The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology

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Australian Government
Australian Centre for
International Agricultural Research

The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology

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June 2008

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International Agricultural Research

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Foreword

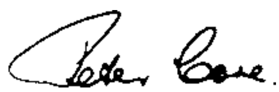
The Australian Centre for International Agricultural Research's impact assessment activities continue to develop a more structured approach to selection of the research activities that impacts are quantified for. This trend is towards more stratified random sampling for selection of research efforts, and use of a country, program or theme focus.

In this study a combination of these factors was used. India has been a long-term partner for ACIAR activities, and a range of research efforts has been supported. The nature of the partnership relationship is changing with rapid economic development in India. It was thus opportune to consider the impact of past efforts and to use a better understanding of them to guide future partnership activities. A brief review of past impact assessment studies for India and an overview of all projects completed in that country were used to guide two case studies for impact assessment. This report presents the results for one of these.

The brief review of past impact assessment studies of Indian projects indicated that all but one had been of crop research. It was felt that it would be important to look more closely at livestock activities. As indicated in the report, this project was selected using a 'top-down, quasi-random process'. The project was not chosen with a prior expectation of large benefits, rather it was selected because it was in the livestock program and had been finished long enough for impacts, if generated, to be seen and measured.

The dairy industry is a large and important sector for India and availability of quality feed is a significant issue for cow productivity. The project assessed in this study focused on this major constraint and adapted some technologies readily available in Australia to suit the types of feed available in India. The impact has been substantial, with relatively rapid adoption. The study shows that the returns on investment are very high with a net present value of benefits of $232.1m, a benefit:cost ratio of 124:1 and an internal rate of return of 43.8%.

The impacts were estimated using the feed-plant facilities constructed during and after the project. However, information collected during the project visit suggests an additional 20 plants could be developed in the future. This will be on top of the five plants currently in production or being developed. It was too early to be certain that these additional plants will be built so the impact of this potential additional capacity was not included. If these additional plants are developed, the impact of the research will be substantially higher than the results presented in this report.



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From: Monck M. and Pearce D. 2008. *The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology*. ACIAR Impact Assessment Series Report No. 53, 32 pp

Summary

This report presents the findings of an economic impact assessment of ACIAR project AH/1997/115 on *Increasing efficiency and productivity of ruminants in India and Australia by the use of protected-nutrient technology*.

The project was found to have impacts on farmers that yielded benefits after costs were taken into consideration. These benefits are partially dependent on training provided to Indian staff as part of the project, enabling them to maintain production of high-quality, bypass protein-feed supplements. There are also minor benefits from the increased knowledge and awareness of occupational health and safety practices that were not previously employed, and increased knowledge of bypass protein and lipid supplements, quality-control practices and nutritional-evaluation methods. These benefits, being limited to one laboratory used throughout the research, are very small in comparison to the gains from productivity increase and are not quantified as part of this study.

For Australia the benefits are small and not quantified in this study. They arose mainly through the establishment of research networks with partners in Indian research institutions.

The benefits that are quantified in this study (Table 1) accumulate to over $230 million and have required an expenditure of only $1.9 million. Using the relative funding contributions as a basis for attribution, almost half of the benefits can be attributed to ACIAR. Furthermore, it is possible that these benefits are underestimated as more plants using the technology developed during the project are planned. National Dairy Development Board staff suggested that more than 20 extra plants are in the pipeline but the uncertain nature of this planning prevents the benefits arising from this additional capacity from being valued here.

The overall benefit:cost ratio for the project is 123.6:1, which gives an internal rate of return of 43.8%.

Table 1. Summary benefits and costs of ACIAR project AH/1997/115

Item	Unit	To total project funding	To ACIAR funding
Total costs (excluding feed)	*$m*	1.90	0.95
Total benefits	*$m*	234.00	114.80
Net benefits	*$m*	232.10	113.90
Benefit:cost ratio	*Ratio*	123.60	121.20
Internal rate of return	*%*	43.83	42.31

Note: All values are discounted at 5% and deflated to 2007 dollars.

Source: Centre for International Economics' estimates

From: Monck M. and Pearce D. 2008. *The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology*. ACIAR Impact Assessment Series Report No. 53, 32 pp

1 Introduction

This study presents the findings of an economic impact assessment of AH/1997/115 on *Increasing efficiency and productivity of ruminants in India and Australia by the use of protected-nutrient technology*. The project was not selected for assessment because of an a priori expectation of large benefits but through a top-down, quasi-random process. Within the constraint of seeking a project in India relating to animals it was chosen simply because it had been completed long enough for benefits to be seen and measured.

The commissioned organisation for the project was initially CSIRO and subsequently the Faculty of Veterinary Science at the University of Sydney, which partnered with the National Dairy Development Board (NDDB) in India. Funding was sourced from ACIAR and the partnering organisations and, over the course of 4 years, totalled $2.8 million in nominal terms.

The project took an existing technology and modified it to make it suitable for production of bypass protein-feed supplement in India in order to overcome nutritional deficiencies in ruminants. Pilot plants were established for production of the feed and, since completion of the project, others have been established and more are planned.

The benefits from productivity gains accrue to India but both partner countries also benefit from the establishment of working relationships with one another in the area of feed-supplement research. India in particular has built up a good stock of knowledge and established a laboratory that has earned an excellent reputation for research.

Chapter 2 of this report outlines the project. It discusses the history of the problems that the project investigated, and the solutions proposed. The research outputs and outcomes are detailed together with some of the final impacts. Chapter 3 summarises the parameters used in quantifying the impacts. The methodology used in estimating the benefits is also explained. Chapter 4 presents the findings of the analysis and tests the sensitivity of the results to changes in key parameters. The paper finishes with concluding remarks in Chapter 5.

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2 The project

Poor nutrition is a major limitation to ruminant production in many parts of India and some regions in Australia. The lack of nutrition results in reduced availability of bypass protein and fat, and lowers the levels of essential amino acids and energy to below those needed for even reasonable levels of production.

At the time of the project India had a population of around 970 million people with some 70% of them involved in agricultural activities, typically in a small-farm setting. Since that time the population has grown by around 13% to over 1.1 billion, presenting a significant challenge in terms of meeting the nutritional requirements of the people. ACIAR project AH/1997/115—*Increasing efficiency and productivity of ruminants in India and Australia by the use of protected-nutrient technology*—sought to help meet this challenge by increasing the level of nutrition available in stock feed and subsequently improving the productivity of livestock.

CSIRO has developed a formaldehyde treatment technology that protects lipids and protein feedstuffs from digestion in the rumen, allowing them to be digested in the remainder of the gastrointestinal tract. This enables a better balance of nutrients to be absorbed, resulting in an improvement in productivity (Ashes et al. 1995). The technology has been used successfully in Australia but only with high-quality substrates. The technology has resulted in a 10–15% improvement in milk output of high-production dairy cows (25–30 litres per day). Adapting the technology to feed stocks available in India and transferring the technology to farmers will assist in their attempts to meet the demands of consumers.

History of the problem and the project

The Indian Government recognised the high-priority need to add value to the large amounts of agricultural by-products available. The executive director of NDDB wrote (Banerjee 1994):

> The adoption of appropriate technologies for production, procurement, processing and marketing—after the unique environmental, social, economic, political and cultural environment of the individual country has been considered—is an important aspect of dairy development.

