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NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Sheep CRC Renewal Proposal: Economic Evaluation of the Proposed Scientific Themes

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Abstract

The Australian sheep industry and its associated research and development agencies have developed a proposal for the CRC for Sheep Industry Innovation. "Top-down" and "bottom-up" procedures were used to assess the expected economic benefits from this proposal. Formal "with-CRC" and "without-CRC" scenarios were defined for each product and each research theme. Relevant costs were similarly defined. The requested investment by the Commonwealth and the Australian sheep industry in the CRC is assessed relative to a scenario where an alternative, lower cost research program into this industry is implemented. These extra resources have a discounted value of about $34 million over the 25-year period of this evaluation. These resources are sufficient to allow some new research components to be added to the portfolio, some existing components to produce better outcomes, and a more targeted approach to development and extension that speeds up and increases the adoption of the new technologies that are generated by the research program. The benefit from this extra investment and consequent research effort is estimated to be worth about $518 million in present value terms, which is far in excess of the marginal investment. Thus every $1 of these extra resources brought into the Australian sheep industry through funding the proposed CRC is expected to return around $15.30 to the industry in present value terms.

Keywords: wool; sheep meat; research and development; economic; evaluation; Australia

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Acronyms and Abbreviations Used in the Report

ABARE	Australian Bureau of Agricultural and Resource Economics
ARC	Australian Research Council
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio, defined as the ratio of discounted benefits to discounted costs
Beef CRC	Cooperative Research Centre for Beef Genetic Technologies
Consumer surplus	A measure of economic welfare change affecting consumers, defined as the area below the demand curve and above the price line
DREAM	**D**ynamic **R**esearch **E**valu**A**tion for **M**anagement model
EDM	Equilibrium displacement model
Elasticity (price)	An economic measure of supply or demand response to a price change, defined as the percentage change in quantity supplied or demanded for a one per cent change in price
NPV	Net present value, defined as the difference between discounted benefits and discounted costs
Producer surplus	A measure of economic welfare change affecting producers, defined as the area above the supply curve and below the price line
R&D	Research and Development
Sheep CRC	Australian Sheep Industry Cooperative Research Centre
TFP	Total factor productivity

Executive Summary

The Australian sheep industry and its associated research and development agencies have developed a proposal for submission to the Commonwealth government for the refunding of the Australian Sheep Industry Cooperative Research Centre (Sheep CRC1). This new CRC is referred to as the CRC for Sheep Industry Innovation (or Sheep CRC2). There are three proposed research programs: Productive Sheep and their Management, Wool Quality, and Meat Quality. There are also a Communication and Utilisation program, an Education and Training program, an Administration program, and an industry-based sheep resource known as the Information Nucleus. Funding is sought for a second seven-year term to commence in 2007/08, overlapping by one year the completion of the term of Sheep CRC1.

The main accountability criteria on which the Commonwealth will assess the funding proposal for Sheep CRC2 are: (a) that Sheep CRC2 has the potential to generate sound returns to all stakeholders from the public and private funding that is being sought relative to the costs, and, (b) that the research outcomes of Sheep CRC2 will contribute substantially to Australia's industrial, commercial and economic growth. In this Report we provide an assessment of this impact.

Following successful applications to other CRC renewal bids, a 'top-down' method was initially proposed to evaluate the research themes of Sheep CRC2. The basic requirements are to examine the overall rates of productivity growth in the sheep industry, to assess the role of technological change in generating this growth and to estimate the likely improvements in this growth due to the activities of Sheep CRC2. That is, the initial plan was to evaluate the Sheep CRC2's proposed research as an overall investment package, since most of the production-based projects are grouped into program themes or clusters of projects and thus have similar objectives. Subsequently, once the structure of the various research themes became clear, it was decided to treat Theme 2 separately since this was now defined more like a very specific research project that had little interaction with Themes 1 and 3. Theme 3 was also treated as an individual project given that there was a particularly detailed biological justification for the proposed research which suggested that this Theme could be modelled separately. The various sub-themes within Theme 1 were still evaluated using the "top-down" methodology.

Formal "with-CRC" and "without-CRC" scenarios were defined for each product and each research theme with the assistance of Sheep CRC research managers, research staff and advisory staff in a workshop situation. Relevant costs were similarly defined.

The economic welfare change and benefit-cost analysis calculations were made using the DREAM model (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 widely used for research evaluation by major world and Australian agricultural research funding agencies. The required parameter values include equilibrium prices and quantities, supply and demand elasticities, supply and/or demand shifts, probabilities of success, R&D lags, adoption rates and adoption lags. In implementing the DREAM model for this assessment, the national Australian market was considered as one region and China, the European Union, New Zealand, the United States and the rest of the

world (ROW) were defined as the international regions to represent Australia's main customers and competitors in the world wool and sheep-meats markets.

In the benefit-cost analyses, the fixed costs of the Communication and Utilisation program, the Administration program, and the Information Nucleus were allocated pro-rata across the three R&D programs.

Under the *with-Sheep CRC2* scenario, the total PV of the estimated benefits from the three research themes is about $1.3 billion over the 25-year period of the BCA simulation. The corresponding NPV is $1.2 billion and the BCR is 15:1 where the present value of the full costs of the investments in these Sheep CRC2 programs, plus the pro-rata allocation of the full costs of Programs 4, 5 and 7, (nominally $100 million) is $89 million when discounted over the simulation period. Without funding of Sheep CRC2, the present value of the total estimated benefit is $820 million over 25 years. Total costs have a present value of around $55 million (including the total costs of Programs 4, 6 and 7 under the without scenario), so the NPV is $765 million and the BCR is just under 15:1.

The main concern in this evaluation is the difference in the BCA results between the *with-* and *without-Sheep CRC2* scenarios, i.e., the marginal returns from the marginal investment. Under the assumptions made in this evaluation, the investment by the Commonwealth and the Australian sheep industry in Sheep CRC2 is relative to a scenario where an alternative, lower cost research program into this industry is implemented. These extra resources have a discounted value of about $34 million over the 25-year period of this evaluation. These resources are sufficient to allow some new research components to be added to the portfolio, some existing components to produce better outcomes, and a more targeted approach to development and extension that speeds up and increases the adoption of the new technologies that are generated by the research program. The benefit from this extra investment and consequent research effort is estimated to be worth about $518 million in present value terms, which is far in excess of the marginal investment. Thus every $1 of these extra resources brought into the Australian sheep industry through funding the proposed Sheep CRC2 is expected to return around $15.30 to the industry in present value terms. Investing in the CRC brings forth a higher return than if the investment was not made.

Disaggregating the estimates by region and market group shows that almost two-thirds of the anticipated benefits from Sheep CRC2 will be claimed by Australian sheep producers and Australian consumers of sheep products. These benefits are valued at $824 million at the anticipated maximum adoption levels for the Sheep CRC2 technologies, indicating significant potential payoffs to Australia from the investment in Sheep CRC2. Sheep producers will receive most of this, some $796 million, because they have direct access to the new technologies. Australian wool and lamb consumers and consumers in Australia's sheep export markets also benefit to varying proportions from being able to access more product at lower prices resulting from supply-increasing technologies.

Disaggregating the estimates by type of impact shows that more than $300 million can be attributed to the proposed accelerated adoption program of Sheep CRC2. This is some 22 per cent of the total estimated benefit.

1. Introduction

The Australian sheep industry and its associated research and development agencies have developed a proposal for submission to the Commonwealth government for the refunding of the Australian Sheep Industry Cooperative Research Centre (Sheep CRC1). This new CRC is referred to as the CRC for Sheep Industry Innovation, or Sheep CRC2 in its abbreviated form.

Sheep CRC2 is proposing a program of research that involves three broad themes:
Theme 1: Productive Sheep and their Management
- 1.1: Integrated wool production packages
- 1.1: Integrated sheep meat production packages
- 1.2: Improved lamb and weaner survival in wool
- 1.2: Improved lamb and weaner survival in meat
- 1.3: Reduced chemical use in wool
- 1.3: Reduced chemical use in meat

Theme 2: Wool Quality: Increased wool demand
Theme 3: Meat Quality: Increased lean meat yield and enhanced nutrition attributes.

The proposed themes are designated by these numbers throughout the economic evaluation that is described in the following sections. As well, there is a Communication and Utilisation program, an Education and Training program, an Administration program, and an industry sheep resource known as the Information Nucleus. Funding is sought for a second seven-year term to commence in 2007/08, overlapping by one year the completion of the term of Sheep CRC1.

As was the case with Sheep CRC1, Sheep CRC2 represents a rural research consortium that is based on inputs of resources and personnel from universities, governments and private industry. The main objective of Sheep CRC1 was to develop new technologies, management practices and marketing strategies to enable the sheep industry to become more profitable and sheep products more highly valued by consumers. The scientific research undertaken by Sheep CRC1 comprised a group of programs that related to most aspects of Australian sheep production, marketing and technology transfer. The total value of the research program was around $90 million, with about two-thirds of this as in-kind contributions made by the collaborating agencies. Two production science programs focussed on genetics, wool and meat science, parasite management, nutrition and on the development of electronic identification technologies for individual animal management. These research activities varied from new areas of research to expediting other research that was being developed before the advent of Sheep CRC1. Other programs were concerned with communication and extension, knowledge management and education and training.

