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Estimating the economic impact of a major beef industry research and development investment: the renewal of the Cooperative Research Centre for Beef Genetic Technologies

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Abstract

The expected benefits from the proposed scientific programs of the recently renewed CRC for Beef Genetic Technologies were estimated using the DREAM economic modelling framework. A with-CRC versus without-CRC approach was used. Based on a consensus data gathering process, different assumptions were made about levels of investment, rates of improvement in meat quality, rates of productivity improvement, probabilities of success and rates and levels of adoption. The two scenarios were compared in separate demand and supply analyses that incorporated data on prices, quantities and market elasticity values for each Australian state and the major beef trading countries. Total estimated benefits from the with-CRC scenarios were in the order of $1.930b. The present value of the full cost of the CRC program was $98m when discounted. This resulted in a NPV of $1.831b and a BCR of 19.7:1. Total estimated benefits from the without-CRC scenarios were $516m with total costs of $58m. This resulted in a NPV of $458m and a BCR of 8.9:1. Thus, the benefit from the extra investment and consequent research effort was estimated to be worth over $1.4b in present value terms. Every $1 of these extra resources brought into the Australian beef industry through funding the new Beef CRC was expected to return around $35 to the industry.

Keywords

Technical change, beef industry, economic analysis, return on investment

1. Introduction

There have been two previous Cooperative Research Centres (CRCs) researching aspects of the Australian cattle and beef industry. From 1993/94 until 2000/01 the CRC for the Cattle and Beef Industry was funded, and then from 1999/00 until 2005/06 the CRC for Cattle and Beef Quality has been funded. Both previous CRCs have been highly regarded by industry, the science community and the CRC Secretariat. Many of the same organisations and personnel have been involved in the two previous CRCs and are involved in the renewed CRC.

Following a successful mid-term Review of the CRC for Cattle and Beef Quality in mid 2003, planning for the renewal bid commenced. Numerous meetings and workshops were convened and a wide range of potential partners, industry leaders and scientists were consulted. The Stage I preliminary case was submitted in March 2004 and the Stage II full business case in July 2004[1]. The bid team were notified of their success in late December 2004, with a planned start date of July 2005. The CRC for Beef Genetic Technologies was one of 14 successful bids from an initial list of 80 expressions of interest.

There are 19 core and supporting partners of the CRC that have committed more than $90m in cash or in-kind resources to match the Australian Governments $30m contribution.

The proposed areas of research were outlined and argued in a "Prospectus" document (CRC for Cattle and Beef Quality 2004). In brief, the proposal contained four major areas of scientific research (high quality beef for global consumers; feed efficiency, maternal productivity and responsible resource use; adaptation and animal welfare; and female reproductive performance), as well as an education and training program including specialists in economics and adoption methods, and a cross-program group of underpinning science, bioinformatics and database specialists. The focus of the CRC is on gene discovery and gene expression, and enhancing adoption[2], and some seven major industry outcomes have been targeted across some 20 individual project areas.

Two of the four assessment criteria on which the CRC renewal proposal was judged are: (1) outcomes will contribute substantially to Australia's industrial, commercial and economic growth; and (2) the funding sought will generate a return and represents good value for the taxpayer. Both of these criteria imply the need for rigorous economic assessment of the expected impacts of the proposed science programs. The objective here is to report the process involved in making such an assessment. The methodology used to make these estimates is described and the results generated are reported. This information should be useful for other groups involved in justifying large integrated investment packages such as CRCs, ARC large grants and other collaborative ventures.

2. Methodology

Assessment philosophy

Measuring the long-term *net* benefits from the proposed program of research in the renewed CRC required us to define appropriate "with-research" and "without-research" scenarios. This is often very difficult because many evaluations are concerned with on-going, rather than completely new, research programs (Alston, Norton and Pardey 1995). For example, in the present case, there are three issues compounding this difficulty. First, there have been significant past RD&E investments, and there were significant concurrent investments, in the general areas covered in the proposed program of research, and there have been, and will be in the future, productivity improvements that result from these earlier programs. These will arise because we are assessing RD&E investments in the beef cattle industry and there are very long biological lags involved in this industry.

Second, the nature of the technology under investigation (genetics) means that the impacts of adopting such technologies are spread out over a long time period and the impacts accumulate over time. The benefits of both of these components of future productivity improvement that are based on past R&D programs cannot be claimed to be benefits of research in the proposed CRC. They are the benefits of past investments, even though they form the building blocks of some of the new proposals.

Third, there has been a long history of collaboration achieved by researchers and agencies through involvement in the predecessor CRCs. Also, the research issues making up the renewed CRC program are the result of substantial consultation between industry and potential core partners and are consequently highly valued by them.

Given this context, it was highly probable that in the absence of Commonwealth funding for the proposed CRC, an alternative program of research would have been undertaken by many of the same researchers and many of the same agencies, covering many of the same issues. However, such a research program would certainly have been less comprehensive and/or less intensive, as total available funding would be substantially reduced (no CRC cash, less partner in-kind contributions). More importantly though, there would have been a crucial lack of discretionary funds for the purchase of expensive new equipment and contracted services, for the coordination of the RD&E effort across the partner agencies, for the required focus on extension and adoption of the RD&E outcomes, and for the attraction of postgraduate students into the RD&E programs. Further, there may have been some "withering on the vine" effect over time as experienced and cooperating researchers moved on to other problems and issues and were replaced by naive researchers.

So the benefits of the proposed CRC were thought of as falling into three possible areas:

- *genuinely new research outputs*, that would not be possible to generate without the proposed CRC funding (ie genuinely new technologies);
- *enhanced research outputs*, that would have significantly greater impact than those outputs generated by an alternate RD&E program undertaken by the same researchers and agencies but without the proposed CRC funding (ie 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 proposed CRC funding (ie faster and/or more widespread adoption of profitable technologies).

Such an approach to assessing large, integrated RD&E programs was also used to estimate the net benefits of a research program undertaken by the CRC for Weed Management Systems to reduce *vulpia* infestations in Australian temperate pastures (Vere, Jones and Griffith 2003). Here, we adopted this same overall approach to estimating the benefits of the proposed Beef CRC research programs. Thus, we attempted to measure the *marginal* economic benefits of the proposed research programs. Crucially, the measured benefits have to be defined as net of any ongoing benefits derived from past RD&E and net of the expected benefit from any alternative RD&E programs that most likely would have been implemented in the absence of CRC funding. What we were looking to measure was the marginal return to all participants in the Australian cattle and beef industry, both domestically and internationally, from the additional investment attributable to the renewed CRC.