Since India has similar conditions to those in Australia but significantly lower milk yields per animal it was envisaged that Australian production systems could be adapted to suit Indian farmers.

Around two-thirds of the 680 million people involved in agriculture in India live in villages displaying a range of climatic conditions. Landholdings tend to be small, generally ranging between 1 and 10 acres (0.4–4 ha), with milk-producing ruminants being an important resource. These animals provide milk and income, and are a source of fuel, fertiliser and draught power for farming.

Traditionally, farmers fed their animals on by-products such as straw. The nutritional value of these feed stocks is low and reduces the productivity of the animal. The challenge for the project researchers was to transform these by-products into a more valuable feed stock that will enhance the nutritional uptake of the animal and improve productivity through higher milk yields.

Many groups around the world have been involved in research that aims to improve the feed-to-production ratio and reduce costs associated with wastage. Australia in particular undertook considerable amounts of research in the area of protected nutrients. The work was supported by various industry bodies and aimed to improve milk yields and enhance meat quality.

The proponents of the project were of the view that the protected-nutrient technology as developed by CSIRO during this period could assist Indian researchers and farmers to develop optimally protected feed and deliver improved feeding strategies. This would not only increase milk yields but also improve the quality of the product.

Talks were held between the Indian Government, the NDDB and CSIRO Animal Production, and a proposal for ACIAR project AH/1997/115, a research program based on the following hypotheses, was developed:

1. If suitable raw materials can be identified and cost-effective treatment procedures developed it will enable the production of 'optimally protected' feed supplements with enhanced nutritive value for dairy cows.
2. The inclusion of these protected feed supplements in the diet of dairy cows will enhance milk production, milk metabolites such as fat/protein and overall reproductive performance by providing key nutrients to alleviate the deficiencies that exist in the feeding regimes of dairy cows in India.
3. The production and utilisation of protected feed supplements will add value to the different segments of the Indian economy, including the oilseed and dairy sectors, with concomitant socioeconomic benefits.

The research proposal detailed five objectives and their expected outputs, as shown in Table 2.

The project was initially due to commence in mid 2000 and finish in 2002, but an extension to this time frame was approved and it was completed in late 2006.

Funding for the project came from the collaborating organisations: CSIRO, NDDB and ACIAR. The budgeted contributions for CSIRO and NDDB were $783,213 and $169,477. Actual expenditures are not available. CSIRO left the project before its completion, reducing its planned expenditure to $682,896. Over the course of the project ACIAR budgeted for expenditure of $556,514. Its actual contribution was $821,152, the increase due in part to the extension of the project. One of the project leaders, Dr Suresh Gulati, left CSIRO during the research and joined the University of Sydney but continued to participate in the project. Assuming the actual expenditure from CSIRO and NDDB was as planned, the total expenditure would have been almost $1.7 million in nominal terms.

Research outputs and outcomes

The research identified several by-products—sunflower meal, guar-bhardo and rapeseed meal—that were suitable as input to bypass protein meal, and a pilot plant was built in Anand, India in April 2001. The plant was capable of producing 150 kilogram batches of bypass protein meal with 75% rumen undegradable protein (RUP) at a time. This was used for feeding trials.

Trials of the feed with cows and buffaloes in the Gujarat (western) region of India replaced 1 kilogram of untreated meal per animal per day with 1 kilogram of the processed feed. The results of the trials are listed in Table 3 and showed yield increases of between 0.7 and 1.1 litres per day depending on the by-product used in the feed and the type of milch animal being examined.

Other trials were undertaken in different parts of India with the results for the Karnal (northern) and Orissa (eastern) regions being similar. Results for trials in the Kerala (southern) region of India showed slightly smaller increases in yield.

Farmers are typically paid on the basis of the fat content of the milk they are producing. This means that while the first trial involving sunflower meal in cows yielded the biggest increase in milk production, potential increases in farmer income may lie elsewhere. Table 4 shows the increase in fat content of milk produced from animals using by-product protein meal compared with those using untreated feed.

A study done by the Centre for Development Studies (Garg et al. 2005) confirms that farmer incomes did rise. They found that incomes increased most for those farmers with buffaloes, followed by those with local cows, while those with crossbred cows gained the smallest benefit. The additional income per animal net of bypass protein costs for these farmers was estimated to be Rs12.41, 9.26 and 7.28, respectively.

Table 2. Objectives and expected outputs of ACIAR project AH/1997/115

Objective	Expected outputs
To develop improved procedures to protect Indian and Australian by-product nutrients	Estimation of protection responses under Indian conditions Digestibility and bio-availability of nutrients Production response data in dairy cows in India: (a) milk production responses (volume) (b) quality of milk Improved protection procedures for application in India and Australia
To identify and evaluate 2–3 of the most appropriate Indian by-products and develop a protected-protein pilot plant	Nutrient composition, physical and chemical evaluation of Indian by-products Optimal protection curves for identified materials Estimation of the degree to which by-products are protected from degradation in the rumen, using in-vitro and in-sacco procedures
To design for India a pilot plant to produce optimally protected lipid supplements and to evaluate Indian protected lipid with Australian protected-lipid nutrients	Responses of protected Indian by-products in dairy cows on: (a) milk production responses (b) quality changes of milk (c) economic benefits under various regional production systems
Evaluation of Indian protected by-products—protein and lipid nutrient supplements	Suitable processes available for adoption by Indian industry
The application in Australia of improved methods to protect nutrients and the identification of new Australian non-conventional by-products as ruminant feeds	Production data in ruminants in Australia In dairy cows: (a) milk production responses (b) quality of milk In sheep: (a) wool growth responses (b) economic benefits under various production systems Suitable feeding strategies for less-intensive industries in Australia

Table 3. Increase in milk yield from field trials of by-product protein meal

By-product used in meal and animal type	Yield increase (compared to untreated feed)
	Litres per day
Sunflower meal in cows	1.0
Rapeseed meal in cows—experiment 1	1.1
Rapeseed meal in cows—experiment 2	0.9
Guar meal in cows	0.9
Sunflower meal in buffaloes	0.8
Rapeseed meal in low-yielding cows	0.7

Source: Garg et al. (2005)

Table 4. Increase in fat content from field trials of by-product protein meal

By-product used in meal and animal type	Increase in fat content (compared to untreated feed)
	%
Sunflower meal in cows	0.3
Rapeseed meal in cows—experiment 1	0.2
Rapeseed meal in cows—experiment 2	0.3
Guar meal in cows	0.2
Sunflower meal in buffaloes	0.4
Rapeseed meal in low-yielding cows	0.2

Source: Garg et al. (2005)

Following the success of the trials a new plant was commissioned at Itola in Vadodara in 2002. This plant can produce 120 tonnes of by-product protein meal per month and currently runs at about 50 tonnes per month. Another plant was established in 2005 at Godhra, with a capacity of 300 tonnes per month. Three more plants are planned in the near future: in Rajkot, Gujarat State (50 tonnes per day), the HOSPET Oil Plant, Karnataka (50 tonnes per day) and Kolhapur Milk Union, Maharashtra (25 tonnes per day). Each of these plants supplies (or will supply) bypass protein-feed supplement for cows and buffaloes owned by local villages in their region.