A recent economic evaluation concluded that the science programs of Sheep CRC1 had the potential to generate significant economic benefits to the Australian sheep industry (Vere *et al.* 2005). With-CRC and without-CRC situations were specified and modelled. A summary of the net benefit-cost analysis outcomes of that evaluation is given in Table 1. The total marginal or incremental benefit that could be attributed to this research had a net present value of $191.3 million and a benefit-cost ratio of 8.1:1 (projected over 20 years and discounted at 5 per cent real). Based on the benefits to the science programs, it was estimated that the total research investment by Sheep CRC1 over all programs could return about $8 for every $1 of public and private funds invested (Table 1). This benefit resulted from the

differences in the expected impacts of the program research areas on productivity growth in the sheep industry, from the differences in the expected adoption profiles for the programs' technologies, and from differences in the research costs under the two evaluation scenarios.

Table 1. Summary of net benefit-cost outcomes for Sheep CRC1 science programs

Science program area	Present value of benefits ($m.)	Present value of costs ($m.)	Net present value ($m.)	Benefit-cost ratio ($:1)
Genetics	62.115	3.534	58.581	
Wool Science and Production	35.050	4.872	30.178	
Meat Science	35.418	5.882	29.536	
Parasite Management	52.143	4.940	47.203	
Strategic Nutrition	10.655	3.194	7.461	
Individual Animal Management	23.023	4.689	18.334	
Total net outcome	**218.403**	**27.111**	**191.292**	**8.06**

Source: Vere *et al.* (2005). Figures are net present values discounted at a 5 per cent real rate over 20 years.

The research proposed under Sheep CRC2 seeks both to expand on the research achievements of Sheep CRC1, and to investigate new areas that have previously received little research attention. The main accountability criteria on which the Commonwealth will assess the funding proposal for Sheep CRC2 are:

- that Sheep CRC2 has the potential to generate sound returns to all stakeholders from the public and private funding that is being sought relative to the costs, and,
- that the research outcomes of Sheep CRC2 will contribute substantially to Australia's industrial, commercial and economic growth.

These assessment criteria highlight the need for the rigorous evaluation of the potential benefits of the research that is being proposed by Sheep CRC2. Our objective here is to provide such an assessment of this impact.

2. Evaluation Methods

2.1 Assessment Philosophy

The research problem addressed in this evaluation is the measurement of the long-term net benefits from the proposed program of research in Sheep CRC2. This requires the definition of appropriate 'with-CRC' and 'without-CRC' scenarios. Alston *et al.* (1995) note that defining the relevant scenarios is potentially one of the most useful parts of the research evaluation process, but also that it is often difficult because many evaluations are concerned with on-going, rather than completely new, research programs. Our emphasis is to measure the *marginal* or *incremental* benefits that could be generated by Sheep CRC2, where it is recognised that there has been a long history of research that has resulted in substantial productivity improvements in the Australian sheep industry. Some of this past research has been in areas that are similar to the proposed themes, and so there have been past and will be future benefits from these other programs. Also, genetics is a major part of the technologies under investigation and so the impacts of adopting such technologies are spread out over a long time period and the impacts accumulate over time. Thus the benefits of future productivity improvements cannot be claimed to be totally due to the research proposed by Sheep CRC2 since they will partly comprise the benefits of past investments. The estimated benefits from Sheep CRC2's proposed research themes will therefore be net of the expected benefits from past research that has yet to have an impact, and net of the expected benefits from other research that it is assumed would continue to be funded if Sheep CRC2 was not funded. This measure of economic benefit therefore represents the marginal return to all participants in the sheep industry from the additional investment attributable to the Sheep CRC2 funding proposal.

After Griffith *et al.* (2004), the benefits of Sheep CRC2 could fall into three possible areas:

- genuinely new research outputs, that would not have been generated without Sheep CRC2 funding (i.e., completely new technologies);
- enhanced research outputs, that would have significantly greater impact than those outputs generated by an alternate research program undertaken by the same researchers and agencies but without Sheep CRC2 funding (i.e., better technologies); and
- significantly improved development and extension of research outcomes based on the findings of past or new research that increases the value of the information available for industry decision-making, beyond what would have been possible without the funding of Sheep CRC2 (i.e., faster and/or more widespread adoption of profitable technologies).

Based on these definitions, two broad evaluation scenarios were defined:

- the *with-Sheep CRC2* scenario representing an expansion of the research investment in the Australian sheep industry following the winding-up of CRC1, and
- the counterfactual *without-Sheep CRC2* scenario representing a continuing research investment at a lower level of funding similar to that in place before CRC1.

This meant that the main effects of the proposed research themes were assumed to be to increase the quantity and/or intensity of sheep-related research and to bring forward the delivery of new technologies to the sheep industries. This outcome is assumed to be achieved by Sheep CRC2 providing additional research funding and by strengthening the existing collaborative links between the research institutions (Griffith *et al.* 2004). The potential benefits to investment in Sheep CRC2 were estimated on this basis.

2.2 Evaluation Context

The two broad contexts in which this evaluation could be undertaken were either to evaluate proposed individual projects or to evaluate proposed projects as groups within separate programs. The first context involves the use of a 'bottom-up' method by which the proposed projects are evaluated individually and the expected benefits from each project are aggregated over the full research program. The main problem with this method in the context of a CRC is that many project outcomes will be highly interrelated where they share resources or where one program's outputs provides inputs into another. It can then be very difficult to properly allocate costs across projects and equally difficult to apportion benefits to the separate projects.

The second context involves the use of a 'top-down' method that is designed to provide a benchmark or conservative estimate of the impact of research funding on productivity growth. This method follows one that was adopted for an economic evaluation of the research funding programs of the Australian Research Council (ARC) by the Allen Consulting Group (2003) and more recently of the CRC program in general by the same agency (Allen Consulting Group 2005). Implementing this method in the ARC evaluation depended on being able to determine the extent to which all public and private research in the economy contributed to productivity growth, the contribution to productivity growth made by publicly-funded research in Australia, and the share of the impacts of that contribution that could be attributed to ARC-funded research. It was stated that the purpose of using a 'top-down' method was mainly to provide a plausible order of magnitude of the impact of research funding.

Griffith *et al*. (2004) first applied this procedure to evaluating the economic benefits of a proposed CRC, and this 'top-down' method was initially proposed to evaluate the research themes of Sheep CRC2. The basic requirements are to examine the overall rates of productivity growth in the sheep industry, to assess the role of technological change in generating this growth and to estimate the likely improvements in this growth due to the activities of Sheep CRC2. That is, the initial plan was to evaluate the Sheep CRC2's proposed research as an overall investment package, since most of the production-based projects are grouped into program themes or clusters of projects and thus have similar objectives.

Subsequently, once the structure of the various research themes became clear, it was decided to treat Theme 2 separately since this was now defined more like a very specific research project that had little interaction with Themes 1 and 3. Theme 3 was also treated as an individual project as there was a particularly detailed biological justification for the proposed research available which suggested that this Theme could be modelled separately. The various sub-themes within Theme 1 were still evaluated using the "top-down" methodology.

2.3 Modelling Methods

The potential economic benefits to the proposed research programs of Sheep CRC2 were estimated using the well-recognised partial equilibrium measures of economic welfare change that result where the adoption of new technology across an industry results in shifts in supply (Alston *et al.* 1995). Economic welfare is improved when new technologies generate increases in industry productivity, where the size of this benefit is proportional to the reductions in production costs. Increases in the willingness of consumers to pay for desired attributes of wool or sheep

meat can be modelled in the same way an increase in a demand curve. Important considerations in this process are the distribution of this benefit, measured in terms of economic welfare change, between the main social groups of producers and consumers, and between domestic and overseas markets.

The potential benefits from each of the Sheep CRC2 research themes were evaluated in terms of the annual changes in economic welfare that could result from the generation and increased adoption of new technologies, as specified in each themes' target outcomes, in the relevant component of the sheep industry (wool, or sheep-meat). The benefits include the effects of estimated production increases and reduced production costs (producer benefit) and reduced commodity prices (consumer benefit), and provide the measures of potential benefits that were then evaluated in an *ex ante* benefit-cost analysis (BCA) context, where the benefits were forecasts of the potential payoffs to the Sheep CRC2's investment. Benefits were assumed to commence after the time of the combined R&D and adoption lags and were converted to net present values (NPVs) and benefit-cost ratios (BCRs) at a 4 per cent real discount rate over a 25-year period.

Research costs were derived from the managers of the CRC rebid process and included estimates of all direct grants and in-kind contributions from the collaborating agencies. These costs were estimates of the cash and the value of in-kind contributions (based on the DEST valuation guidelines) that were expected by Sheep CRC2 at the time of this evaluation. These costs are outlined in more detail in Section 3.