Choice of broad approach to the assessment

This measurement task could have been done in either of two ways (see The Allen Consulting Group 2003). A "bottom-up" approach would involve examining a range of proposed project areas on a case by case basis, estimating the expected benefits from each of these project areas, and then aggregating the expected benefits over the entire proposed RD&E program. However the nature of the proposed scientific programs in the CRC was such that there was a lot of interlocking projects, where resources were applied across a number of projects and where outputs from some projects become inputs into other projects. Under these circumstances it was difficult to allocate costs across project areas and it was equally as difficult to apportion benefits to individual project areas.

The alternative is a "top-down" approach. Here, overall rates of productivity improvement were examined and the role of technological change in generating this productivity growth was assessed. Expert opinion was used to disaggregate the shares of potential productivity growth due to the CRC across the various outcome areas, and the benefits from the expected shifts in these various outcomes were then estimated. That was the approach followed here.

Choice of modelling framework

The DREAM benefit-cost analysis program (Wood, You and Baitx 2001) was selected as the modelling framework to undertake the required assessments. This program is based on the economic principles developed in the highly regarded text *Science Under Scarcity* (Alston, Norton and Pardey 1995), and it has been widely used in impact assessment studies over a number of years by many different national and international institutions.

DREAM has a number of different sub-models representing different types of market situations. One of these is the "horizontal multi-market" option. This provides a means of assessing the economic impact of a new technology in the context where the product under study is (relatively) freely traded across a number of regions, a situation closely approximated in the Australian beef industry. Northern and Southern Australia, and traditional and potential export markets, can all be defined as separate regions. This facility was considered crucial given that some of the technologies in the renewed CRC would have a particular North or South focus. Unfortunately, selection of one of the market situation options in DREAM precludes joint use of the other options. Choosing to focus on the multi-regional and traded status of the industry meant that we could not simultaneously generate information on the impact of the proposed RD&E in the vertical market segments of the industry (such as feedlots, processors, retailers, etc.). Thus, the transactions modelled essentially referred to the farm-gate as the point of exchange and the values we chose reflect this market level.

Two other relevant constraints in DREAM are that (a) we can only analyse one product market at a time (so we cannot jointly examine different types or qualities of beef such as grass-fed and grain-fed, or competing products such as lamb, pork or chicken), and (b) we can only analyse a supply shift or a demand shift, but not both.

The Beef Equilibrium Displacement Model (Zhao *et al.* 2000, Zhao, Griffith and Mullen 2001) would have been an alternative aggregate beef industry modelling framework to use. It has a well-developed vertical market structure and is also well regarded by industry, but the trade section of that model is relatively weak and it has no linkages to the beef markets in the rest of the world.

In our implementation of the DREAM model for this assessment, we defined each Australian state as a separate region (where Western Australia is separated into North and South) and later in the analysis we aggregated these into Northern and Southern Australia. Four separate export markets were defined - the US, Japan, Korea and an aggregate Rest of World. Australian beef was allowed to be available in all possible regional markets and to compete with beef from all possible regional suppliers.

Data required

The economic models underlying the DREAM software are equilibrium displacement models just like the EDM, and they require the same basic sets of input data: (1) "equilibrium" prices and quantities, to define the size and structure of the market in each defined region under consideration at a specified point in time; (2) 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 RD&E); and (3) some idea of how the proposed RD&E will change either producers' cost structures or consumers' willingness to pay for different quality products in the region(s) where the technology will be adopted (the so-called K shift).

For this study, the financial year 2001/02 was chosen as the base year for the price and quantity data. This was the most recent year where the full set of required data was available, prior to the disruptions to markets caused by the drought. The analysis used "real" values based on 2001/02 values. This year was considered to be broadly representative of the peaks and troughs of the world beef market during the coming couple of decades, taking into account the inevitable consequences of the US cattle cycle (Griffith and Alford 2002, 2005) and the increasing risks associated with market disruptions caused by droughts and disease outbreaks.

The base price and quantity data for each region are given in Table 1. Notes explaining calculations relating to these data are given under the table.

Table 1. Base Price and Quantity Data, Beef and Veal, 2001/02

Region	Production (ktcw)	Consumption (ktcw)	Beef Exports (ktcw) (ktsw)	Cattle Exports (ktcw) (head)	Price ($AU/tonne)
NSW	474	296	204	0.733 3877	3130
VIC	355	171	144	8.464 44785	3223
QLD	978	129	556	28.507 150829	2634
SA	86	54	37	4.571 24184	2714
WA	96	68	21	62.608 331258	2550
TAS	45	17	21	-	2773
NT	1	7	-	50.121 265190	2592
AUST	2034	742	1292 984	155.0 820139	
US	11762	12268	(506)		4016
JAPAN	457	1207	(750)		5110
KOREA	190	580	(390)		4295
ROW	35753	35399	354		4016
WORLD	50196	50196	0		

Source: Unless otherwise noted, all data are from *MLA Statistical Review July 2001 - June 2002*

Notes: Consumption in each state is calculated as 35.5 kg/capita times state population for 2001/02 as given in ABS (2003), *Australia at a Glance*, Cat. No.1309.9. Live cattle exports are assumed to have a live weight of 350kg and an average dressing percentage of 54%. In the model, these equivalents are added to production in each Australian State, to ROW consumption and to both world production and consumption. In the model WA is split into north and south; in the absence of firm data, production is set equal in both halves and demand is set to 50 in the south and to 18 in the north. Domestic prices are for steers 260-300 kg HSCW; NT price is an average of QLD and WA; US price is Australian boneless cow beef, 90%CL, FAS; Japan price is Australian chilled boneless grassfed fullset, FAS; Korea price is unit value of all Australian beef and veal exports to Korea, FOB.