The project also developed a slow-release ammonia source to be used in conjunction with the bypass protein feed. The intention is to incorporate this product, which can increase milk production by a further 5–10%, into existing and future plants. During the field visits to current plants, however, it was not apparent that this technology had been implemented.

A ration-balancing system was also developed by the NDDB to assist farmers to maximise the nutritional and economic benefits of correct utilisation of existing feed resources. Educational programs have been put in place to help disseminate this knowledge to farmers and reduce the cost of milk production.

Each of these outputs has been well documented with over 80 articles contributed to scientific journals during the life of the project. A further 75 media pieces have been released and ACIAR produced for project staff 'Methods for the analysis of protected-nutrient supplements for ruminants', a manual detailing the methods developed and used.

There have been other significant aspects of the project that may lead to benefits. NDDB staff travelled to Australia and were trained in the techniques used to produce bypass protein and lipid supplements, quality-control practices, nutritional evaluation methods, and occupational health and safety requirements. This last-mentioned area has had significant impacts on the way that the Indian researchers conduct their laboratory work, but there is little evidence that these work practices have extended beyond those directly involved in the project.

The Indian researchers who participated in the project have adapted the methods developed by CSIRO (and later the University of Sydney) to measure the rumen-undegraded and rumen-degraded protein (RDP/RUP) content of proteinaceous feedstuffs. These methods have been found to be superior to the standard phosphate buffer procedure currently used in India and plans are being made to adopt them as part of the National Feeding Standards for India.

Furthermore they are continuing their research into bypass protein-feed supplements by examining alternative by-products that can be used in their production. These include oilseeds, oils and other meals. The group doing this work is producing small amounts of bypass feed from these sources and evaluating the role such feeds can play in a nutritional and economic sense in the future. This research is still in its infancy so it is difficult to determine the full set of benefits that will arise. With this in mind no attempt at quantifying them is made here.

Other aspects of the project have seen NDDB establish a well-equipped laboratory that has highly trained staff. The laboratory is regarded as a national resource for further research in the area of feed technology and ruminant nutrition.

While there is no indication that the project has direct benefits outside the Gujarat region in India there is substantial research evidence to suggest the results could be replicated elsewhere in India and other parts of the world.

Figure 1 provides a summary of how the research maps inputs through to final impacts.

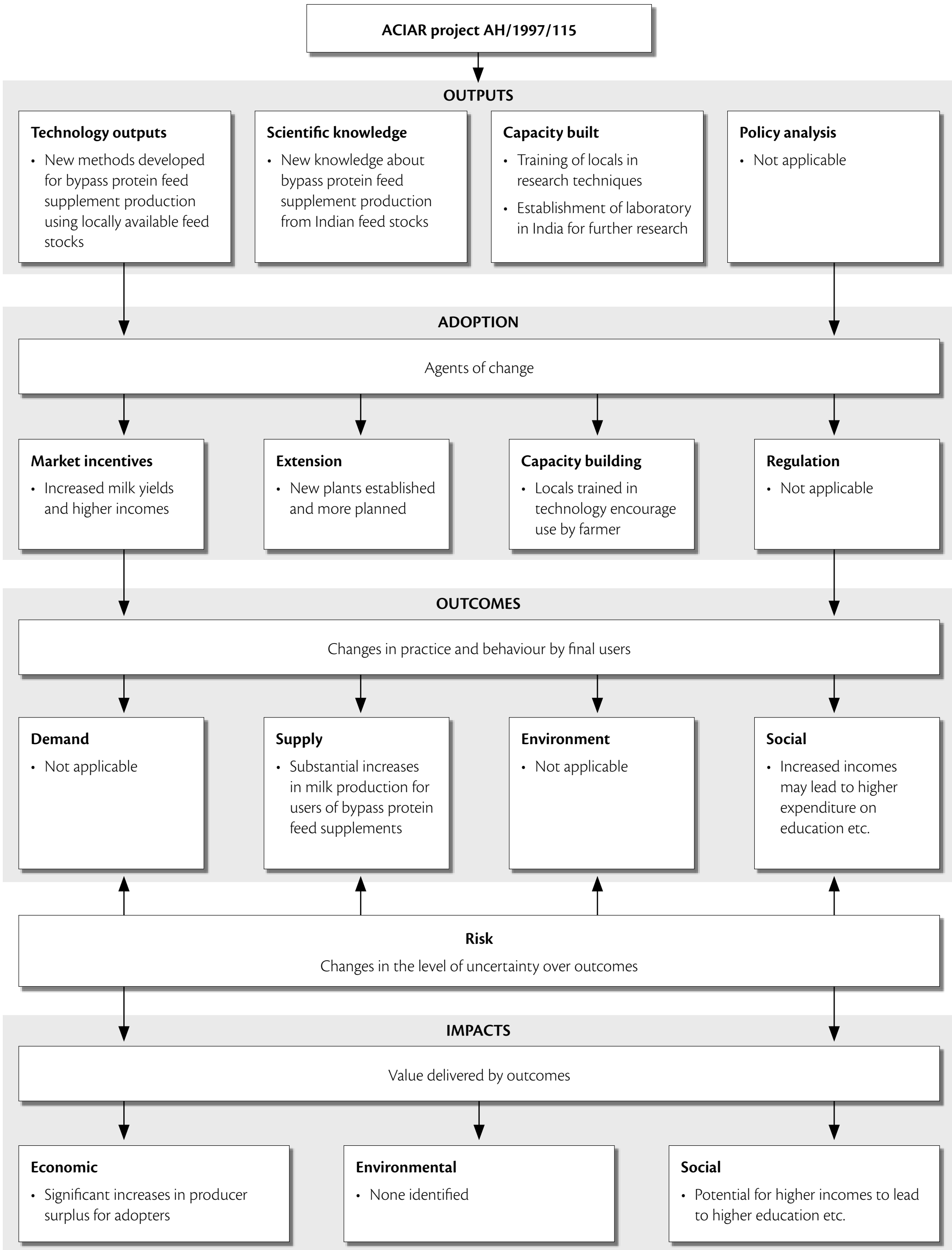

Figure 1. Flow of outputs from project. Data source: Centre for International Economics

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3 Data and methodology

This chapter sets out the key parameters and methodology used to estimate the benefits and costs of the ACIAR project. The data used in the analysis come from a survey of 360 households consisting of 122 bypass protein users and 238 non-users (Garg et al. 2005).

The effect on supply and prices

Within the Gujarat region there are approximately 6.9 million milch animals consisting of local breeds of cows, crossbred cows and buffaloes. Table 5 shows that buffaloes account for almost two-thirds of the total while local cows make up one-third. The remainder are crossbred cows.

The average milk yields in litres per day for each of these classes of animals are 4.58, 7.78 and 4.49, respectively. Feeding the animals 1 kilogram of bypass protein-feed supplements increases the yield by between 0.41 and 1.1 litres per day (Garg et al. 2005). Gulati et al. (2005) review several other studies that support this finding.

Garg et al. (2005) estimate the daily average feed expenditures per head in the Gujarat region to be Rs39.11 for local cows, Rs45.02 for crossbred cows and Rs41.37 for buffaloes. Information collected during field visits to farmers and personal communication with NDDB staff has shown that the cost of feeding the animals 1 kilogram of bypass protein-feed supplement is approximately Rs1.00 per day.