The economic welfare change and BCA calculations were made using the DREAM model (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 widely used for research evaluation by major world and Australian agricultural research funding agencies. DREAM requires data on equilibrium prices and quantities, supply and demand elasticities, supply and/or demand shifts, probabilities of success, R&D lags, adoption rates and adoption lags. The horizontally disaggregated multi-region option was used to evaluate the Sheep CRC2 benefits. An advantage of this option is that it captures the multi-regional and traded features of the Australian sheep industries. The main disadvantage is that the commodity is defined to be perfectly homogenous, such that Australian lamb or wool is the same as New Zealand lamb or wool or US lamb or wool. Thus any potential benefits from the heterogenous nature of Australian lamb or wool (such as that that has been designed to be different to other lamb or wool), cannot be properly measured in this framework and DREAM will provide a lower-bound impact. Another disadvantage is that the potential impacts of the programs on the vertical market segments of the industry, such as on processors and retailers, cannot be evaluated separately. Therefore, the estimated benefits relate to the farm-level as the point of exchange and the price, quantity and elasticity values chosen reflect this part of the relevant industries. Processors and retailers are lumped in with final consumers (although in a competitive market these groups are likely to have only small benefits).

In implementing the DREAM model for this assessment, the national Australian market was considered as one region and the international regions were defined as China, the European Union, New Zealand, the United States and the rest of the world (ROW) to represent Australia's main customers and competitors in the world wool and sheepmeats markets.

3. Data Required

The main data sets and other information used in this evaluation were either sourced from the literature or from the research theme managers.

3.1 Data and information sourced from the literature

The first data requirement was to derive estimates of the rates of productivity growth that have been achieved by the Australian sheep industries over time. This information enabled the annual rates of productivity growth in the industries to be compared to the potential rates of growth that could result from Sheep CRC2's research themes. The growth estimates reported in Table 2 were derived from published studies and were the same as those reported in Vere *et al.* (2005). They indicate low rates of productivity growth relative to the rates being achieved in other agricultural sectors, eg., 3.4 per cent in crops (Knopke *et al.* 1995) and 2.0 to 2.6 per cent in all broadacre enterprises (Mullen and Cox 1996).

Table 2. Recent estimates of long-term productivity growth in the Australian sheep industries (annual rates of change)

Period	Industry sector	Productivity growth (% pa)	Source
1975-1995	all sheep producers	1.0	Knopke *et al.* (1995)
1977-1997	all sheep producers	0.4	Stoneham *et al.* (1999)
1977-2002	specialist sheep producers	0.9	ABARE (2004b)
1977-2002	specialist lamb producers	1.6	ABARE (2004b)

According to Manson and Black (2004), some 70 per cent of the measured productivity improvements in the Australian sheep industry can be attributed to R&D investments. This suggests that assumed rates of potential productivity improvement due to the activities of Sheep CRC2 should be somewhat less than those assumed for the beef industry for example, where some 95 per cent of measured productivity improvements were thought to be due to R&D investments (Manson and Black 2004).

The second data requirement was to parameterise the DREAM model with the basic sets of input data that it requires to operate in its equilibrium displacement context[1]. These data relate to:

- 'equilibrium' prices and quantities, to define the size and structure of the market in each defined region under consideration at a point in time;
- elasticities of supply and demand, to predict how producers and consumers in each defined region will react to new prices generated by the simulated shocks to the market (the impact of the proposed research); and
- how the proposed research will change either producers' cost structures or consumers' willingness to pay for products in the region(s) where the technology will be adopted or the products will be consumed (the K shift).

[1] An equilibrium displacement model is a static economic model of an industry or market that is assumed to be operating in an "equilibrium" situation, that is, with stable demand and supply schedules and therefore stable prices and quantities. A shock or "displacement" is then applied to the model (such as a new technology that reduces costs), and the resulting changes in prices and quantities are recorded and used to measure changes in economic welfare as discussed above. These models are usually designed to reflect medium to longer term changes, over a time period of several years.

Quantity and price data were derived from published sources (eg., ABARE 2004a, 2005) and were set as 5-year averages from 1999-2000 to 2003-04 to dampen the effects of the recent droughts and the normal economic cycles in the Australian and world wool and sheep-meat market. Elasticity values were sourced from Griffith *et al.* (2001a,b) and Vere *et al.* (2005). The domestic demand elasticities were reduced to reflect the farm level demand that is modelled here rather than the retail demand at which these elasticities are typically calculated.

3.2 Data and information sourced from research leaders

The main requirement here was to obtain realistic estimates of the expected impacts of the research proposed by Sheep CRC2 on the sheep industries. These data were elicited from the research managers at a workshop held on March 31, 2006, and refined over subsequent months.

The first set of data concerned the contributions to sheep industry productivity growth that were expected to result from Sheep CRC2's research themes. Whilst it is possible to identify several types of impacts that a particular CRC could have on industry growth (Vere *et al.* 2005), the main objective is to reduce the differences between the potential rates of growth that could be achieved and actual rates of growth that are being achieved. This objective recognises that there are large differences between the potential and actual growth rates being achieved in Australia's sheep industries, and that the research activities of a CRC could provide new opportunities for cost savings in addition to those that are being realised by the existing group of adopters (i.e., as under the *without-Sheep CRC2* scenario). It also recognises that if there is no investment in new technology development, there is no change in the underlying potential for productivity growth and the actual rate of growth can only be increased through higher adoption. Increasing both the technology stock and its level of adoption has the potential to generate substantial industry benefits (Griffith and Vere 2006).

It was considered that the main impact of Sheep CRC2 would be in providing opportunities to increase the use of existing sheep management technologies, by adding new technologies to the current stock and by improving the level of adoption of existing and new technologies. In their economic evaluation of the science programs undertaken by Sheep CRC1, Vere *et al.* (2005) drew on past studies of productivity growth in the Australian sheep industry and estimates of adoption levels to assume that the maximum potential industry growth rate was about 5 per cent per annum. It was further assumed that the total impact of that research would contribute an extra 2.5 per cent if there was maximum adoption of all of the research outcomes. Therefore, the comparative evaluation was based on a maximum potential annual growth rate of 5 per cent under the *without-Sheep CRC1* scenario and a 7.5 per cent maximum potential annual growth rate under the *with-Sheep CRC1* scenario. The additional 50 per cent growth increase attributed to Sheep CRC2 is consistent with the most recent estimates of changes in total factor productivity growth for Australian specialist sheep producers (from 0.6 per cent per year in 1977/78-1989/90 to 1.2 per cent per year in 1988/89-2001/02) (ABARE 2004b). The same growth potentials have been used in this current evaluation because there is no evidence from the intervening period that actual growth rates and technology adoption levels have changed.

Many of the same researchers who contributed to Sheep CRC1 are involved in Sheep CRC2. So, without Commonwealth funding, some of the planned research would still be done, some would be partially done and some would never be done. The current underlying rate of

potential productivity gain of around 5 per cent would be just maintained. With Commonwealth funding (an overall increase in available funding), the potential for increased productivity growth would be raised to 7.5 per cent because of Sheep CRC2's additional investment in technology development and its promotion throughout the sheep industry. Table 3 contains the research managers' estimates of the contributions to industry productivity growth that were expected to result from Theme 1 of Sheep CRC2's research program. Theme 1 was constrained to contribute one-third of the total 7.5 per cent annual improvement in potential productivity. Within this constraint, the managers had to allocate contributions across sub-themes and between lamb and wool, such that lamb productivity improvement summed to 2.5 per cent and wool productivity improvement summed to 2.5 per cent.

Table 3. Sheep CRC2 impacts: estimates of supply and demand shifts from the Theme 1 research programs of Sheep CRC2

	With-Sheep CRC2 **(7.5% growth potential)**		***Without-Sheep CRC2*** **(5% growth potential)**	
Theme	**Research contribution (%)**	**Growth proportion (%)[a]**	**Research contribution (%)**	**Growth proportion (%)[a]**
1.1 wool	0.4	1.00	0.4	0.67
1.1 lamb	0.3	0.75	0.3	0.50
1.2 wool	0.2	0.50	0.2	0.33
1.2 lamb	0.5	1.25	0.5	0.83
1.3 wool	0.4	1.00	0.4	0.67
1.3 lamb	0.2	0.50	0.2	0.33

[a] proportion of productivity growth potential.

The fine wool demand shift estimate for Theme 2 (a net 10 per cent increase for Australian fine wool in the EU market) was derived from the research managers of this Theme.

The supply shift for the Quality Lamb program (Theme 3) was derived from Banks (2006, unpublished) and represents a 20 per cent increase in the rate of improvement of lean meat yield (from 0.48 per cent to 0.57 per cent per annum) over 42 per cent of lambs born. The demand shift for Theme 3 resulting from new types of lamb with enhanced nutritional attributes was taken to be sufficient to keep real lamb prices constant, rather than declining under the increased retail yield scenario.