Ktcw is 000 tonnes carcase weight; ktsw is 000 tonnes shipped weight

Table 2. Base Supply and Demand Elasticity Values

Region	Supply Elasticity	Demand Elasticity
NSW	1.00	-0.33
VIC	1.00	-0.33
QLD	0.75	-0.27
SA	1.00	-0.33
WA (north/south)	0.75/1.00	-0.27/-0.33
TAS	1.00	-0.33
NT	0.75	-0.27
US	1.00	-3.00
JAPAN	0.70	-2.00
KOREA	0.70	-2.00
ROW	1.00	-5.00

Source: The base values are taken from Zhao *et al*. (2000)

The base elasticity values are given in Table 2. These were taken mainly from Zhao *et al*. (2000). We note that the domestic demand elasticities given in Zhao *et al*. (2000) were reduced by 2/3 to reflect the demand at the farm level modelled here rather than demand at the retail level modelled in that study. The demand elasticities were scaled down to reflect the ratio of the approximate farm price of $3/kg divided by the approximate retail price of $10/kg. The demand elasticities for the Northern states were set lower than those for the Southern states because of fewer possible substitute products available to consumers. Also, the demand elasticities for US, Japan, Korea and the ROW are export demand elasticities for Australian product, and therefore were set as being moderately elastic. While there are many possible substitute products available to consumers in these regions and many possible sources of supply of beef, each of these regions still implement some form of border protection policy which constrains the ability of importers to fully react to price changes. Finally, the supply elasticities for the extensive Northern states were set lower than those for the Southern states because of less flexibility in enterprise choices and expansion opportunities. The same reasoning held for Japan and Korea compared to the US and the ROW.

The relevant measures of K are defined in the assessments for each version of the proposed RD&E programs that follow in Section 3 below. The data in Tables 1 and 2 plus the relevant measures of K allow DREAM to calculate the gross annual benefits from a shift in demand or supply brought about by the proposed RD&E program.

Because DREAM undertakes a rigorous benefit cost analysis, information is also required on the following variables and parameters (Wood *et al*. 2001): costs of the RD&E and the lag before results are available, adoption rates, lags and levels, dis-adoption if relevant, probability of success in producing the expected outputs, the time period over which the RD&E program is to be assessed, the discount rate, the degree to which regions are linked together by prices, and whether the technology is to be available outside the region where the RD&E occurs (see also Marshall and Brennan 2001). Data on these variables and parameters are discussed below[3].

3. Defining the with-CRC and without-CRC scenarios

Given the "top-down" approach employed, the potential outcomes were discussed with a wide range of scientists, extensionists and managers involved in the renewal process and most of the assumptions made below are based on the consensus views from these discussions.

Resource availability

We took the total cost for the proposed CRC for Beef Genetic Technologies to be $110m over the seven year life of the CRC, made up of $30m in Commonwealth CRC funding, $5m in private sector cash contributions, and $75m in in-kind contributions[4].

If the CRC was not funded, our estimate of the total cost of an alternative seven year RD&E program was $65m, made up of $5m in private sector cash contributions (essentially MLA funding) and $60m in in-kind contributions from the currently cooperating agencies involved in beef industry RD&E. Staff in industry organisations and in specified programs of some agencies such as State Departments would continue to be involved in beef industry RD&E irrespective of the existence of a renewed CRC, as would other in-kind resources such as cattle and land. However, staff in other agencies like CSIRO or universities or foreign partners would have greater flexibility to change direction and undertake RD&E in other industries. Based on discussions with research and extension managers, our assessment was that some 80 per cent of in-kind resources would still be involved in beef industry RD&E activities if the CRC for Beef Genetic Technologies was not funded.

Rates of productivity improvement

Two crucial pieces of input data for the analysis of the benefits of the proposed CRC were the underlying rate of productivity improvement in the Australian beef industry and the expected rate of productivity improvement if the CRC proposal was funded. To assist in making some judgements about these inputs, a review of past studies on productivity growth and returns to RD&E investments in the livestock industries was undertaken (see Appendix A). Based on this review, we estimated that the underlying potential rate of productivity improvement available to the beef industry was about 5 per cent pa. This was based on documented measured rates of productivity improvement of 1.0-1.5 per cent pa (ABARE 2004) and rates of adoption of new technologies by the beef industry in the order of 25 per cent (MLA pers. com. 2004).

We estimated the aggregate impact of the renewed CRC on the Australian cattle and beef industry to be an additional 4 percentage points in the potential annual rate of productivity improvement. This would occur after maximum adoption of the research outcomes of the CRC. Such a figure reflected recent estimates of the benefits flowing from specific genetic technologies (for example Burrow *et al*. 2003a,b; Farquharson *et al*. 2003; Griffith *et al*. 2004), the strong expectations by the scientists involved that CRC funding would provide the resources necessary to duplicate these types of successes in the future, and the estimates by Manson and Black (2004) that 95 per cent of the measured rates of productivity improvement in the Australian beef industry were attributable to RD&E investment (see also Wilson 2006). For example, the huge benefit captured by the Northern Australian beef industry in infusing *Bos indicus* genes (some $8.1 billion in present value terms over the past 30 years or so), was based on an improvement in herd gross margin of some 50 per cent (Farquharson *et al*. 2003, p26). This converts into an implied productivity improvement of about 16 per cent for that production system. Similarly, the potential huge benefit of moving into composite cattle in the Northern herd is based on improvements in herd gross margins of 14 per cent for grass-finishing and 22 per cent for grain-finishing. These figures imply an improvement in productivity of between 5 and 8 per cent for that production system. Taking account of both the high expectations of the scientists involved and the risks involved in achieving such high payoff outcomes again, a conservative estimate of just a 4 percentage points addition to the underlying potential annual rate of productivity improvement, was selected[5].

Distribution of the overall rates of productivity improvement

The wide range of participants in the renewal process reached some consensus on the relative contributions of each of the seven major outcome areas to the success of the new CRC. We used these consensus estimates to allocate the selected overall potential rate of productivity improvement across different types of impacts based on the RD&E activities in the various proposed programs of research. These shares are shown in the central column of Table 3, that is, 20 per cent of the total productivity impact comes from the beef quality improvement outcome, 10 per cent from the reduced feed cost outcome, etc. We took these overall allocations to relate to the whole Australian industry. Based on the material provided for each of the science programs in the Prospectus document (CRC for Cattle and Beef Quality 2004), we further allocated these impacts as cost-saving (C), yield-increasing (Y) or demand-enhancing (D), and as applying to either the Northern industry, the Southern industry, or to both. These allocations are shown on the left-hand-side of Table 3.