Converting these yields and costs to a per litre basis shows that production costs have decreased from the pre-research levels by Rs1.48, Rs0.17 and Rs0.89 for local cows, crossbred cows and buffaloes, respectively.

Field visits showed that the feed is distributed via the milk collection points which means the composition of animals using the feed is similar to the composition of the total population of milch animals. No assumptions are made about how this composition might change over time. This simplifies the calculations by allowing the use of weighted averages. The weighted average cost saving across all three animal types is Rs1.05 per litre (Table 5).

Furthermore, farmers are better off due to the impacts of the bypass protein feed on quality. In essence, the market for milk in India is a market for fat. As the fat content of milk increases the price received also increases. Therefore, while the price of fat remains constant[1] the per litre revenue for milk can vary. Several studies (Gulati et al. 2002; Garg et al. 2002, 2003) reveal statistically significant increases in the fat content of milk in the order of 4.5–8.6% leading to higher prices. Garg et al. (2005) show the price received for the milk rises by between Rs0.56 and Rs2.38 per litre. Table 6 shows the increases in revenue for every litre of milk. The weighted average increase in revenue is equal to Rs1.72 per litre.

Production and feed requirements

NDDB officials estimate that the initial plant built in Itola achieved 15% utilisation by 2002 and was running at approximately 30% of capacity in 2008. They expect that by 2011 the plant will be running at full capacity. An adoption curve was fitted to these points for use in the analysis.

1 The true demand for fat is not perfectly elastic but, since the overall impact of this project is not large enough to affect price, for simplicity and tractability a perfectly elastic demand curve is used.

Table 5. Milch animal population and cost information

	Local cows	Crossbred cows	Buffaloes
Number ('000)	2,342	340	4,232
Percentage of total population	33.9	4.9	61.2
Yields	L/day	L/day	L/day
Without feed supplement	4.58	7.78	4.49
With feed supplement	5.68	8.19	5.09
Change	1.1	0.41	0.6
Feed costs	Rs/day	Rs/day	Rs/day
Without feed supplement	39.11	45.02	41.37
With feed supplement	40.11	46.02	42.37
Change	1.00	1.00	1.00
Milk production costs	Rs/L	Rs/L	Rs/L
Without feed supplement	8.54	5.79	9.21
With feed supplement	7.06	5.62	8.32
Change	1.48	0.17	0.89
Weighted average change (Rs/L)		1.05	

Source: National Dairy Development Board, India; Garg et al. (2005)

Table 6. Milk revenue increase

	Local cows	Crossbred cows	Buffaloes
	Rs	Rs	Rs
Per litre revenue (before)	9.65	7.60	10.40
Per litre revenue (after)	10.21	8.93	12.79
Increase	0.56	1.33	2.38
Weighted average revenue increase (Rs/L)		1.72	

Source: Garg et al. (2005)

Figure 2 shows the adoption profile for the Itola plant and plants built since then based on advice from NDDB staff. The Itola plant will take approximately 11 years to become fully utilised with 2002 being year 1. The rate of uptake will be determined by both the speed with which the plant can be built and the rate at which farmers adopt the new feed. While dairy production is quite fragmented, dissemination of the feed occurs through the cooperative mechanism. Farmers will initially be sceptical of the new feed but, as more of them begin to use it, the cooperative set-up leads to news of the positive results spreading throughout the community quite rapidly. The adoption profile for a plant thus starts slowly but then picks up rapidly before reaching full utilisation.

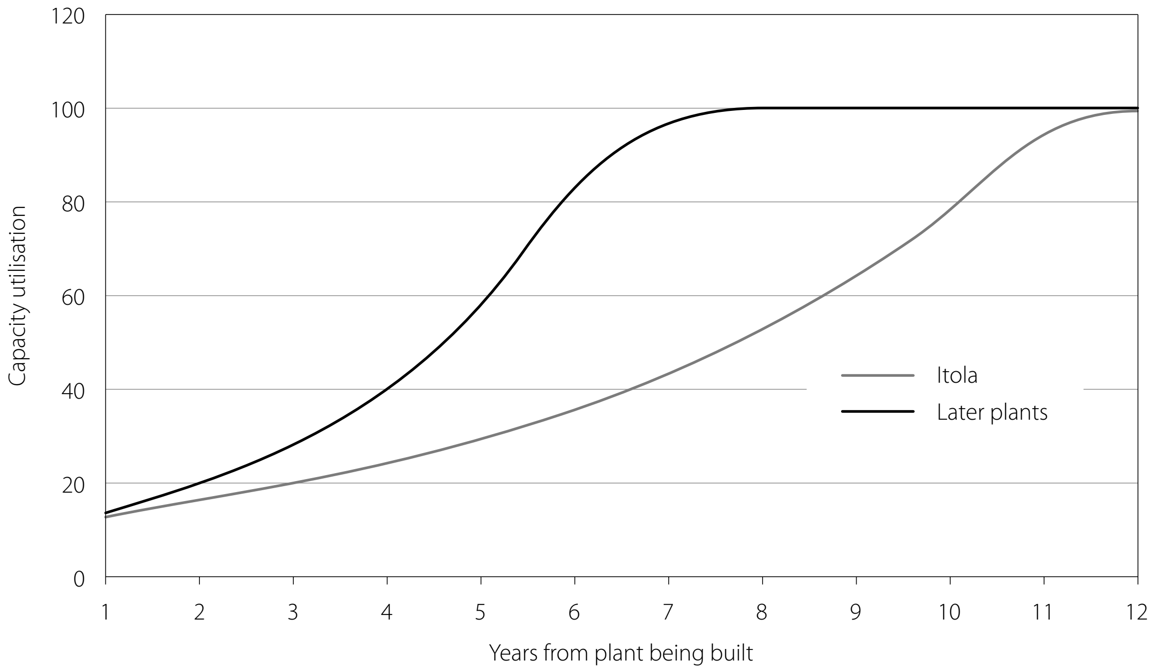

Figure 2. Adoption profiles. Note: Itola plant utilisation is estimated to be 10.896*exp(0.1972*period) while later plants are estimated as 9.2369*exp(0.3677*period). Data source: Centre for International Economics' curves fitted to National Dairy Development Board estimates

The same logic is applied to new plants but the profile is accelerated. It is assumed that the yield increase from the feed is more widely known before more capacity is added, so the utilisation rates of these plants increase faster. These plants utilise approximately 15% of their full capacity in year 1, 30% in year 4 and achieve 100% utilisation by the end of year 6.

The analysis is based on five plants—Itola, Godhra, CFP Rajkot, HOSPET Oil Plant and Kolhapur Milk Union—other plants are planned but they are still quite uncertain at this point and are not included in the analysis. The production capacities and utilisation rates using the NDDB estimates are given in Table 7. By 2020 all plants are running at full capacity, supplying a total of 150 tonnes of feed supplement per day.

Using the NDDB rate of 1 kilogram of feed per animal per day it can be seen that by 2020 when the plants are fully utilised they will be able to serve 150,000 animals per day.