The second set of data that was derived from the research managers concerned the industry's expected uptake of the new technologies generated by the research of Sheep CRC2. There were two considerations here. The first was to assess what industry adoption levels have actually been over time because adoption is an important factor in determining the full potential for productivity gains in the industry. There has been little 'hard' measurement of technology adoption levels in Australia's rural industries, but they are recognised as having been relatively low. This has particularly been the case in relation to the sheep and beef industries where historical adoption levels have been assumed to have been 25 per cent for beef and 20 per cent for sheep (Griffith *et al.* 2004, Vere *et al.* 2005). Expediting the release of new technologies and promoting their adoption was seen to be an important role for Sheep CRC2 in assisting the sheep industry to move closer to its full growth potential. For this evaluation, the assumed rates of adoption for the without-CRC case were also held to be around the 20 per cent level.

The second part of the adoption information required for the evaluations was to elicit the expectations about the adoption profiles for Sheep CRC2's research outcomes from the program managers. The components of the adoption 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 those outcomes.

These elicited values are summarised in Table 4 for the *with-* and *without-Sheep CRC2* scenarios, where the assumed adoption values for the *without-Sheep CRC2* scenario had R&D and adoption lags that were lengthened by three years and adoption ceilings that were 80 per cent of the ceilings for the *with-Sheep CRC2* scenario values.

Table 4. Assumed adoption values for the *with-* and *without-Sheep CRC2* scenarios

	With-Sheep CRC2			***Without-Sheep CRC2***		
Theme	**R&D lag (years)**	**Adoption ceiling (%)**	**Adoption lag (years)**	**R&D lag (years)**	**Adoption ceiling (%)**	**Adoption lag (years)**
1.1 wool	4	20	4	7	16	7
1.1 lamb	4	20	4	7	16	7
1.2 wool	3	25	3	6	20	6
1.2 lamb	3	25	3	6	20	6
1.3 wool	4	30	4	7	24	7
1.3 lamb	4	30	4	7	24	7
2. Quality Wool	5	33	4	8	24	7
3. Quality Lamb-yld	2	42	1	2	42	1
3. Quality Lamb-pri	3	35	5	5	30	5

Other assumptions and parameter values used in the benefit-cost calculations are summarised in Table 5.

Table 5 Summary of BCA assumptions used in the DREAM modelling

Variable	**Unit**	**Value**
Base year for onset of benefits		2008
Period of BCA simulation	years	25
Real discount rate	%	4
Probability of research success with Sheep CRC2[a]	%	80
Probability of research success without Sheep CRC2[a]	%	70
Research and development lags for programs	years	see Table 4
Adoption lags for programs	years	see Table 4
Adoption ceilings for programs	%	see Table 4
Price linkages (L) between regions (0<L<1) [a]	%	0.8

a this parameter measures the extent to which price changes in one region are transmitted to other regions. L=1 means a free and open pricing system; L=0 means a closed or regulated pricing system.

3.3 Cost data

Research costs were derived from the managers of the CRC rebid process and included estimates of all direct grants and in-kind contributions from the collaborating agencies (Table 6). These costs were estimates of the cash and the value of in-kind contributions (based on the DEST valuation guidelines) that were expected by Sheep CRC2 at the time of this evaluation. The costs provided in Table 6 are in current $ and are not discounted.

Table 6. Assumed cash and in-kind costs for the *with-* and *without-Sheep CRC2* scenarios

Theme	***With-Sheep CRC2***			***Without-Sheep CRC2***		
	Cash	**In-kind**	**Total**	**Cash**	**In-kind**	**Total**
1.1 wool	1.266	2.179	3.445	0.457	1.743	2.200
1.1 lamb	1.266	2.179	3.455	0.457	1.743	2.200
1.2 wool	1.266	2.179	3.455	0.457	1.743	2.200
1.2 lamb	1.266	2.179	3.455	0.457	1.743	2.200
1.3 wool	1.498	2.280	3.778	0.540	1.824	2.364
1.3 lamb	1.498	2.280	3.778	0.540	1.824	2.364
1. Productive Sheep	8.060	13.276	21.336	2.907	10.620	13.527
2. Quality Wool	7.809	9.251	17.060	2.816	7.401	10.217
3. Quality Lamb	8.448	12.026	20.474	3.047	9.621	12.668
4. Information nucleus	12.392	6.106	18.498	4.467	4.885	9.352
5. Education and Training	4.950	3.885	8.835	1.785	3.108	4.893
6. Commercialisation and utilisation (additional to C&U embedded in the programs)	7.045	7.586	14.631	2.541	6.069	8.610
7. Central Administration	6.720	0.925	7.645	2.423	0.740	3.163
Total[a]	**57.124**	**53.055**	**110.179**	**20.600**	**42.444**	**63.044**

a Includes the costs of CRC1 windup activities**, estimated to be $1.7** million.

Cash costs for the *with-CRC2* scenario were the budgeted costs of operating the various programs that matched the expected cash contributions from the Commonwealth and industry and State government partners. Total cash contributions are expected to exceed $57 million. In the in-kind column, salary in-kinds were estimated to be 290 FTEs in total, valued at an average of $104,000 each, which sum to $30.160 million. These were allocated by the rebid managers across the various programs. Non-salary in-kinds were estimated to be almost $23 million, and these were allocated across the various programs in the same ratios as the salary in-kinds. The total cost is estimated to be more than $110 million in current value terms.

Cash costs for the *without-Sheep CRC2* scenario were estimated to be those commitments made by Sheep CRC2 industry partners only ($20.6 million). The value of the Commonwealth grant being sought and the value of other non-industry contribution are assumed not to be available to sheep industry R&D if CRC2 was not funded. For expedience, the cash budget items across all programs were reduced by the relevant proportion. The in-kind contributions for the *without-CRC2* case were held to be 80 per cent of the total value of the in-kind contributions made by the Sheep CRC2 partners. After the approach of Griffith *et al.* (2004), the 80 per cent 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 to be made in the absence of Sheep CRC2. Total in-kind contributions were estimated to be around $42.4 million, which gives a total *without-Sheep CRC2* program cost of just over $63 million.

All costs involved in the BCA evaluations were defined in real terms.

4. Results and Discussion

The results of the DREAM modelling simulations for the industry demand and supply shifts that are relevant for Program Themes 1-3 under the *with*- and *without-Sheep CRC2* scenarios are given in Tables 7 and 8. As previously noted, it was not possible to jointly model more than one type of shift, one type of product, or one type of market environment. These results are therefore reported on a commodity and industry sector basis. An attempt is made below to separately value the Education and Training Program, but no attempt is made to separately value the Commercialisation and Utilisation Program, the Information Nucleus or the Administration Program. Thus in terms of the return on investment measures, the costs of Programs 4, 6 and 7 as detailed in Table 6 (some $41 million) were allocated across Programs 1-3 on a pro-rata basis.

4.1 *With-Sheep CRC2* scenario

Table 7. BCA outcomes for the proposed research themes: *with-Sheep CRC2* scenario

	***With*-Sheep CRC2**			
Theme	**PV[a] benefits ($m.)**	**PV costs ($m.)**	**NPV ($m.)**	**BCR ($:1)**
1.1 Precision management in wool	59.551	5.203	54.348	11.4
1.1 Precision management in lamb	14.215	5.203	9.102	2.7
1.2 Increased survival in wool	48.927	5.203	43.724	9.4
1.2 Increased survival in lamb	35.285	5.203	30.082	6.8
1.3 Reduced chemicals in wool	97.590	5.705	91.885	17.1
1.3 Reduced chemicals in lamb	29.480	5.705	23.775	5.2
1. Total Productive Sheep[b]	285.048	32.222	252.826	8.8
2. Quality Wool	511.166	25.764	485.402	19.8
3. Quality Lamb	541.269	30.919	510.350	17.7
Totals	**1337.483**	**88.905**	**1248.578**	**15.0**

[a] benefits and costs are discounted at 4 per cent real over 25 years using the DREAM model; [b] includes NPVs of lamb and wool supply and demand outcomes that were calculated separately.

Under the *with-Sheep CRC2* scenario, the total PV of the estimated benefits from the three research themes is about $1.3 billion over the 25-year period of the BCA simulation. The corresponding NPV is $1.2 billion and the BCR is 15:1 where the present value of the full costs of the investments in these Sheep CRC2 programs, plus the pro-rata allocation of the full costs of Programs 4, 5 and 7, (nominally $100 million in total) is $89 million when discounted over the simulation period. If Sheep CRC2 was funded, it is estimated that this R&D program would return more than $15 to all components of the Australian sheep-meat and wool industries for every $1 invested by all funding providers.

The benefits are shared across the three Themes, with Themes 2 and 3 providing over $500 million each over the 25-year simulation period, and Theme 1 providing close to $300 million over the same period. Each theme has a benefit cost ratio of at least 8:1.

The large net benefit that is estimated to result from Theme 2 results from the assumption that this research would have a high probability of success (80 per cent) of being able to achieve the anticipated increase in the demand for fine apparel wools in Western Europe (10 per cent net after accounting for the adoption ceiling). This is a very large demand shift. However the

benefits from this Theme are probably under-estimated for two reasons. First, as noted earlier, the DREAM model as specified here is unable to separate out wool from different suppliers as being different. Thus all fine wool is treated the same. Independent modelling undertaken by Islam *et al*. (2005) suggests that if this assumption was relaxed, a significantly higher share of the benefits from this Theme would flow back to Australian wool producers. Second, there would undoubtably be spillover benefits from the development of the new "prickle" technology and grading system to other high quality markets such as the US and some Asian markets. These additional benefits have not been estimated in this analysis.