Therefore, due to the expected impacts of the proposed CRC, on the left-hand side of the table we assumed an overall 9 per cent potential rate of growth in productivity in the Australian cattle and beef industry, or an increase of 4 percentage points on the estimated underlying rate of potential productivity growth. This 9 per cent figure was then allocated across the various impact areas according to the proportions shown in the centre column. Thus, in the second row of the table, 20 per cent of the 9 per cent overall figure, or 1.8 per cent, was estimated to be due to increased beef quality[6]. Half of this 1.8 per cent was assumed to directly influence consumer demand; the other half was assumed to be reflected in reduced transactions costs throughout the marketing chain. These costs were further assumed to be split 50:50 between the north and the south, with cattle numbers assumed to be approximately 50:50 between the north and the south over the simulation period, so each region has the same cost saving of 0.9 per cent. For the impact areas of increased yield, increased reproduction rates and miscellaneous enhanced management, the cost savings were equally spread between north and south, so their values were the same for both regions. Reduced input costs were assumed to have an impact only in the north, so the impact there has to be twice as large as the aggregate national impact of 0.9 per cent. Conversely, reduced feed costs were assumed to have differential impacts in the north and south, but mainly in the south, so their impacts have to average out at 0.9 per cent.

Table 3. Specific Assumptions about RD&E Impacts

With-CRC (9% potential productivity improvement)			**Component of Growth**	**Without-CRC (5% potential productivity improvement)**		
North C or Y	South C or Y	Demand D	(aggregate share of each component in brackets)	Demand D	North C or Y	South C or Y
C (0.9)	C (0.9)	D (0.9)	Increased beef quality (0.2)	D (0.5)	C (0.4)	C (0.4)
C (0.45)	C (1.35)		Reduced feed cost (0.1)		C(0.2)	C (0.8)
C (1.8)	C (0)		Reduced input costs (0.1)		C (0)	
		D (0.9)	Increased market access (0.1)	D (0.5)		
Y (0.9)	Y (0.9)		Increased yield (0.1)		Y (0.6)	Y (0.9)
Y (2.7)	Y (2.7)		Increased reproduction rate (0.3)		Y (2.0)	Y (1.0)
C (0.9)	C (0.9)		Misc. enhanced management (0.1)		C (0.9)	C (0.9)

To summarise, in the with-CRC scenario, the components of the 9 per cent potential productivity growth that go into the DREAM model included:

- a 1.8 per cent increase in demand for Australian beef in the domestic market and in Australias share of high value export markets (Japan and Korea),
- a 4.05 per cent decrease in the cost of producing Australian beef in the North,
- a 3.15 per cent decrease in the cost of producing Australian beef in the South,
- additionally, a 3.6 per cent increase in output in the North, and

- additionally, a 3.6 per cent increase in output in the South.

It is explicitly assumed (see also Table 4) that none of the productivity improving technologies spills over into other countries. This was a simplifying assumption at the time as each of the major beef R&D countries was competing directly against each other and it seemed unlikely that IP agreements and royalty payment systems would be a reality in the short to medium term. Since then the beef R&D market has changed dramatically and the Beef CRC is now part of an international consortium of gene marker research and commercialization agencies. However it remains the case that many of the gene markers tested so far are both breed and population specific, which limits the potential for effective spillovers.

In the absence of any funding from the Commonwealth CRC program from 2006 onwards, we assumed that under the reduction in available funding, some of the planned RD&E would still be done, some would be partially done and some would never be done. Our estimate was that the current underlying rate of potential productivity gain would be just maintained, that is, at around 5 per cent. Further, based on discussions with several groups of the scientists involved in the process, our estimates of the expected changes in the various components of the overall program are given on the right-hand-side of Table 5.

Without CRC funding, on the right-hand side of the table we assumed an overall 5 per cent potential rate of growth in productivity in the Australian cattle and beef industry. In a similar way as described above, this 5 per cent figure was then allocated across the various impact or outcome areas according to the proportions shown in the centre column. Thus, 20 per cent of the 5 per cent overall figure, or 1.0 per cent, was estimated to be due to increased beef quality. Half of this was assumed to directly influence consumer demand, and the other half was assumed to be reflected in reduced transactions costs. However, this is an area of RD&E that would suffer proportionally more from the lack of Commonwealth funds and the impact on costs would not be 0.5. There was a similar expected reduction in impact in the area of reduced input costs. Both of these areas rely heavily on the gene expression and gene discovery infrastructure proposed in the new CRC. These areas are offset to some extent by assumed greater than proportional impacts in increased yield, in reduced feed costs in the South (as the net feed efficiency work (Griffith *et al.* 2004) progresses) and in cost savings due to miscellaneous enhanced management (traditional areas of RD&E by State Departments that would continue without CRC funding).

To summarise, due to the expected impacts of an alternative RD&E program that would still go ahead if the proposed CRC was not funded, we assumed:

- a 1.0 per cent increase in demand for Australian beef in the domestic market and in Australia's share of high value export markets (Japan and Korea),
- a 1.5 per cent decrease in the cost of producing Australian beef in the North,
- a 2.1 per cent decrease in the cost of producing Australian beef in the South,
- additionally, a 2.6 per cent increase in output in the North, and
- additionally, a 1.9 per cent increase in output in the South.

Adoption profiles

Mullen and Cox (1995, 1996) estimated a minimum of 15 years before changes in R,D&E investments in Australian broadacre agriculture are reflected in measurable changes in productivity growth rates. Beef cattle genetic technologies in particular take a long time to produce measurable change. By their nature they have very small initial impacts that slowly accumulate in the population over time. For example, Farquharson *et al*. (2003) examined changes in BREEDPLAN genetic parameters between 1985 and 2000 and found only small changes in weight measures. There were no measurable changes in carcase quality traits by 2000, even though the R&D on these had commenced at least a decade earlier. Griffith *et al.* (2004) calculated that after 25 years of adopting net feed intake technology, the improvement in the net feed intake of a typical southern Australian herd was only 6.9 per cent.

However, these long lags will be shortened by the assumption that the CRC commercialization and adoption strategies, and to a lesser extent the commercialization and adoption strategies in an alternate RD&E program, also impact on the adoption of existing pipeline stocks of technologies produced from previous CRCs or elsewhere. Thus it was expected that there would be some measurable change in adoption of new technologies, attributable to CRC activity, in the short to medium term.