Discount rate, deflator and exchange rate

The discount rate is set to 5% throughout the analysis. The deflator series and exchange rates are taken from Gordon and Davis (2007) and reproduced in Table 8. All values, unless otherwise stated, are converted to 2007 dollars.

Attribution

The funding for the project came from three sources: ACIAR, CSIRO and NDDB. The amounts contributed by each organisation are shown in Table 9. The method used to attribute benefits to ACIAR is based on the relative contributions in terms of funding. ACIAR funding accounted for 49.1% of the total research expenditure for the duration of the project so attribution is fixed at that rate.

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Table 7. Production capacities of feed-supplement plants and utilisation rates over time

	Itola	Godhra	CFP, Rajkot	HOSPET Oil Plant	Kolhapur Milk Union	Total production	Cows fed
Capacity (tonnes/day)	5	20	50	50	25	150	
Utilisation	**%**	**%**	**%**	**%**	**%**	**tonnes**	**number**
2002	13.3	0.0	0.0	0.0	0.0	0.7	664
2003	16.2	0.0	0.0	0.0	0.0	0.8	808
2004	19.7	0.0	0.0	0.0	0.0	1.0	984
2005	24.0	0.0	0.0	0.0	0.0	1.2	1,199
2006	29.2	13.3	0.0	0.0	0.0	4.1	4,129
2007	35.6	19.3	0.0	0.0	0.0	5.6	5,633
2008	43.3	27.8	13.3	0.0	0.0	14.4	14,404
2009	52.8	40.2	19.3	0.0	0.0	20.3	20,315
2010	64.3	58.1	27.8	0.0	0.0	28.7	28,746
2011	78.3	83.9	40.2	13.3	0.0	47.5	47,464
2012	95.4	100.0	58.1	19.3	0.0	63.4	63,440
2013	100.0	100.0	83.9	27.8	0.0	80.9	80,858
2014	100.0	100.0	100.0	40.2	13.3	98.4	98,438
2015	100.0	100.0	100.0	58.1	19.3	108.9	108,854
2016	100.0	100.0	100.0	83.9	27.8	123.9	123,900
2017	100.0	100.0	100.0	100.0	40.2	135.1	135,051
2018	100.0	100.0	100.0	100.0	58.1	139.5	139,518
2019	100.0	100.0	100.0	100.0	83.9	146.0	145,970
2020	100.0	100.0	100.0	100.0	100.0	150.0	150,000

Note: Utilisation rates for individual plants are given as a percentage of total capacity.

Source: Values for Itola and Godhra plants are based on historical information up to 2007 and National Dairy Development Board (NDDB) projections thereafter. All other plants are NDDB projections.

Methodology

Measuring the change in producer surplus offers an indication of the benefits arising from the project. The research has a dual impact on the producer surplus. First it reduces the costs of production, which moves the supply curve downwards. Second, farmers are now receiving a higher price for their output. Figure 3 shows the two effects.

The first effect, a shift in the supply curve, can be seen to increase output from Q_1 to A. Producer surplus is increased by the area P_1P_2ab. This area can be calculated as:

$$0.5 \cdot k_1 \cdot (Q_1 + A)$$

The price effect is estimated in a similar way. The price received by farmers increases by k_2 giving an increase in surplus equal to the area P_3P_4cb. Using the same formula as above, the area is equal to:

$$0.5 \cdot k_2 \cdot (A + Q_2)$$

From: Monck M. and Pearce D. 2008. *The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology*. ACIAR Impact Assessment Series Report No. 53, 32 pp

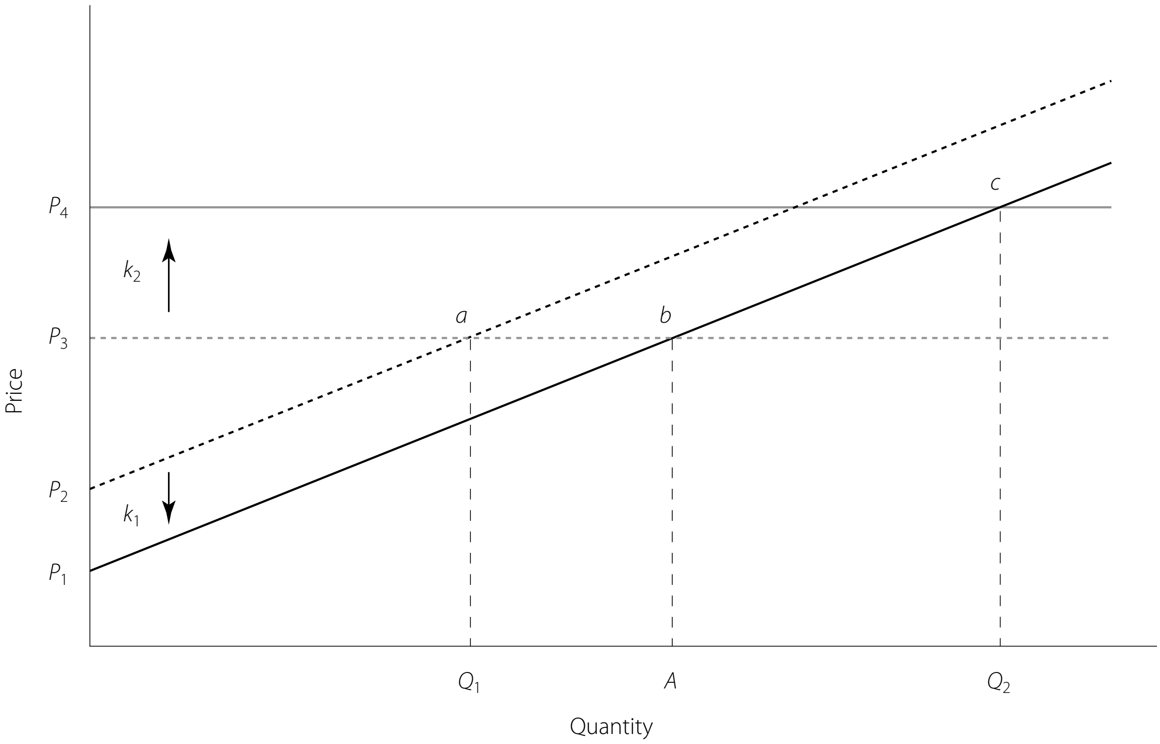

Figure 3. Impact of a productivity boost. Data source: Centre for International Economics

The total producer surplus is therefore equal to:

$$0.5 \cdot k_1 \cdot (Q_1 + A) + 0.5 \cdot k_2 \cdot (A + Q_2)$$

A simple linear supply curve was estimated using the prices and quantities from the survey data. The supply equation was then used to estimate the production of milk at point *A*, allowing the above formula to be applied. This also has the benefit of breaking the surplus benefits into its two components—cost savings and revenue increase. Table 10 reports the values used in the analysis over a 30-year period.

The surplus amounts are then converted to Australian dollars using the rates in Gordon and Davis (2007). These are then discounted at 5% per annum and accumulated. The attribution rate is then applied to determine the benefits that are attributable to the ACIAR funding. By 2028 the benefits have reached a steady state, as per Gordon and Davis (2007). The value of the benefits reported for this year reflects the annuity value of the future flow of benefits. Table 11 shows these values along with the discounted cumulative benefits.