The large net benefit that is estimated to result from Theme 3 results from the assumption that this research would have a high probability of success (80 per cent) of being able to achieve the anticipated improvement in the rate of increase in lamb meat yield over the whole period of the simulation. Some 90 per cent of the benefit from Theme 3 is due to the change in the rate of improvement in retail yield ($493 million), and only 10 per cent is due to the maintenance of a stable real retail price for lamb through providing enhanced nutritional attributes.

Close to $300 million of the estimated economic benefit from funding CRC2 is contributed by the Productive Sheep theme, with reduced chemical use in wool and lamb production contributing over 40 per cent of this benefit.

4.2 *Without-Sheep CRC2* scenario

Table 8. BCA outcomes for the proposed research themes: *without-Sheep CRC2* scenario

	***Without*-Sheep CRC2**			
Theme	**PV[a] benefits ($m.)**	**PV costs ($m.)**	**NPV ($m.)**	**BCR ($:1)**
1.1 Precision management in wool	21.750	3.322	18.428	6.5
1.1 Precision management in lamb	4.843	3.322	1.521	1.5
1.2 Increased survival in wool	16.218	3.322	12.896	4.9
1.2 Increased survival in lamb	11.759	3.322	8.437	3.5
1.3 Reduced chemicals in wool	32.284	3.571	28.713	9.0
1.3 Reduced chemicals in lamb	9.700	3.571	6.129	2.7
1. Productive Sheep[b]	96.554	20.430	76.124	4.7
2. Quality Wool	299.473	15.430	284.043	19.4
3. Quality Lamb	423.884	19.131	404.753	22.2
Totals	819.911	54.991	764.920	14.9

[a] benefits and costs are discounted at 4 per cent real over 25 years using the DREAM model; [b] includes NPVs of lamb and wool demand outcomes that were calculated separately.

Under the *without-Sheep CRC2* scenarios, the pattern of benefits is much the same as in the *with-Sheep CRC2* scenarios. Total benefits from Theme 1 are around a third of those under the *with-Sheep CRC2* scenario, whereas the costs of conducting these R&D programs have only fallen by about a third. The BCR is about a half of what it would be under the Sheep CRC2 proposal.

Total benefits from the wool demand-enhancing components of the portfolio (Theme 2) have a present value of around $300 million when summed over the 25-year period of the BCA simulation. These estimates are based on a long R&D lag (15 years, Table 4) to accommodate

the view of the program leaders that this research would not have been undertaken without Sheep CRC2. The values for the other parameters are the same as for the *with-Sheep CRC2* scenario, and are included in this analysis for completeness. Even so, the large anticipated demand shift in the large EU market stills generates substantial benefits when it does occur.

Total benefits from Theme 3 are around 80 per cent of those under the *with-Sheep CRC2* scenario. This reflects the substantial rate of improvement in meat yield already being achieved in the lamb industry and the expectation that this will at least continue at this rate over the period of the analysis. Note also that the adoption parameters of the yield part of Theme 3 are the same as under the with-Sheep CRC2 scenario.

Without funding of Sheep CRC2, the present value of the total estimated benefit is $820 million over 25 years. Total costs have a present value of around $55 million (including the total costs of Programs 4, 6 and 7 under the without scenario), so the NPV is $765 million and the BCR is just under 15:1. If Sheep CRC2 was not funded and an alternative research program was developed along the lines as that has been proposed here, with funding over the same seven year period of the proposed CRC, it is estimated that this R&D program would return a little less than $15 for every $1 invested[2].

4.3 Marginal returns on the Commonwealth investment

The main concern in this evaluation is the difference in the BCA results between the *with-* and *without-Sheep CRC2* scenarios, i.e., the marginal returns from the marginal investment (Table 9).

Table 9. Marginal BCA outcomes for the proposed research themes of Sheep CRC2

	With-Sheep CRC2 minus Without-Sheep CRC2			
Theme	**PV[a] benefits ($m.)**	**PV costs ($m.)**	**NPV ($m.)**	**BCR ($:1)**
1.1 Precision management in wool	37.801	1.881	35.920	20.1
1.1 Precision management in lamb	9.372	1.881	7.491	5.0
1.2 Increased survival in wool	32.709	1.881	30.828	17.4
1.2 Increased survival in lamb	23.526	1.881	21.645	12.5
1.3 Reduced chemicals in wool	65.306	2.134	63.172	30.6
1.3 Reduced chemicals in lamb	19.780	2.134	17.646	9.3
1. Productive Sheep[b]	188.494	11.792	176.702	16.0
2. Quality Wool	211.693	10.334	201.359	20.5
3. Quality Lamb	117.385	11.788	105.597	10.0
Totals	517.572	33.914	483.658	15.3

[a] benefits and costs are discounted at 4 per cent real over 25 years using the DREAM model; [b] includes NPVs of lamb and wool supply and demand outcomes that were calculated separately.

Under the assumptions made in this evaluation, the investment by the Commonwealth and the Australian sheep industry in Sheep CRC2 is relative to a scenario where an alternative, lower cost research program into this industry is implemented. These extra resources have a discounted value of about $34 million over the 25-year period of this evaluation. These

[2] It is curious that the total BCRs are so similar between the with-CRC and without-CRC scenarios, especially as the BCRs for the individual themes vary so widely. One contributing factor might be the elicited adoption ceilings in the without-CRC scenario which are close to 80 per cent of the with-CRC scenario ceilings, and this is the same proportional reduction applied to the in-kind costs.

resources are sufficient to allow some new research components to be added to the portfolio, some existing components to produce better outcomes, and a more targeted approach to development and extension that speeds up and increases the adoption of the new technologies that are generated by the research program. As shown in Table 9 the benefit from this extra investment and consequent research effort is estimated to be worth about $518 million in present value terms, which is far in excess of the marginal investment. Thus every $1 of these extra resources brought into the Australian sheep industry through funding the proposed Sheep CRC2 is expected to return around $15.30 to the industry in present value terms. Investing in the CRC brings forth a higher return than if the investment was not made.

The marginal BCR for Program 1 is substantially greater than for either the with- or without-scenarios individually. This suggests that the type of R&D contained in Program 1 would benefit most from the Commonwealth funding, or conversely, would suffer most if the funding was not provided. On the other hand, the marginal BCR for Program 3 is quite a bit lower than either the with- or without- scenarios individually, and this reflects (as noted above), the strong progress being made in lamb retail yield already. The marginal BCR for Program 2 is about the same in the three tables, but it is worth noting again that there is also a strong argument that some of the wool-demand benefits from Theme 2 are substantially underestimated in this analysis.

4.4 Regional Disaggregation of the Benefits to Sheep CRC2

Table 10 contains the regional disaggregation of the NPV estimates of the *with-CRC2* scenario. These disaggregated estimates show the general distribution of benefits between producers and consumers and regions that typically result from new technology adoption in an industry that is as competitive in its structure and is as prominent in world trade as the Australian sheep industry.

Table 10. Regional disaggregation of the total benefits from Sheep CRC2

	NPVs of economic surplus changes ($m.)				
	Wool supply	**Wool demand**	**Meat supply**	**Meat demand**	**Total**
Australian producers	155.9	65.1	521.6	53.1	795.7
Australian consumers	1.3	-2.7	29.6	0.2	28.4
Overseas producers	-115.3	105.4	-638.9	-18.2	-667.0
Overseas consumers	158.6	348.9	654.0	19.2	1,180.7
Totals	**200.2**	**516.7**	**566.3**	**54.3**	**1,337.5**

These disaggregated estimates show that almost two-thirds of the anticipated benefits from Sheep CRC2 will be claimed by Australian sheep producers and Australian consumers of sheep products. These benefits are valued at $824.1 million at the anticipated maximum adoption levels for the Sheep CRC2 technologies, indicating significant potential payoffs to Australia from the investment in Sheep CRC2. Sheep producers will receive most of this, some $795.7 million, because they have direct access to the new technologies. The benefit shares gained by Australian wool and sheepmeat producers are 31 and 94 per cent, respectively. Australian wool and lamb consumers and consumers in Australia's sheep export markets also benefit to varying proportions from being able to access more product at lower prices resulting from supply-increasing technologies. The exception is the fine wool demand shift, where consumers in the EU benefit since their increased willingness-to-pay is still

greater than the price rise induced by the demand shift, but Australian consumers lose because they have not experienced an increased willingness-to-pay.

Sheep producers in other countries lose welfare from the wool and sheep meat supply R&D programs because they cannot achieve the cost savings from new technology adoption but they still suffer the price reductions from the Australian increases in wool and sheepmeat production. These results are consistent with the theory of regionally-disaggregated economic welfares change measurement where technology adoption that increases supply and reduces production costs in one region benefits that region's producers, while producers in other regions who are unable to adopt the technology and lower production costs lose welfare from the decreased price. For the simulated increase in the demand for fine wool in the EU resulting from Theme 2 R&D, the upward shift in demand raises the price for all producers, including overseas producers.