In the without-CRC scenario, we assumed that adoption rates and adoption levels would continue on from current levels in a similar way that the current underlying rate of potential productivity improvement would continue. Although there is no published specific evidence on these parameters, based on discussions with research and extension staff we assumed a 7-year R&D lag, a maximum adoption level of 25 per cent, and a 5-year lag till that level was reached. This fits broadly with the Mullen and Cox timeframe.

In the with-CRC scenario, there was an explicit focus on adoption methodologies and industry take-up of the outcomes generated (in particular a continuous improvement and innovation cycle). The CRC had a stated target of reaching the adoption ceiling within two years of the CRC technologies becoming available. In addition, the RD&E itself would be more coordinated and intense, and adoption and commercialization activities would be developed as the R&D was being undertaken, not just when it was finished. Because of these factors, there were expected to be shorter lags in achieving results and in industry adopting them, and an overall higher level of industry adoption (see Vere *et al*. 2003 for similar assumptions in relation to Weeds CRC activities). Thus, we assumed a 5-year R&D lag, a maximum adoption level of 35 per cent, and a 2-year lag till that level was reached[7].

With the lack of specific resources for equipment, etc, we also assumed that the overall quality of the work would be slightly diminished, with slightly lower probabilities of successful outputs, in the without-CRC scenario. These assumptions, and common assumptions across all assessments, are given in Table 4.

Table 4. Common Assumptions for the Benefit Cost Analysis

Item	Without-CRC	With-CRC
Base year	2006	2006
Simulation period (years)	25	25
Real discount rate (%)	4.00	4.00
Probability of success (%)	70	80
RD&E lag (years)	7	5
Adoption lag (years)	5	2
Maximum adoption level (%)	25	35
Dis-adoption lag (years)	None	None
Price linkages (L) between regions (0<L<1)	Imperfect (L around 0.8)	Imperfect (L around 0.8)
Technology spillovers (S) between regions (0<S<1)	Allowed within Aust but not between Aust and other countries	Allowed within Aust but not between Aust and other countries

4. Results and discussion

The DREAM modelling framework described and tested above was simulated under four separate scenarios, ie, the with- and without-CRC scenarios for each of the demand and supply shifts. As noted above, in the DREAM framework it is not possible to jointly model more than one type of shift, one type of product, or one type of market environment. These results are reported in Table 5 and 6 for the with-CRC and without-CRC scenarios, respectively.

Table 5. Results for the With-CRC Scenarios, 2006-2030, PV ($M)

Shift	Region	Producer Benefits	Consumer Benefits	Total Benefits	Total Cost	NPV	BCR
Demand	Northern Australia	5	21	26			
	Southern Australia	5	95	100			
	Export markets	152	315	467			
	All markets	162	431	593			
Supply	Northern Australia	691	1	692			
	Southern Australia	628	5	633			
	Export markets	-299	311	12			
	All markets	1020	317	1337			
TOTAL		1182	748	1930	98	1832	20

Table 6. Results for the Without-CRC Scenarios, 2006-2030, PV ($M)

Shift	**Region**	**Producer Benefits**	**Consumer Benefits**	**Total Benefits**	**Total Cost**	**NPV**	**BCR**
Demand	Northern Australia	1.341	5.631	6.972			
	Southern Australia	1.236	25.152	26.388			
	Export markets	40.163	82.909	123.072			
	All markets	42.740	113.692	156.431			
Supply	Northern Australia	176.866	0.338	177.214			
	Southern Australia	177.525	1.374	178.899			
	Export markets	-81.034	84.271	3.237			
	All markets	273.357	85.983	359.341			
TOTAL		316.097	199.675	515.772	58.057	457.715	8.88

The with-CRC scenario

In the with-CRC scenario, the total benefits from the demand-enhancing components of the portfolio have a present value of about $593m when summed over the 25-year period of the simulation. More than half of these benefits accrue to consumers in export markets because of the greater size of these markets and the higher prices that consumers in these markets are willing to pay for higher quality, compared to Australian consumers. Producers in our export markets, and in competing supply regions, also gain from this investment since the overall demand for beef is increased and they are large suppliers to these markets. Domestic producers and consumers gain about $125m from these impact areas. The annual benefit of this set of impacts is $55m after reaching maximum adoption levels, with about $12m accruing in Australia.

The total benefits from the cost-reducing and yield-increasing components of the portfolio have a present value of about $1.337b when summed over the 25-year period of the simulation. The great majority of these benefits accrue to cattle producers in Australia because they have direct access to the new technologies. Consumers in our export markets are also beneficiaries as they have access to more beef at lower prices. However, producers in our export markets, and in competing supply regions, lose from the research program since they suffer the consequence of an overall fall in prices but do not have the cost savings from the technologies to compensate. The annual benefit of this set of impacts is about $124m after reaching maximum adoption levels, with about $123m accruing in Australia.

Total estimated benefits from the with-CRC scenarios are in the order of $1.930b. The present value of the full costs of the CRC program (nominally $110m) is $98m when discounted. This results in a net present value of $1.831b ($1.930b - $98m) and a benefit cost ratio of 19.65:1 ($1.930b/$98m). Thus the proposed research portfolio of the CRC for Beef Genetic Technologies is expected to return around $20 for every $1 invested.

Since the demand-side and supply-side simulations had to be run separately, we were not able to calculate an IRR for the whole RD&E portfolio. However, if all of the $98m in costs were set against the cost-saving and yield-increasing impact areas, this would generate a BCR of 13.6:1 and an IRR of 47.8 per cent.

The without-CRC scenario

In the without-CRC scenarios, the pattern of benefits is much the same as in the with-CRC scenarios although the magnitudes are of course lower. Total benefits from the demand-enhancing components of the portfolio have a present value of around $156m when summed over the 25-year period of the simulation, but most of these accrue to foreign producers and consumers and only $33m accrues to the domestic industry. The annual benefit reaches $19m at maximum adoption levels, $4m of which accrues to the domestic industry. Total benefits from the cost-reducing and yield-increasing components of the portfolio have a present value of almost $360m, with an annual benefit at full adoption of around $44m. Almost all of this accrues to the domestic industry.

With total estimated benefits of $516m and total costs of $58m, the NPV is $458m and the BCR is 8.9:1. If the CRC were not funded and an alternative RD&E program was developed along the lines as that assumed here, with funding restricted to some $65m over seven years, it is estimated that this program would only return about $9 for every $1 invested. Again, we were not able to calculate an IRR for the whole RD&E portfolio, but if we assume all of the $58m in costs were set against the cost-saving and yield-increasing impact areas, this would generate a BCR of 6.2:1 and an IRR of 22.4 per cent.