The change in producer surplus is a good estimation of the welfare gains but the research costs must be subtracted from it. These costs are calculated in each year and deducted from the producer surplus, leaving the net benefits. The research and plant establishment costs are shown in Table 12 as nominal values before being deflated to 2007 dollars and discounted.

It is also worth noting that when CSIRO terminated its involvement in the project the University of Sydney provided in-kind support of the project in the form of administrative duties etc. These costs are not captured in the project documentation and are thus excluded from the analysis.

Table 13 summarises the total net benefit flows from the project.

Table 8. Deflator series and exchange rates

Year	Deflator	Exchange rate (Rs/A$)
1999	75.91	27.79
2000	79.06	26.13
2001	82.19	24.42
2002	84.29	26.44
2003	86.96	30.33
2004	89.88	33.37
2005	93.94	33.68
2006	97.53	34.13
2007	100.00	34.13

Source: Gordon and Davis (2007)

Table 9. Project funding contributions

	ACIAR	CSIRO	NDDB	Total
	A$	A$	A$	A$
1999	298,326			298,326
2000	138,286	193,248	50,682	382,216
2001	131,571	279,014	82,135	492,720
2002	108,884	210,634	24,440	343,958
2003	74,000		12,220	86,220
2004	70,085			70,085
Total	821,152	682,896	169,477	1,673,525
Percentage of total	49.1	40.8	10.1	

Note: The project did not commence until mid 2000 but the funding came from the 1999 budget.

Source: ACIAR project documentation

Table 10. Producer surplus calculation inputs

Year	Cost saving (k_1)	Revenue increase (k_2)	Pre-research quantity (Q_1)	New quantity due to cost saving (A)	Total post-research quantity (Q_2)	Surplus from cost savings	Surplus from revenue increase	Total surplus
	Rs/L	Rs/L	L (millions)	L (millions)	L (millions)	Rs (millions)	Rs (millions)	Rs (millions)
1999	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2000	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2002	1.05	1.72	1.13	1.20	1.32	1.23	2.16	3.39
2003	1.05	1.72	1.38	1.47	1.61	1.50	2.63	4.13
2004	1.05	1.72	1.68	1.79	1.95	1.83	3.21	5.03
2005	1.05	1.72	2.05	2.17	2.38	2.22	3.90	6.13
2006	1.05	1.72	7.05	7.49	8.20	7.66	13.46	21.12
2007	1.05	1.72	9.63	10.22	11.19	10.45	18.36	28.81
2008	1.05	1.72	24.62	26.14	28.61	26.73	46.95	73.68
2009	1.05	1.72	34.72	36.86	40.35	37.70	66.22	103.92
2010	1.05	1.72	49.13	52.16	57.10	53.35	93.70	147.04
2011	1.05	1.72	81.12	86.13	94.28	88.08	154.71	242.79
2012	1.05	1.72	108.42	115.12	126.02	117.73	206.78	324.51
2013	1.05	1.72	138.19	146.72	160.62	150.05	263.56	413.61
2014	1.05	1.72	168.23	178.62	195.54	182.68	320.86	503.53
2015	1.05	1.72	186.03	197.52	216.23	202.01	354.81	556.81
2016	1.05	1.72	211.75	224.82	246.12	229.93	403.85	633.77
2017	1.05	1.72	230.81	245.06	268.27	250.62	440.20	690.82
2018	1.05	1.72	238.44	253.17	277.14	258.91	454.76	713.67
2019	1.05	1.72	249.47	264.87	289.96	270.88	475.79	746.67
2020	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2021	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2022	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2023	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2024	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2025	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2026	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2027	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29
2028	1.05	1.72	256.35	272.19	297.97	278.36	488.92	767.29

Source: Garg et al. (2005) and Centre for International Economics' estimates
n.a. = not applicable

Table 11. Project benefits

Year	Total project Benefits	Discounted project benefits	Cumulative benefits	Benefits attributed to ACIAR Funding
	A$ m	A$ m	A$ m	A$ m
1999	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00
2002	0.13	0.11	0.11	0.05
2003	0.14	0.11	0.22	0.11
2004	0.15	0.12	0.34	0.17
2005	0.18	0.14	0.48	0.23
2006	0.62	0.44	0.92	0.45
2007	0.84	0.57	1.49	0.73
2008	2.16	1.39	2.88	1.41
2009	3.04	1.87	4.75	2.33
2010	4.31	2.52	7.27	3.57
2011	7.11	3.96	11.23	5.51
2012	9.51	5.04	16.27	7.98
2013	12.12	6.12	22.39	10.99
2014	14.75	7.10	29.49	14.47
2015	16.31	7.47	36.96	18.13
2016	18.57	8.10	45.06	22.11
2017	20.24	8.41	53.47	26.24
2018	20.91	8.27	61.74	30.30
2019	21.88	8.24	69.99	34.34
2020	22.48	8.07	78.06	38.30
2021	22.48	7.68	85.74	42.07
2022	22.48	7.32	93.06	45.66
2023	22.48	6.97	100.03	49.08
2024	22.48	6.64	106.67	52.34
2025	22.48	6.32	112.99	55.44
2026	22.48	6.02	119.01	58.40
2027	22.48	5.73	124.75	61.21
2028[a]	449.59	109.23	233.97	114.80

[a] The value shown in 2028 is the present value of an annuity for the benefits arising from 2028 onwards.

Note*:* The exchange rate is held constant at Rs34.13 per A$1 from 2007 onwards. Attribution for ACIAR benefits is fixed at 49.1%.

Source: Centre for International Economics' estimates; exchange rate data from Gordon and Davis (2007)

Table 12. Research funding contributions

Year	ACIAR	CSIRO	NDDB	Total costs	Deflated costs	Discounted costs
	$	$	$	$	$ (2007)	A$
1999	298,326			298,326	393,000	393,000
2000	138,286	193,248	50,682	382,216	483,451	460,429
2001	131,571	279,014	82,135	492,720	599,489	543,754
2002	108,884	210,634	24,440	343,958	408,065	352,502
2003	74,000		12,220	86,220	99,149	81,570
2004	70,085			70,085	77,976	61,096
2005						
2006						
2007						
2008						
2009						
2010						
2011						
2012						
2013						
Total	**821,152**	**682,896**	**169,477**	**1,673,525**	**2,061,130**	**1,892,351**

Source: ACIAR project documentation

From: Monck M. and Pearce D. 2008. *The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology*. ACIAR Impact Assessment Series Report No. 53, 32 pp

Table 13. Total net benefit flows

	Discounted benefits	**Costs**	**Net benefits**	**Cumulative net benefits**
	$A million	$A	$A million	$A million
1999	0.00	393,000	−0.39	−0.39
2000	0.00	460,429	−0.46	−0.85
2001	0.00	543,754	−0.54	−1.40
2002	0.16	352,502	−0.24	−1.64
2003	0.17	81,570	0.03	−1.61
2004	0.17	61,096	0.06	−1.55
2005	0.20		0.14	−1.42
2006	0.65		0.44	−0.98
2007	0.84		0.57	−0.40
2008	2.06		1.39	0.99
2009	2.76		1.87	2.86
2010	3.72		2.52	5.37
2011	5.85		3.96	9.34
2012	7.45		5.04	14.38
2013	9.04		6.12	20.50
2014	10.48		7.10	27.59
2015	11.04		7.47	35.07
2016	11.97		8.10	43.17
2017	12.43		8.41	51.58
2018	12.22		8.27	59.85
2019	12.18		8.24	68.10
2020	11.92		8.07	76.17
2021	11.35		7.68	83.85
2022	10.81		7.32	91.17
2023	10.30		6.97	98.14
2024	9.81		6.64	104.78
2025	9.34		6.32	111.10
2026	8.90		6.02	117.12
2027	8.47		5.73	122.85
2028[a]	161.38		109.23	232.08

[a] The value shown in 2028 is the present value of an annuity for the benefits arising from 2028 onwards.

