC investment. The DREAM model simulations provided the NPV of benefits over the 25-year evaluation period, which were included with the annual series of cost data from section 4.3 into the benefit-cost analysis framework to obtain the investment criteria.

The without-CRC scenario indicates that satisfactory benefits and returns on investment can be obtained from ongoing weed research with a discounted net benefit, or NPV, of $710 million and a BCR of 18:1. The with-CRC scenario results in substantially greater returns (BCR 35:1) and net benefits (NPV $2,764 million). The marginal impact of investment in the IPCRC is given by the net-CRC results, with measures of NPV of $2,054 million and a BCR of 55:1.

The relatively large NPVs and BCRs derived in Table 5.7 are a result of:

(i) the size of the weed problem in Australia

(ii) the increases in productivity that occur in agriculture which is a large industry

(iii) weeds research is very effective in terms of the short time required for biological responses to new technology, as reflected in the adoption lags.

The benefit-cost analysis was also undertaken at the business unit level (Table 5.8). This analysis was only reported for the net-CRC scenario. Business Unit 1 (Integrating people, products and delivery) has the largest benefits and NPV ($1,024 million), accounting for 50% of the total NPV derived from investment in the IPCRC. This business unit also generates a very high rate of return represented by a BCR of 85:1.

Business Unit 2 (Production systems) also gives a high return on investment, with a BCR of 49:1. The NPV ($778 million) from this unit accounts for 38% of the total IPCRC net benefit.

Finally, despite not being as large as the other two business units, Business Unit 3 (Protection) also provides a high return on investment reflected by the BCR of 20:1 and a NPV of $248 million. The lower returns from Business Unit 3 are simply a reflection of the longer time lags required to achieve the CRC benefits compared to Business Units 1 and 2.

Sensitivity analysis

The benefit-cost analysis was extended to estimate the impact of higher discount rates (ie 7%) on the results. This led to a reduction in the BCR for the without-, with- and net-CRC scenarios to 11:1, 25:1 and 40:1 respectively.

The benefit-cost analysis of the IPCRC can also be undertaken in a partial manner by considering only the benefits and costs incurred over the 7-year life of the CRC. Although this excludes a large proportion of the relevant benefits from weeds research, it allows an examination of the short-term returns from such investments. This reveals that the IPCRC can provide a positive return within the life of the CRC with a NPV of $53 million (Table 5.9). A BCR of 2.39:1 from the net-CRC scenario, although considerably lower than the full BCR, indicates a positive return on investment within the life of the CRC, which can thereby be considered to have repaid the additional investment made from weed research within this period.

Table 5.7 Benefit-cost analysis of the IPCRC

	Without-CRC	With-CRC	Net-CRC
Present value of benefits ($m)	753	2,845	2,092
Present value of costs ($m)	43	81	38
Net present value ($m)	710	2,764	2,054
Benefit-cost ratio	18:1	35:1	55:1

Table 5.8 Benefit-cost analysis of the business units of the IPCRC

Business Unit	Value
Business Unit 1: Integrating people, products and delivery	
Present value of benefits ($m)	1,036
Present value of costs ($m)	12
Net present value ($m)	1,024
Benefit-cost ratio	85:1
Business Unit 2: Production systems	
Present value of benefits ($m)	794
Present value of costs ($m)	16
Net present value ($m)	778
Benefit-cost ratio	49:1
Business Unit 3: Protection	
Present value of benefits ($m)	262
Present value of costs ($m)	13
Net present value ($m)	248
Benefit-cost ratio	20:1

Table 5.9 Restricted benefit-cost analysis of the IPCRC to the 7-year life of the CRC

	Without-CRC	With-CRC	Net-CRC
Present value of benefits ($m)	11	101	91
Present value of costs ($m)	43	81	38
Net present value ($m)	-32	20	53
Benefit-cost ratio	0.25:1	1.25:1	2.39:1

6. Summary

In this evaluation a top-down approach was used to estimate the expected economic benefits of the proposed research programs of the IPCRC. This involved specifying appropriate with- and without-CRC scenarios to account for opportunity costs, identifying differences in the underlying rate of productivity growth in relevant industries, adoption rates and lags and the probability of success of individual research programs. The industries considered relevant to the IPCRC evaluation are grains, beef, wool and sheep-meat. The DREAM research evaluation program (Wood et al 2001) was selected as the appropriate modelling framework. The horizontal multi-market model option was adopted in DREAM, which allows evaluation of the economic impact of a new technology where the product is (relatively) freely traded across a number of regions (Alston et al 1995). The weed research benefits estimated by the DREAM model for with- and without-CRC scenarios were then incorporated into a benefit-cost analysis model which determined net present values (NPV) and benefit-cost ratios (BCR) for these separate scenarios as well as the marginal impact of investment in the proposed IPCRC (ie net-CRC).

Peer-reviewed methodologies and published data were used where-ever possible. In addition, some parameter values were developed through a consensus data approach in a formal workshop situation using the expert opinions of experienced weeds research and advisory staff.

The investment in the proposed IPCRC is shown to provide a high return on public expenditure. Investing $30 million of taxpayer funds into the IPCRC will leverage a further $64 million of in-kind and cash contributions from research providers and generate an additional $2,071 million in discounted benefits to the broader Australian grains, beef, wool and sheep-meat industries.

The estimated annual benefit streams from weed research indicate the two key features of the investment in the IPCRC:

(i) it brings forward in time the benefits from weed research

(ii) it results in an increase in the industry ceiling benefits.

As well as those benefits accruing to domestic producers and consumers (some 96% of the total benefits), there will be additional economy-wide benefits as calculated by macroeconomic models such as the MONASH model. For agricultural industries, these multipliers are typically in the range of 40% to 60% of the relevant industry benefits (Griffith 2006). Therefore these results satisfy criteria 1 as the IPCRC can confidently claim that it can contribute substantially to Australia's economic growth through the generation of benefits to the grains, beef, wool and lamb industries and to the wider economy.

The estimated marginal BCR of 55:1 from the IPCRC investment represents a high return to the investment thus representing good value for the taxpayer and consequently satisfies criteria 4. Almost all of the potential benefits of the IPCRC would accrue to Australian producers and consumers, further justifying the investment of Australian taxpayer's funds.

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