The marginal returns

We are primarily interested in the differences between these two scenarios, that is, the marginal returns from the marginal investment by the Commonwealth Government. These are shown in Table 7.

Table 7. Differences between the with-CRC and without-CRC scenarios, PV and NPV ($m)

Scenario	Region	Producer Benefits	Consumer Benefits	Total Benefits	Total Cost	NPV	BCR
With-CRC	Total Market	1182	748	1930	98	1832	20
Without-CRC	Total Market	316	200	516	58	458	9
Difference		865	548	1414	40	1374	35

Under the assumptions made in this assessment, investing $30m of taxpayer funds into the CRC for Beef Genetic Technologies will leverage another $15m of in-kind contributions from research providers. This is relative to a scenario where an alternative, lower cost research program into the Australian cattle and beef industry is implemented. These extra resources have a discounted value of about $40m over the period of the analysis undertaken here. 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.

As shown in Table 7 the benefit from this extra investment and consequent research effort was estimated to be worth over $1.4b in present value terms, far in excess of the marginal investment. Every $1 of these extra resources brought into the Australian beef industry through funding the CRC for Beef Genetic Technologies was expected to return around $35 to the industry.

Conclusions

Under the assumptions made in this assessment, investing $30m of taxpayer funds into the proposed CRC for Beef Genetic Technologies will leverage another $15m of in-kind contributions from research providers, and these $45m in extra funds will generate an expected benefit of just over $1.3b to the Australian beef industry. There was therefore a sound economic argument for funding the CRC for Beef Genetic Technologies: the outcomes will contribute substantially to Australia's industrial, commercial and economic growth; and the funding sought will generate a return and represents good value for the taxpayer. The Commonwealth Government agreed and wrote the cheque!

Further, it is apparent that both the with-CRC and without-CRC results fit comfortably in the ranges of outcomes covered in the studies reviewed in Tables A1 and A2. In particular, the BCR and IRR calculated for the with-CRC scenarios are of similar orders of magnitude to other large programs of RD&E such as all previous beef cattle genetics R&D, all broad-acre agriculture, and all ARC projects.

Other potential benefits from this investment such as economy-wide benefits, environmental benefits and social benefits, are reviewed in Griffith *et al*. (2006).

This information should be useful for other groups involved in justifying large integrated investment packages such as CRCs, ARC large grants and other collaborative ventures (see for example Griffith, Vere and Jones 2006; Jones, Griffith and Vere 2006).

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Appendix A: A review of returns from investments in agricultural research

Measured productivity growth in Australian broadacre agriculture between the mid-1970s and the mid-1990s averaged 2.7 per cent per year (Knopke, Strappazzan and Mullen 1995; Mullen 1997). The performance of specialist producers within this broad category has varied from 0.9 per cent for the sheep industry to 1.0-1.5 per cent for the cattle industry to 3.4 per cent for the cropping industry. Since these are measured rates of growth, we can estimate the underlying *potential* rate of productivity improvement available to the beef industry to be in the order of about 5 per cent given anecdotal evidence of low adoption rates in the order of 25 per cent.

Using these same data, Mullen and Cox (1995, 1996) and Cox, Mullen and Hu (1997) in a series of papers estimated that the return to Australia from public sector investments in broad-acre agriculture RD&E have been in the range of 15 to 40 per cent.

This is consistent with international studies of the returns to agricultural research investments. Alston, Marra, Pardey and Wyatt (2000) have recently reviewed almost 300 studies of RD&E in agriculture which provided more than 1800 estimates of rates of return. The data period covered 1958 to 1998 and the studies came from a range of universities, government departments and international institutions across both the developed and developing worlds. The rate of return across all studies (with some extreme outliers excluded) ranged from -100 per cent to +910 per cent. The average was 59 per cent. The rate of return for livestock-only studies was not significantly different from this average, but that for research and extension together (47 per cent) was significantly less than for research-only studies. They went on to argue that the rate of return may be much lower than those reviewed, and may be closer to 10 per cent, because of measurement problems in many earlier studies.

Rates of return information for some studies relating to Australian livestock industries are given in Tables A1 and A2.

Appendix Table A1. *Ex Ante* Appraisals of Livestock Industries Research and Extension Proposals

Nature of Project	Year	BCR/IRR
Pasture management		5
Pasture establishment		9
Bomoxynil tolerant sub-clover		24
Biological control of Paterson's Curse		38%
National forage conservation network - dairy	1999	6
Wool production from mixed lucerne/perennial grass pastures in Northern NSW	2000	3
Spring v's Autumn lambing in the Central West of NSW	1998	3
Sub-clover breeding		39
Cattle quality in South Africa	2000	11
Whole farm planning	2000	27

Appendix Table A2. ***Ex Post*** **Evaluations of Livestock Industries Research and Extension Projects**

Nature of Project	Year	BCR/IRR
Grafton crossbreeding research	1992	8.5 13.5%
Trangie/Glen Innes growth rate selection in beef	1992	3.2 13.5%
Developing and using BREEDPLAN	2000	9
Beef cattle genetics (selection and crossbreeding only) in Australia	2002	3.6 19%
Beef cattle genetics (all sources) in Australia	2002	28
Net feed efficiency cluster of projects	2003	9.6 14%

For example, a NSW Agriculture review of returns to the NSW beef industry from investments in selection and crossbreeding RD&E was conducted in 1992 as part of an RD&E program evaluation (Parnell, Cumming, Farquharson and Sundstrom 1992). That review estimated that the Grafton crossbreeding program would yield a NPV of approximately $170 million by 2020, a BCR of 8.5:1 and an IRR of 13.5 per cent. Corresponding figures for the Trangie/Glen Innes program were $170 million, 3.2:1 and 13.5 per cent. See also Barlow *et al*. (1989).

Graser and Barwick (2000) estimated a NPV of over $350 million and a BCR of over 9:1 for the genetic improvements from developing and using BREEDPLAN (1985-2005, 8 per cent discount rate).