Source: Centre for International Economics’ estimates

From: Monck M. and Pearce D. 2008. *The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology*. ACIAR Impact Assessment Series Report No. 53, 32 pp

4 Results

The project generated benefits well in excess of the costs incurred in undertaking the research. Table 14 presents a summary of the benefits and costs, and shows the benefit:cost ratio to be 123.6. The internal rate of return is 43.8%. The total research costs sum to $1.9 million and the benefits are valued at $234.0 million, giving a net benefit of $232.1 million. Some 49.1% of the net benefits, or $113.9 million, are attributable to ACIAR funding.

Before the first plant began operating in 2002 there are no benefits. They begin to accumulate as each plant opens and increases production of bypass protein-feed supplements. Figure 4 shows how the net benefits accumulate from the beginning of the project through to 2027. Early in the project the net benefits are negative, reflecting the relatively large upfront costs of the research component. By around 2009 these benefits turn positive, accumulating to $122.85 million in 2027. The benefits from 2028 onwards are constant and valued at $109.2 million.

Sensitivity of the results to the assumptions used

The results presented here are dependent on the assumptions surrounding parameters used in the modelling, as outlined in previous chapters. The results will be particularly sensitive to three parameters—revenue increases, cost savings and the discount rate.

The revenue increases and cost savings are dependent on the yield increase that comes from a given amount of feed and the price of the feed. The studies referred to in Gulati et al. (2005) have an average standard deviation of 0.42 litres around the mean milk yield increase. The sensitivity analysis takes this and applies a normal distribution to the yield increase. Feed costs are estimated at Rs1.00 throughout the study but estimates range from Rs0.70 to Rs1.2. A normal distribution is used with a mean of 1.00 and a standard deviation of 0.18. This means that approximately 95% of the observations will fall into the range Rs0.70–1.30.

Table 14. Benefits and costs

		To total project funding	To ACIAR funding
Total costs (excluding feed)	*$m*	1.90	0.95
Total benefits	*$m*	234.00	114.80
Net benefits	*$m*	232.10	113.90
Benefit:cost ratio	*Ratio*	123.60	121.20
Internal rate of return	*%*	43.83	42.31

Note: All values are discounted at 5% and deflated to 2007 dollars.
Source: Centre for International Economics' estimates

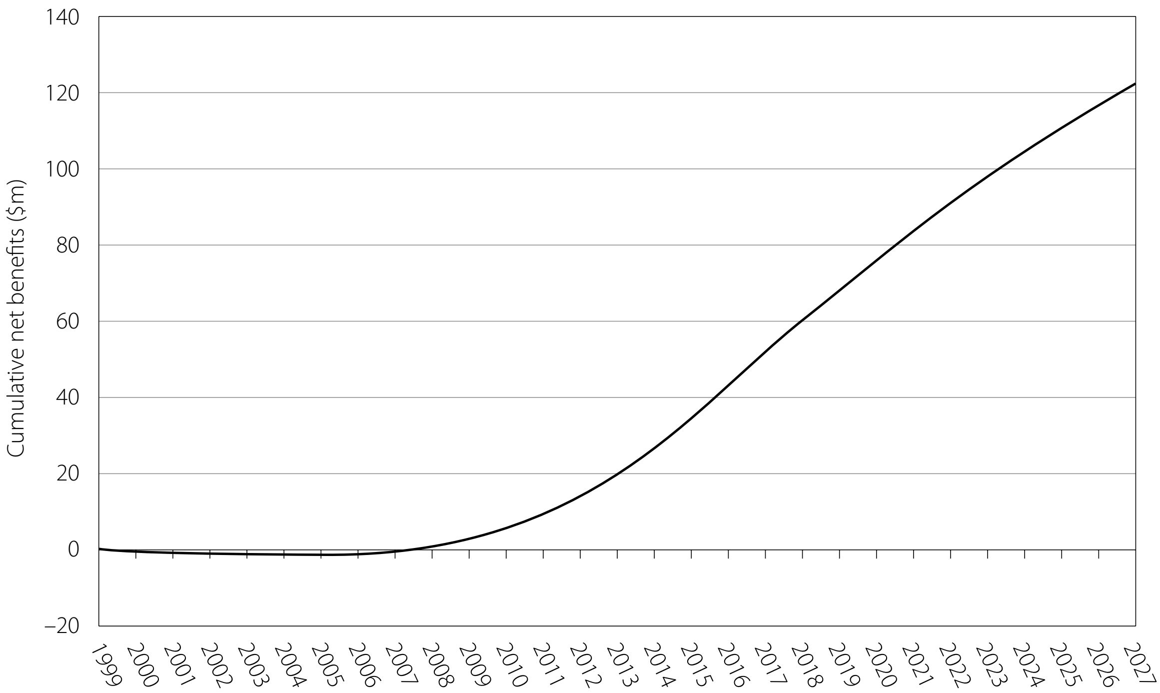

Figure 4. Cumulative net benefits over time. Data source: Centre for International Economics' estimates

Figure 5 shows the distribution of the net benefits with the 95% confidence interval. Applying the parameters as outlined above shows the lower end of the net benefits may fall to $228.0 million with low yields and high feed costs. On the other hand, the benefits may be as high as $239.9 million if the yield increase is at the upper end and feed costs are low.

Using the same inputs the internal rate of return will range from 33.7% to 34.4% while the benefit:cost ratio has a 95% confidence interval of 120.5:1–126.8:1.

Following the impact evaluation guidelines of Gordon and Davis (2007) the impact of the discount rate is also assessed. The guidelines suggest using 0, 5 and 10% but, since using 0% will yield an annuity value of infinity for the final year of benefits, the values 1, 5 and 10% are used here. The net benefits at each of these discount rates are shown in Table 15.