Across all types of shifts, the losses to sheep producers in other regions are more than offset by welfare gains to consumers in those regions.

5. The Commercialisation and Utilisation Program

The estimates of economic benefits reported above are based on various combinations of changes in potential productivity growth rates, changes in consumer's willingness-to-pay, changes in R&D lags, changes in probabilities of success, changes in adoption lags and changes in adoption ceilings. Typically, the first four factors are regarded as relating to enhanced research while the last two are regarded as relating to enhanced adoption. The simulations can be re-solved using the with-Sheep CRC2 supply and demand shifts, R&D lags and probabilities of success, and the without-Sheep CRC2 adoption lags and ceilings. This allows the disaggregation of the total estimated benefits reported in Table 7 into that proportion attributable to enhanced research and that attributable to enhanced adoption. These results are reported in Table 11.

Table 11. Disaggregation of the total benefits from Sheep CRC2 into research and adoption components

Theme	**PV[a] benefits, with-CRC2 ($m.)**	**PV benefits without accelerated adoption ($m.)**	**PV benefits of accelerated adoption ($m.)**
1.1 Precision management in wool	59.551	42.859	16.692
1.1 Precision management in lamb	14.215	10.229	3.986
1.2 Increased survival in wool	48.927	35.467	13.460
1.2 Increased survival in lamb	35.285	25.571	9.714
1.3 Reduced chemicals in wool	97.590	70.222	27.368
1.3 Reduced chemicals in lamb	29.480	21.211	8.269
1. Productive Sheep[b]	285.048	205.559	79.489
2. Quality Wool	511.166	294.706	216.460
3. Quality Lamb (yield)	493.167	493.167	0
Quality Lamb (demand)	48.102	41.230	6.872
Totals	**1337.483**	**1034.662**	**302.821**

[a] benefits and costs are discounted at 4 per cent real over 25 years using the DREAM model; [b] includes NPVs of lamb and wool supply and demand outcomes that were calculated separately.

Based on the assumptions outlined above, more than $300 million can be attributed to the proposed accelerated adoption program of Sheep CRC2. This is some 22 per cent of the total estimated benefit.

An unknown proportion of this $303 million will be attributable to commercialisation and utilisation activities embedded in the research programs and thus these benefits should be added to the aggregate figure of $1.035 billion for the returns to R&D shown in Table 11. The costs of these embedded activities will already have been counted in the Theme costs.

The remainder of the benefit will be attributable to commercialisation and utilisation activities contained within the specific commercialisation and utilisation program. If just half of the aggregate commercialisation and utilisation benefits were set against the specific program, which has a cost of $14.6 million (Table 6) (or $13.1 million when discounted), this would result in a NPV of some $138 million and a BCR of about 11.5:1. The potential gains from small investments in commercialisation and utilisation outcomes are quite significant.

6. The Education and Training Program

To value the Education and Training (E&T) Program, data have been taken from the TNS (2004) survey of requirements for trained students and industry advisors, the schedule of scholarships the Sheep CRC is expecting to deliver (6 per cent of the estimated requirements), estimates of the increase in sheep and wool industry potential productivity growth rate from 5 per cent to 7.5 per cent, and an assumed share of this total due to productivity alone. These data suggest that every 1 per cent change in the rate of growth of sheep industry productivity (say from 1.00 per annum to 1.01 per annum) is worth about $2.3m.

Brennan *et al.* (2006) estimated a response elasticity of 0.47 for percentage improvements in productivity from percentage improvements in human capital for the case of wheat rust R&D. If the same estimate for the sheep and wool industry was used (likely to be very cautious given the relatively low levels of underlying productivity growth compared to the wheat industry), a 6 per cent increase in postgraduate human capital capacity due to CRC activities would therefore be expected to increase sheep and wool industry productivity by about 3 per cent, and this increase would have an expected value of around $6.9m in present value terms. For the cost of running the postgraduate program until 2010, about $2.650m, this return represents a benefit-cost ratio of about 2.6:1. At almost worst-case scenario, the postgraduate program should have a reasonable pay-off to the investment. If an elasticity of 1.0 was used, a 6 per cent increase in postgraduate human capital capacity due to CRC activities would have an expected value of around $13.8m in present value terms. This return represents a benefit-cost ratio of about 5.2:1 for the investment in the postgraduate program.

It is more difficult to estimate the returns for the full term of the proposed CRC as there are no estimates of the capacity requirements out to 2014. However if it is assumed that skilled workers will be required at the same annual rate as to 2010, than the estimated requirements for the period 2008 -2014 will be 315 postgraduates, 630 undergraduates and 980 school and college trained workers. The CRC is proposing to deliver 40 postgraduates, which represent 13 per cent of the required postgraduate capacity. At the lower bound elasticity of 0.47, that means an increase in productivity of around 6 per cent which has a value of just over $12m and produces a benefit cost ratio of 3.3:1 for the $3.6m budget allocated against postgraduate training. If the elasticity was around 1.0 the benefit cost ratio would be around 7:1. The postgraduate education component would be expected to generate a positive return to the planned expenditure of the whole E&T program.

The second part of the E&T program is a specialised training course for agricultural consultants. It is expected that about 8 consultants will be trained per year, and each of these will then work with groups of around 50 sheep producers to deliver R&D program outcomes. Thus over the term of the CRC, some 2,800 new producers will be receiving specialised training to enhance Sheep CRC2 outcomes, each year, or some 12,400 in total. This is almost 20 per cent of the number of sheep producers in Australia. The returns from improved productivity and/or accelerated adoption would need to be just over $100 per producer over the seven year term to pay the cost of $1.35 million to operate this component of the E&T program. For comparison, a 1 per cent improvement in the gross margin of a 1000 head wether flock would be in the order of $170 in just one year (NSW DPI 2006).

7. Summary and Conclusions

The Australian sheep industry and its associated research and development agencies have developed a proposal for submission to the Commonwealth government for the refunding of the Australian Sheep Industry Cooperative Research Centre (Sheep CRC1). This new CRC is referred to as the CRC for Sheep Industry Innovation (or Sheep CRC2). There are three proposed research Programs: Productive Sheep and their Management, Wool Quality, and Meat Quality. In addition, there is a Communication and Utilisation program, an Education and Training program, an Administration program, and an industry sheep resource known as the Information Nucleus. Funding is sought for a second seven-year term to commence in 2007/08, overlapping by one year the completion of the term of Sheep CRC1.

The main accountability criteria on which the Commonwealth will assess the funding proposal for Sheep CRC2 are: (a) that Sheep CRC2 has the potential to generate sound returns to all stakeholders from the public and private funding that is being sought relative to the costs, and, (b) that the research outcomes of Sheep CRC2 will contribute substantially to Australia's industrial, commercial and economic growth. In this Report we provide an assessment of this impact.

Following successful applications to other CRC renewal bids, a 'top-down' method was initially proposed to evaluate the research themes of Sheep CRC2. The basic requirements are to examine the overall rates of productivity growth in the sheep industry, to assess the role of technological change in generating this growth and to estimate the likely improvements in this growth due to the activities of Sheep CRC2. That is, the initial plan was to evaluate the Sheep CRC2's proposed research as an overall investment package, since most of the production-based projects are grouped into program themes or clusters of projects and thus have similar objectives. Subsequently, once the structure of the various research themes became clearer, it was decided to treat Theme 2 differently since this was now defined more like a very specific research project that had little interaction with Themes 1 and 3. Theme 3 was also treated as an individual project as there was a particularly detailed biological justification available for the proposed research which suggested that this Theme could be modelled separately. The various sub-themes within Theme 1 were still evaluated using the "top-down" methodology.

Formal "with-CRC" and "without-CRC" scenarios were defined for each product and each research theme with the assistance of Sheep CRC research managers, research staff and advisory staff in a workshop situation. Relevant costs were similarly defined.

The economic welfare change and benefit-cost analysis calculations were made using the DREAM model (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 widely used for research evaluation by major world and Australian agricultural research funding agencies. The required parameter values include equilibrium prices and quantities, supply and demand elasticities, supply and/or demand shifts, probabilities of success, R&D lags, adoption rates and adoption lags. In implementing the DREAM model for this assessment, the national Australian market was considered as one region and China, the European Union, New Zealand, the United States and the rest of the

world (ROW) were defined as the international regions to represent Australia's main customers and competitors in the world wool and sheep-meats markets.

In the benefit-cost analyses, the fixed costs of the Communication and Utilisation program, the Administration program, and the Information Nucleus were allocated pro-rata across the three R&D programs.

Under the *with-Sheep CRC2* scenario, the total PV of the estimated benefits from the three research themes is about $1.3 billion over the 25-year period of the BCA simulation. The corresponding NPV is $1.2 billion and the BCR is 15:1 where the present value of the full costs of the investments in these Sheep CRC2 programs, plus the pro-rata allocation of the full costs of Programs 4, 5 and 7, (nominally $100 million) is $89 million when discounted over the simulation period. Without funding of Sheep CRC2, the present value of the total estimated benefit is $820 million over 25 years. Total costs have a present value of around $55 million (including the total costs of Programs 4, 6 and 7 under the without scenario), so the NPV is $765 million and the BCR is just under 15:1.