Farquharson *et al*. (2003) estimated that over all sources of genetic gain, the total return to the Australian beef industry from genetic technologies since 1970 was $9.4bn against a total investment of $340m. The benefit/cost ratio for this investment is 28:1 over the last 30 years. The biggest contribution to this high benefit/cost ratio has been the infusion of better-adapted *Bos indicus* genetic material into the sub-tropical and tropical herd (although a less reliable method was used to estimate this class of benefits). But even if these northern adaptation benefits are ignored, and all costs are attributed to the other sources of value (within-breed selection, southern crossbreeding and changing breed mix in the south), beef genetics RD&E has generated a NPV of $921 million, a BCR of 3.7:1 and an IRR of over 19 per cent. When only the benefits to selection and cross-breeding are included, the rate of return calculated in this study is less than the average of the studies included in the Alston *et al.* (2000) report. However, the rate of return obviously would be much larger than the average if the benefits from the changing breed composition in the Northern herd were also included.

In a follow-up analysis, the economic performance of a terminal crossbreeding system based on Brahman cows and a tropically adapted composite herd were compared to a straight-bred Brahman herd (Burrow *et al*. 2003a). All systems were targeted to meet specifications of the grass-finished Japanese market. The production system modelled represented a typical individual central Queensland integrated breeding/finishing enterprise or a northern Australian vertically integrated enterprise with separate breeding and finishing properties. Due mainly to a reduced age of turnoff of crossbred and composite sale animals and an improved weaning rate in the composite herd, crossbred and composite herds returned a gross margin of $7 and $24 per Adult Equivalent (AE) respectively above that of the Brahman herd. These figures are equivalent to a 4 per cent and a 14 per cent improvement in profitability respectively. The benefits of changing 25 per cent of the existing 85 per cent of

Brahmans in the northern Australian herd to either crossbreds or composites over a 10-year period were also examined. With no premium for carcass quality in crossbred and composite sale animals, annual benefits were $16m and $61m for crossbreds and composites in 2013. The cumulative present value of this shift over the 10-year period was $88m and $342m respectively, discounted at a nominal 7 per cent. When a potential 5c per kg premium for carcass quality was included, differences in annual benefits rose to $30m and $75m and cumulative present values to $168m and $421m for crossbreds and composites respectively.

A similar analysis was undertaken for the same crossbred and composite animals targeted at the 120 day grain-finished export market (Burrow *et al*. 2003b). The faster growth rate of the crossbred and composite herds and their improved feed efficiency resulted in a gross margin of $38 per AE respectively above that of the Brahman herd. These figures are equivalent to about a 22 per cent improvement in profitability. The gross margin increases by another $5 per AE if just 15 per cent of steers achieve a higher marbling score (worth 10c/kg) and by another $9 per AE if there were to be a 5c/kg premium for tenderness on an assumed 60 per cent of steers. Again, the benefits of changing 25 per cent of the existing 85 per cent of Brahmans in the northern Australian herd to either crossbreds or composites over a 10-year period were examined. With no tenderness premium in crossbred and composite sale animals, annual benefits were some $108m in 2013. The cumulative present value of this shift over the 10-year period was $600m, discounted at 7 per cent. When a 5c per kg premium for tenderness was included, differences in annual benefits rose to $130m and cumulative present values to $730m for crossbreds and composites.

A recent study examined the return on investments in a cluster of projects associated with net feed efficiency (Griffith *et al.* 2004). Comparing the benefits to all recipients in southern Australia relative to the costs incurred by all RD&E suppliers resulted in an NPV of $176.7 million, an IRR of 14 per cent and a BCR of 9.6. Again, while the aggregate benefits are of course much smaller, the rates of return match those found for selection and crossbreeding in the Farquharson *et al*. (2003) study.

In other industries, during 1991/92 the Grains Research and Development Corporation commissioned an independent economic analysis of 16 selected grains RD&E projects undertaken over the previous 15 years (GRDC 1992). Using a 10 per cent discount rate, the benefit cost ratios ranged from 3:1 to 297:1, the rates of return ranged from 34 per cent to 561 per cent, and the aggregate present values of the benefits exceeded the aggregate present values of the costs by just over $1 billion.

In summary, we estimate that the underlying potential rate of productivity improvement available to the beef industry is in the order of about 5 per cent pa. Evaluations of specific livestock sector RD&E projects undertaken in Australia and overseas suggest IRRs in the range 10-20 per cent and BCRs in the range 3-10. Although there have been some studies suggesting much higher IRRs or BCRs, these are either older studies which may have had measurement problems, or studies relating to more specific, rather than more general, types of technical change. Beef genetics studies have generally fallen within the suggested ranges, excluding the very high rates of return estimated from first the Brahman infusion into Northern Australia and then the potential shift into composite breeds. These two areas of RD&E suggest rates of productivity improvement in the order of 25-30 per cent, but the first at least has been and gone.

Appendix B. The impact of assumptions about adoption levels and lags

In these experiments, the supply-side without-CRC scenario from the renewal analysis is set as the base case for this paper. This has a 7-year R&D lag, a 5-year adoption lag and a 25 per cent adoption ceiling (ie, 7,5,25). The productivity improvements and the increased probabilities of success are ignored for the time being. Then, the implications of imposing the improved adoption parameters from the with-CRC scenario are examined individually and jointly. These are a 5-year R&D lag, a 2-year adoption lag and a 35 per cent adoption ceiling (ie, 5,2,35).

For simplicity, the incremental costs to achieve different levels of adoption are assumed away the without-CRC scenario has a discounted cost of $58m irrespective of the pattern of adoption.

Finally, the changes in these adoption parameters are compared with the deduced changes in the risk and productivity parameters.

Some of the key results from these experiments are outlined in Appendix Table B1. Results are reported in terms of present value of benefits (PVB), present value of costs (PVC), net present value (NPV=PVB-PVC), all in $m; benefit-cost ratio (BCR=PVB/PVC); internal rate of return (IRR, where NPV=0) and the change in farm gate price at the end of the adoption period.