Table 15. Sensitivity of benefits to the discount rate used

		Discount rate		
		1%	5%	10%
Benefits	*$m*	1,955.6	234.0	66.0
Costs	*$m*	2.0	1.9	1.8
Net benefits	*$m*	1,953.6	232.1	64.2
BCR	*Ratio*	965.8	123.6	37.7

Source: Centre for International Economics' estimates

From: Monck M. and Pearce D. 2008. *The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology*. ACIAR Impact Assessment Series Report No. 53, 32 pp

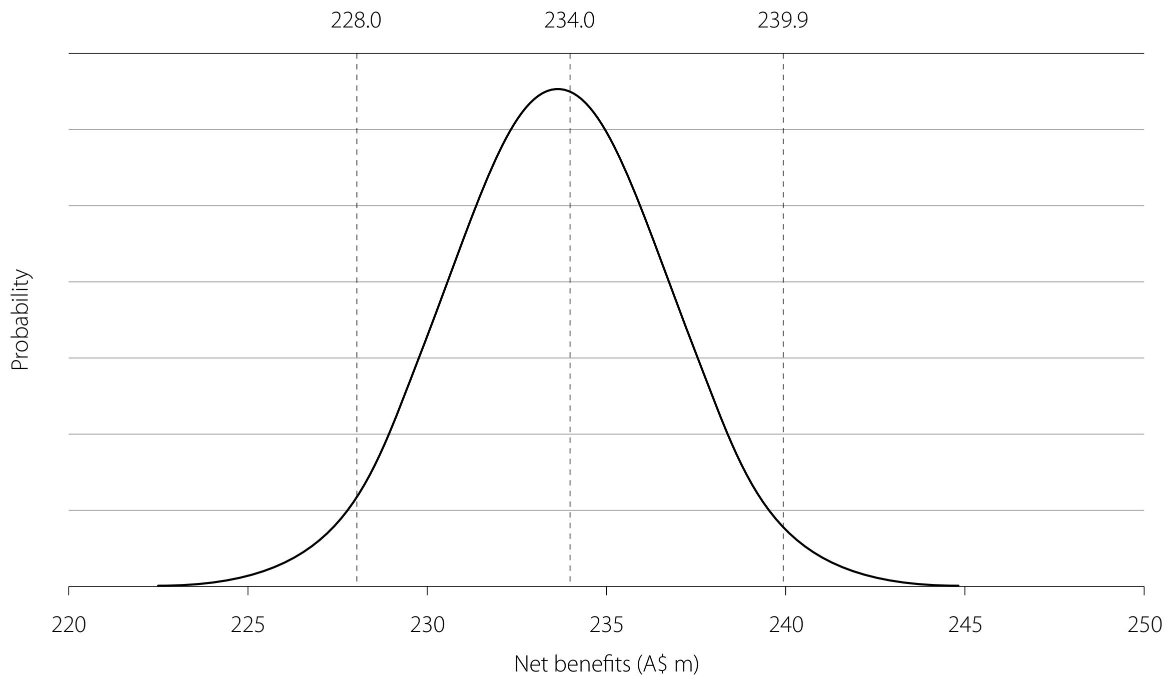

Figure 5. Sensitivity to changes in feed costs and yields. Data source: Centre for International Economics' estimates

From: Monck M. and Pearce D. 2008. *The impact of increasing efficiency and productivity of ruminants in India by the use of protected-nutrient technology*. ACIAR Impact Assessment Series Report No. 53, 32 pp

5 Conclusions

This report examines the economic impacts of ACIAR project AH/1997/115, *Increasing efficiency and productivity of ruminants in India and Australia by the use of protected nutrient technology*. The project sought to solve problems with the low productivity of ruminants due to the low nutritional value of traditional feed stocks. Using the parameters outlined in the report the net benefits of the project are in the order of $234 million, which gives a benefit:cost ratio of 123.6:1. The internal rate of return is 43.8%.

A significant factor in the success of this project is that it was demand driven. The Indian Government identified a problem that needed to be solved and the project was developed around that need. Feed supplements were developed by transferring technology from Australia to India and modifying it to suit Indian conditions. Bypass protein meal is now produced using locally available feed stocks in plants built as part of the project. The simplicity of the technology and the plants required to produce the feed contribute to the overall benefits of the project.

Benefits also arose from the project through the development of strong working relationships between Australian researchers and their Indian counterparts. Some of the Indian researchers travelled to Australia to learn new skills and techniques, many more have been trained locally during the project and since its completion.

Even when the results are tested for sensitivity to changes in certain parameters the net benefits remain positive in all cases. Furthermore it is likely that, with the construction of more bypass protein-feed plants over and above those included in the analysis, the benefits will exceed those shown here. NDDB staff spoke of plans for more than 20 plants in addition to those considered here. The benefits of these will be substantial but, due to the uncertainties surrounding the planning process in these early stages, they have not been included here.

Although this study relies heavily on data from the Gujarat region it is not unreasonable to expect that these results could be extended to other parts of India. Many studies have been done elsewhere[2] that replicate the positive results seen in Gujarat, suggesting that the benefits could be replicated in other regions of India or, indeed, other parts of the world. As the by-product meals used for bypass protein-feed supplement production are available worldwide and have a universally similar composition and nutritional quality there is a potential to use the treatment data and curves developed during the project in other countries. Hence the data and results of the project may be applicable to other developing countries with dairy farming and agricultural systems similar to those in India. Despite this, there is no evidence that this project has directly resulted in any gains outside of the areas considered in this paper.

The benefits to Australia are small at best. The technology used in the project existed and was already used in Australia before the project so adapting it to Indian conditions would yield little, if any, benefit to Australian farming. The main source of benefit would therefore stem from the establishment of new networks between research institutions and the ability to share knowledge amongst researchers.

2 See, for example, Verite and Journet (1977), Madsen (1982), Lundquist et al. (1986), Kairn et al. (1987), Hamilton et al. (1992), Sampath et al. (1997) and, more recently, White et al. (2000).

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IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A. (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Waterhouse, D., Dillon, B. and Vincent, D. (1999)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh, P. (1999)	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod, R. (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell, C. and Wilson, C. (2001)	Breeding and feeding pigs in Australia and Vietnam AS2/1994/023	
18	Vincent, D. and Quirke, D. (2002)	Controlling *Phalaris minor* in the Indian rice–wheat belt	CS1/1996/013
19	Pearce, D. (2002)	Measuring the poverty impact of ACIAR projects—a broad framework	
20	Warner, R. and Bauer, M. (2002)	*Mama Lus Frut* scheme: an assessment of poverty reduction	ASEM/1999/084
21	McLeod, R. (2003)	Improved methods in diagnosis, epidemiology, and information management of foot-and-mouth disease in Southeast Asia	AS1/1983/067, AS1/1988/035, AS1/1992/004 and AS1/1994/038
22	Bauer, M., Pearce, D. and Vincent, D. (2003)	Saving a staple crop: impact of biological control of the banana skipper on poverty reduction in Papua New Guinea	CS2/1988/002-C
23	McLeod, R. (2003)	Improved methods for the diagnosis and control of bluetongue in small ruminants in Asia and the epidemiology and control of bovine ephemeral fever in China	AS1/1984/055, AS2/1990/011 and AS2/1993/001
24	Palis, F.G., Sumalde, Z.M. and Hossain, M. (2004)	Assessment of the rodent control projects in Vietnam funded by ACIAR and AUSAID: adoption and impact	AS1/1998/036

No.	Author(s) and year of publication	Title	ACIAR project numbers
25	Brennan, J.P. and Quade, K.J. (2004)	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014
26	Mullen, J.D. (2004)	Impact assessment of ACIAR-funded projects on grain-market reform in China	ANRE1/1992/028 and ADP/1997/021
27	van Bueren, M. (2004)	Acacia hybrids in Vietnam	FST/1986/030
28	Harris, D. (2004)	Water and nitrogen management in wheat–maize production on the North China Plain	LWR1/1996/164
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