The main concern in this evaluation is the difference in the BCA results between the *with-* and *without-Sheep CRC2* scenarios, i.e., the marginal returns from the marginal investment. Under the assumptions made in this evaluation, the investment by the Commonwealth and the Australian sheep industry in Sheep CRC2 is relative to a scenario where an alternative, lower cost research program into this industry is implemented. These extra resources have a discounted value of about $34 million over the 25-year period of this evaluation. These resources are sufficient to allow some new research components to be added to the portfolio, some existing components to produce better outcomes, and a more targeted approach to development and extension that speeds up and increases the adoption of the new technologies that are generated by the research program. The benefit from this extra investment and consequent research effort is estimated to be worth about $518 million in present value terms, which is far in excess of the marginal investment. Thus every $1 of these extra resources brought into the Australian sheep industry through funding the proposed Sheep CRC2 is expected to return around $15.30 to the industry in present value terms. Investing in the CRC brings forth a higher return than if the investment was not made.

Disaggregating the estimates by region and market group shows that almost two-thirds of the anticipated benefits from Sheep CRC2 will be claimed by Australian sheep producers and Australian consumers of sheep products. These benefits are valued at $824 million at the anticipated maximum adoption levels for the Sheep CRC2 technologies, indicating significant potential payoffs to Australia from the investment in Sheep CRC2. Sheep producers will receive most of this, some $796 million, because they have direct access to the new technologies. Australian wool and lamb consumers and consumers in Australia's sheep export markets also benefit to varying proportions from being able to access more product at lower prices resulting from supply-increasing technologies.

Disaggregating the estimates by type of impact shows that more than $300 million can be attributed to the accelerated adoption program of Sheep CRC2. This is some 22 per cent of the total estimated benefit.

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Appendix: Notes on Valuing the Education and Training Program of the Sheep CRC2 Rebid

G.R. Griffith

Economists think of education and training as an investment in human capital, and human capital has the capacity to produce future income just like other types of capital. Thus increases in real earnings of workers represent a return to the investment that human beings make in themselves.

The association between human capital and economic well-being at the aggregate level is derived from the early work of Schultz (1981). Schultz's research suggests that the economic growth of nations is largely the result of investments in human capital. Thus investments in human knowledge and skill are necessary if regions or industries lacking human capabilities ever expect to attract and fully benefit from infusions of new capital. A number of eminent economists have become interested in this area (for example, Griliches 1997), and the hypothesised relationship has been tested and accepted across a wide range of environments (but mostly in the developing world). These findings of positive economic returns from education to both individuals and nations have resulted in child and adult education programs now forming a basic component of development economics.

The critical issue though is how to apply such a broad economy-wide framework to a very specialised education investment in a small part of a developed country agricultural sector.

A. Meeting the Industry Need

One approach is to simply state that without the proposed investment by the CRC, the Australian sheep industry will face an increasing shortage of skilled workers for the broad sheep and wool industry. The industry needs 222 postgraduates, 445 undergraduates and some 700 school or college trained students over the next 5 years according to the recent survey by TNS (2005). The industry are prepared to invest more than $3.8m over the next 7 years, but this amount will only fund a proportion of the required number of postgraduates, and none of the undergraduates or college or school trained workers. Since higher education is expected to generate significant economic returns to nations, taxpayers could be expected to partially contribute to such specialised training. Having such students funded by and embedded in CRC programs will provide the types of specialised training that industry requires.

B. Aggregate Rates of Return Measures

Another approach is to apply aggregate measures of rates of return from various types of education and training to the expenditures planned under this program. Such relationships are derived from the Schultz type of framework mentioned above. These results are generated by sophisticated econometric cross-section studies that measure the relationships between increased net earnings or increased farm productivity and a large number of possible explanatory variables including years of education, type of education, years of work experience, etc. Large scale surveys are usually required to be able to do such work. Taylor and Yunez-Naude (2000) provide a recent example of such studies.

For example, OECD (2005) annually report on education sector indicators. In the 2002 edition, estimates of the rate of return to higher education across 10 industrialised countries were published. These estimates ranged from a high of 17% in Britain, through 10-15% in the US and several other European countries, to lower rates in other OECD countries. I have not been able to access the publication to see whether Australia is represented, but a conservative assumption of even less than a 10% return for Australia would suggest a return on investment to Sheep CRC funds well in excess of the discount rate likely to be used for these funds (usually 4%).

Jamison and Lau (1982) surveyed 37 studies of the relationship between schooling and farm productivity across many countries and concluded that farm productivity increases by an average of 8.7% as a result of farmers completing just 4 years of elementary schooling. Recently, Taylor and Yunez-Naude (2000) found that households in rural Mexico reap a total income return of nearly 10% per year of household head schooling.

Again, while there are obvious problems in translating such results into developed country contexts, rates of return such as these from investments by the Sheep CRC would be well in excess of the discount rate likely to be used for these funds.

C. Linking Education and Training, Research Capacity and Research Outcomes in an Industry Context

If such survey data are unavailable, another approach is to follow the broad Schultz methodology, but to think of the investments in education and training as human capital capacity building within the context of productivity growth in a single industry. John Brennan and colleagues (Brennan, Quade and Murray 2006) have recently developed a conceptual model of the linkages between capacity building R&D and productivity outcomes in the Australian wheat industry, and their approach is described and outlined here.

C.1 Theoretical Framework

R&D outcomes depend on the capacity to undertake the research, so investment aimed at building research capacity can be an important component of R&D investment (see also Ryan 1999). DANIDA (2000) suggest that the capacity to undertake high-quality and effective research involves four components:

- Tangible capital,
- Human capital,
- Organisational capital, and
- Social capital.

Human capital refers to the people and their skills, motivation, knowledge, training and experience.

The Brennan *et al*. model is constructed on the following propositions:

1. As capacity is increased, research outputs can also increase, and the final outcomes can be expected to have higher economic value.
2. It is likely that there are minimum threshold levels of R&D capacity below which progress will be very slow, so that there can be a critical mass of R&D capacity before strong progress can be expected (eg, see Maredia and Byerlee 2000, Brennan 1993). There may well

also be diminishing returns `to increasing investment in R&D capacity in one production environment.

3. The larger the capacity, the larger the potential productivity enhancement and/or effect of maintenance research, and hence the larger the potential economic outcomes.

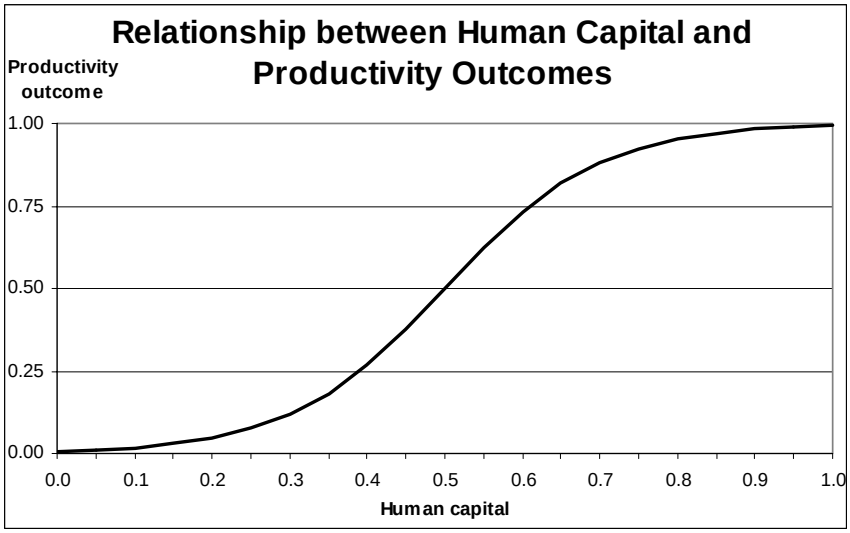
4. Each of the four components of R&D capacity can range from "zero" to "full" capacity. The overall R&D capacity itself is a combination of the components, and the R&D outcomes are a function of the level of each component.

5. The greater the human capital, the greater the productivity outcome, for a given level of the other three components.

Using these principles, an analytical framework was developed to enable the changes in R&D capacity to be quantified. In Figure A1, in the case of human capital, for example, for a given level of the other components of capacity, increases in human capital are likely to follow a logistic curve rather than a linear response. If we assume at this point that there are no technology spill-ins, at low levels of human capital in a given region or industry, productivity outcomes are likely to be very small. As human capital is further developed, the rate of increase of productivity is likely to increase, but then to taper off as human capital is increased even further, to the point where diminishing marginal returns set in and additional human capital is ultimately unlikely to increase productivity.

For simplicity, this relationship ignores lags that are likely to occur between a change in research capacity and the resulting increase in productivity outcomes, and the different response curves that would result with different levels of the other components of R&D capacity.