Appendix Table B1. Sensitivity of the without-CRC supply-side scenario to assumptions about adoption lags and rates

Case	PVB ($M)	NPV ($M)	BCR	IRR (%)	Price Change ($/t)
1. Base case (7,5,25)	359	301	6.2	22	-0.28
2. Adoption lag reduced by 2 years	389	331	6.7	25	-0.28
3. Adoption lag reduced by 3 years	405	347	7.0	26	-0.28
4. R&D lag reduced by 2 years	422	364	7.3	29	-0.28
5. Adoption ceiling raised to 35%	504	446	8.7	27	-0.39
6. Best case (5,2,35)	661	601	11.4	43	-0.39

The base case is shown in row 1. Thus continuation of current cost-reducing or yield-increasing R&D programs and current adoption practices, that are expected to occur if the CRC had not been renewed, are projected to provide benefits to the Australian beef industry of some $360m over a 25 year time horizon when estimated at a 4 per cent real discount rate. This would result in a BCR of 6.2:1 when measured against the costs incurred. The IRR is around 22 per cent and at the end of the period of market adjustments brought about by the new technologies, beef prices are expected to be marginally lower than they would otherwise have been.

If the adoption lag could be reduced from five years to three years (row 2), with no other changes, net benefits to the whole beef industry (producers and consumers in Australia and overseas) would improve by $30m on a NPV basis. This is the result of compressing the partial benefits accrued during adoption from five years to three years, and adding another two years of full benefits to the stream of benefits over time. For comparison, if the R&D lag could be reduced from seven years to five years (row 4), net benefits to the industry would improve by $63m, more than twice that from a similar improvement in the adoption lag. This is the result of two years of extra benefits in years 6 and 7 in the future (the end of the R&D lag) being worth much more than two years of extra benefits in years 11 and 12 in the future (the end of the adoption lag).

If the adoption ceiling could be increased from 25 per cent to 35 per cent (row 5), net benefits to the industry would improve by $145m. This is the result of the extra 10 per cent of the market adopting the technology from year 13 onwards. Thus increasing the adoption ceiling has a larger economic impact than speeding up the adoption rate, in this case.

If the R&D and adoption profiles could be aligned with those assumed in the with-CRC scenario (the best case in row 6), net benefits to the industry would improve by $300m. This result shows that the overall gains from jointly speeding up and increasing adoption in line with the best case scenario are greater than the sum of the components themselves (sum of rows 3,4,5=$254m above the base case). Note that there have been large changes in the BCR and the IRR from this scenario.

The results described above are consolidated in Appendix Table B2 and compared with the other components of the difference between the with-CRC and without-CRC supply-side scenarios.

Appendix Table B2. Components of the total estimated benefits from the with-CRC supply-side scenario

Component	$ million	%
1. With-CRC (9,5,2,35,80)	1,337	
- Contribution of productivity improvements	582	0.595
2. Without-CRC (5,5,2,35,80)	755	
- Contribution of probability of success	94	0.096
3. Without-CRC (5,5,2,35,70)	661	
- Contribution of adoption parameters	302	0.309
4. Without-CRC (5,7,5,25,70)	359	

Line 4 is the without-CRC base case taken from Appendix Table B1: a 5 per cent potential productivity trend, a 7-year R&D lag, a 5-year adoption lag, a 25 per cent adoption ceiling and a 70 per cent probability of a successful outcome (ie, 5,7,5,25,70).

Line 1 is the with-CRC best case taken from the renewal analysis: a 9 per cent potential productivity trend, a 5-year R&D lag, a 2-year adoption lag, a 35 per cent adoption ceiling and a 80 per cent probability of a successful outcome (ie, 9,5,2,35,80). The best case generates an estimated benefit of some $1,337m, so there is a difference of just under $1b between the two extreme cases. The question here is what is the contribution of the changes in the three adoption parameters to explaining this difference, in comparison to the contribution of the changes in productivity and in the probability of success?

Line 3 can be taken directly from Appendix Table B1: with the adoption parameters changed from (7,5,25) to (5,2,35) and nothing else changed, the benefit to the beef industry is estimated to increase by $302m to $661m. This change represents 31 per cent of the overall difference between the with-CRC and without-CRC supply-side scenarios.

Line 2 can be estimated easily because the probability of success is just a scaling factor that shifts the gross benefits up and down in the same proportion as the change in the assumed probability. Thus increasing the probability of success from 70 per cent to 80 per cent is equivalent to a percentage change of 14.29 per cent. Increasing the line 2 value of $661m by 14.29 per cent gives a new value of $755m. The contribution of the probability of success factor is then $94m or just under 10 per cent of the overall difference.

Finally, the residual of $582m is therefore the contribution of the assumed increase in the underlying rate of potential productivity growth due to the renewed CRC: this is just under 60 per cent of the overall difference.

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[1] Thus the analysis reported here was mostly completed by March 2004, although some minor adjustments were made for submission of the Stage II case. Some new information relevant to the analysis (in particular new estimates of productivity growth in the beef industry) has since been released but has not been incorporated in this analysis.

[2] **Gene discovery** refers to finding genes that impact on economically important attributes in cattle and developing diagnostic tests for them (for example, the GeneSTAR marbling test). **Gene expression** refers to understanding the function of the genes associated with economically important traits and identifying non-genetic approaches that can be used to influence the expression of these genes (for example, growing cattle in feedlots to better express their marbling potential). **Accelerated adoption** refers to reducing the adoption lag and/or raising the adoption ceiling in the beef industry.

[3] Before proceeding with the analysis it was necessary to test that the modelling framework developed here provides outputs of the same order of magnitude as other types of modelling frameworks in particular that reported by Zhao *et al*. (2000). This test is described in Griffith, Parnell and McKiernan (2006). The conclusion was that the DREAM model as implemented here gives a similar measure of the total benefits from RD&E in the Australian cattle and beef industry as that reported by Zhao *et al*. (2000) for the beef EDM, when the input data are correctly adjusted for the different base years.

[4] These were the confirmed contributions as at March 2004. New partners that have committed since then have increased the total cost to over $121m.

[5] Although a 9 per cent rate of potential productivity improvement seems large, when this rate is multiplied by the expected adoption level of 35 per cent it is noteworthy that the implied actual or measured rate of productivity improvement is only just over 3 per cent. The Australian grains industry exceeded 3 per cent annual productivity growth long ago, and according to the latest ABARE data, the northern Australian beef industry is close to 3 per cent already.

[6] This is not the ideal way to measure the benefits from improvements in quality but it seems to be the only feasible way in this case given the constraints of the software.

[7] Given that the adoption parameters are probably the most uncertain in this whole analysis, we conducted some simulation experiments to test the impacts of various assumptions (Griffith and Vere 2006). Some of the results of these experiments are summarised in Appendix B and in Appendix Tables B1 and B2.