Figure A1: Relationship between Human Capital and Productivity Outcomes



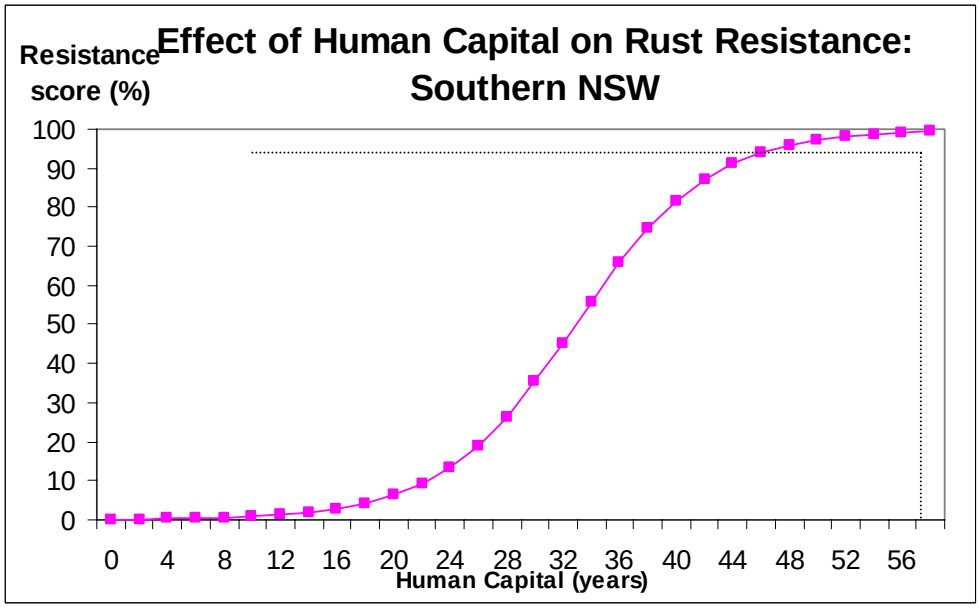
Following the work of Alston *et al.* (1995, p. 357) in relation to adoption curves, a logistic curve can be specified to approximate the above relationship. Once the curve has been defined, changes in human capital represent a movement along the horizontal axis (along the response curve). Then we can calculate the expected change in productivity for a given change in human capital, and then place an economic value on changes in the components of R&D capacity. A change in one of the other components being held fixed in this analysis would lead to a shift in the curve.

Brennan *et al*. (2006) applied this model to valuing an increase in the capacity to produce productivity improvements in the area of rust resistance in wheat. Following Craig *et al.* (1991) and Pardey *et al.* (1991), they used the number of full-time equivalent workers involved in wheat resistance research, defined by educational status, and the total cumulative years of post-graduate experience among the plant pathologists in wheat diseases resistance, as their measure of the human capital input into agricultural research. Their index of human capital was 46.8.

From Brennan and Murray (1998) and elsewhere, the potential losses from diseases that could have been controlled by resistance were available. They estimated that productivity was 94.9% of its potential due to the rust resistance. Assuming that there are no spill-ins of technologies for rust resistance from other regions, they were able to define the parameters of the logistic equation and hence define the relationship between human capital for rust resistance and outcomes for wheat rust resistance in southern NSW (Figure A2). From this relationship, an estimate of the value of a change in human capital can be estimated (ignoring any lags inherent in the system).

For example, sending one of the staff on a 6-month post-graduate training course on wheat rusts would increase the human capital score by 0.5 years to 47.3 (an increase of 1.07%). From the estimated equation, that would produce a productivity outcome of 95.39% (an increase of 0.5%). Given that a productivity outcome of 100% has been estimated to equal $115.6 million per year, the change in the human capital score would lead to an increase in value of $0.6 million per year from rust resistance, sometime in the future.

Figure A2: Effect of Human Capital on Rust Resistance: Southern NSW



As shown in Figure 2, these points on the curve are well into the upper right hand corner, or close to the maximum level of potential productivity. This implies that most of the gains from human capital enhancement in relation to rust resistance in wheat have already been made., Thus, the “elasticity” of the response surface at this point is quite low (0.5/1.07=0.47) and it

requires a relatively large shift in the measure of human capital to generate significant changes in productivity and thus industry benefits.

C.2 Application to the Sheep CRC Rebid ET Program

John Brennan's work discussed here has been developed over a number of years as part of an ACIAR-funded project, and he has been working in the general area of the economics of wheat breeding for many years. For the current task, these types of resources are just not available to develop the sort of response surface shown in Figure A2 (although by the way this would make a very interesting and useful postgraduate topic for any CRC).

However, a couple of relevant points can be made. First, in contrast to the grains industry which has the highest levels of measured productivity growth in Australian broad-acre agriculture, we know that measured levels of productivity growth in the sheep and wool industries are very low and that there is a large gap between measured and potential rates of productivity growth (Vere *et al*. 2005). If we had an equivalent to Figure 2 for the sheep and wool industries, this would imply that the current point on the vertical axis would be somewhat lower, and perhaps substantially lower, than the point in the wheat rust example. This means a point somewhere on the more steeply sloping section of the response surface (a higher elasticity value), which implies that a relatively smaller shift in the measure of human capital is required to generate significant changes in productivity and thus industry benefits. So if a 6 month postgraduate course is worth about $0.6m to the wheat industry, it would be worth considerably more to the sheep and wool industry. How much more depends on the value of the response elasticity on the more steeply sloping portion of the logistic curve.

Second, although the horizontal scale would obviously be much different for the sheep and wool industries, the TNS (2004) survey results suggest that current levels of human capital are much further to the left in Figure A2 than for the rust resistance case. As noted above, 222 postgraduates, 445 undergraduates and some 700 school or college trained students will be required by the sheep and wool industry over the next 5 years (ie to 2010) according to the recent survey by TNS (2004). Again, this supports the argument that the Australian sheep and wool industry is operating in a more elastic portion of the productivity response curve.

According to the planned schedule of scholarships, the Sheep CRC is expecting to deliver to industry about 14 new (completed) postgraduates by 2010. These figures represent about a 6% increase in the forecast capacity requirements for postgraduates.

Vere et al. (2005, Table 5.2) estimated that an increase in sheep and wool industry potential productivity growth rate from 5% to 7.5%, as well as changes in some adoption parameters, would generate net benefits to the industry of some $191m in present value terms (in comparison to a without-investment case). Using as a guide the share of this total due to productivity alone from the Beef CRC rebid analyses (60%), this suggests something around $115m would be due to the hypothesised 50% increase in productivity growth rates. Thus every 1% change in productivity (from say a growth rate of 1% to a growth rate of 1.01% - a tiny change) is worth about $2.3m.

If we used a very cautious estimate of the same response elasticity of 0.47 for the sheep and wool industry as the wheat elasticity shown in Figure 2 (even though we have argued that it should be much larger), a 6% increase in postgraduate human capital capacity due to CRC

activities would therefore be expected to increase sheep and wool industry productivity by about 3%, and this increase would have an expected value of around $6.9m. in present value terms. For the cost of running the postgraduate program until 2010, about $2.650m, this return represents a benefit-cost ratio of about 2.6:1. At almost worst-case scenario, the postgraduate program should have a reasonable pay-off to the investment.

If we used a less cautious and more likely estimate of the response elasticity of 1.0 for the sheep and wool industry (just twice as much as the wheat elasticity shown in Figure 2), a 6% increase in postgraduate and undergraduate human capital capacity due to CRC activities would therefore be expected to increase sheep and wool industry productivity by about 6%, and this increase would have an expected value of around $13.8m. in present value terms. This return represents a benefit-cost ratio of about 5.2:1 for the investment in the postgraduate program.

It is more difficult to estimate the returns for the full term of the proposed CRC as we do not have estimates of the capacity requirements out to 2014. However if we assume skilled workers will be required at the same annual rate as to 2010, than the estimated requirements for the period 2008 -2014 will be 315 postgraduates, 630 undergraduates and 980 school and college trained workers. The CRC is proposing to deliver 40 postgraduates, which represent 13% of capacity. At the lower bound elasticity of 0.47, that means an increase in productivity of around 6% which has a value of just over $12m and produces a benefit cost ratio of 3.3:1 for the $3.6m budget allocated against postgraduate training. If the elasticity was around 1.0 the benefit cost ratio would be around 7:1.

The postgraduate education component would be expected to generate a positive return to the planned expenditure of the whole E&T program.

C.3 Valuing the Industry Training Component

The second part of the E&T program is a specialised training course for agricultural consultants. It is expected that about 8 consultants will be trained per year, and each of these will then work with groups of around 50 sheep producers to deliver R&D program outcomes.

Thus over the term of the CRC, some 2,800 new producers will be receiving specialised training to enhance Sheep CRC2 outcomes, each year, or some 12,400 in total. This is almost 20 per cent of the number of sheep producers in Australia. The returns from improved productivity and/or accelerated adoption would need to be just over $100 per producer over the seven year term to pay the cost of just $1.35 million to operate this component of the E&T program. For comparison, a 1 per cent improvement in the gross margin of a 1000 head wether flock would be in the order of $170 in just one year (NSW DPI 2006).

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