Breeding and Feeding Pigs in Australia and Vietnam

ACIAR

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BREEDING AND FEEDING PIGS IN AUSTRALIA AND VIETNAM

ACIAR Project AS2/1994/023

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TEMTAC
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Executive Summary

This report establishes that ACIAR Research Project AS2/1994/023, 'Breeding and feeding pigs in Australia and Vietnam' (supported by ACIAR from July 1995 to the end of 2000) has yielded an extraordinarily high rate of economic return on the funds invested. The collaborating agencies were the Department of Primary Industries, Queensland, James Cook University and The University of Queensland in Australia, and the Institute of Agricultural Sciences of South Vietnam in Vietnam.

The best estimate benefit–cost ratio for investment in this project is at least 159:1 with a corresponding internal rate of return of 900% and a net present value of A$496 million. This is a total value, not an annual value. To give context to the number A$496 m, in 2000, 1.3 million tonnes of pig meat, worth A$2,323 million, was consumed in Vietnam in that year alone. The returns to the project are still significant even when the net present value up to, and including, 2001 is considered.

While the breeding and the feeding components of the project had highly favourable levels of economic return, the relative economic returns for the genetic component are considerably higher than the nutrition component. In Vietnam, the project has enabled better quality (less fatty) pork to be produced, has resulted in more favourable feed-conversion ratios in pig husbandry and has reduced the number of sows needed to produce a given annual stock of pigs for slaughter. This is mostly a result of genetic improvements in the Vietnamese pig herd made possible by the import of Australian Yorkshire pigs (also known as Australian Large Whites) from Queensland. These pigs have several genetic advantages in the tropical climate of Vietnam. However, nutrition research has also added to these benefits. As a result of changes in the lysine/energy content of concentrated pig meal for fattening and finishing pigs, it has become possible to produce leaner pork more cost effectively in Vietnam. The new feed formula is being adopted by Vietnamese-owned millers of concentrated pig feed, and benefits should flow to Vietnamese pig farmers. In addition, in the near future, results from the nutrition research component of this project should enable Vietnamese-owned mills to produce concentrated feed for weaner pigs for the first time. To date, this production has been exclusive to foreign-owned mills.

Because of the inadequacy of the data available, it was not possible to quantify the benefits to Australia from this project. They are, however, believed to be significant and are listed and discussed. It is pertinent to

observe that this project has been very effective as an Australian foreign aid project. It has made possible substantial advances in pig husbandry in Vietnam, and Vietnam has obtained a high level of economic benefits from the project. The project has been well managed with an appropriate level of attention given to diffusion of economic results. With the nutrition component of the research, there has been effective follow-up and liaison with state farms and Vietnamese-owned produce mills to ensure adoption of the more cost-effective pig feed mixtures developed as a result of this research.

The extremely high net benefits from the project result from the following factors. First, the genetic material transferred as a part of the research package, namely from Australian Yorkshire pigs of the herd of the Queensland Department of Primary Industries (QDPI), was most appropriate to Vietnamese tropical conditions and was capable of adding both to the quantity and quality of pig production in Vietnam. Second, the transfer of this genetic material was not on a commercial basis but essentially was an aid item. Third, the considerable costs involved in developing the pig herd of QDPI (now sold to private interests in Australia) was not assigned as a cost of this project. They were treated as a sunk cost because they had been incurred before the ACIAR project. Fourth, there was an extremely short lag or gestation period before the flow of benefits or results from this subcomponent in Vietnam. Benefits could be obtained almost immediately. Fifth, effective mechanisms were quickly put into place to help diffuse the superior genes. These included their adoption on state farms, and the construction or reconstruction of five regional artificial insemination (AI) centres and associated improvement in their facilities and the skills of their staff. The latter initiatives were supported by the Australian International Development Assistance Bureau (AusAID), but are not costed against the project since the AI centres have multiple uses and they remain as long-term assets for Vietnam.

1 Introduction

This study identifies and examines the impacts of ACIAR research project AS2/1994/023, 'Breeding and feeding pigs in Vietnam'. This project was supported by ACIAR from July 1995 until December 2000. The analysis concentrates on economic impacts of this project in Vietnam but gives some attention to its impacts in Australia. When the project was commenced, it was expected that 70% of its benefits would be obtained by Vietnam and the remaining 30% by Australia.

The commissioned organisation for this animal science project was the Department of Primary Industries, Queensland (QDPI), collaborating with James Cook University (JCU) and The University of Queensland in Australia and the Institute of Agricultural Science of South Vietnam.

The primary mission of this project was to develop and implement a research program focusing on genetic and nutrition research to improve pig productivity in Vietnam and Australia, and in particular to produce leaner pork with greater production cost-effectiveness. It was proposed to meet these objectives 'by the development of new techniques for selecting for improved breeding and by devising new diets based on novel, low-cost feed ingredients' (McPhee and Hai, ACIAR Project Document, 1994, p. 86). The research program was divided into four sub-programs:

- Genetic development;
- Feed evaluation;
- Nutrient requirements; and
- Pig production technology transfer, which includes international training courses and communication of results.

The feed evaluation and nutrient requirements sub-programs constitute the feeding component of this project. Although there was some separation in undertaking research between the feeding component and the genetic component of the project, scientific interdependence occurred because it was hypothesised and subsequently confirmed that the feeding requirements of pigs vary with their genetic composition. For example, the ratio of lysine (or protein) in pig feed in proportion to its energy content normally needs to be higher for exotic pig varieties than for local breeds in Vietnam, but this ratio can also be too high for optimal economic performance and productivity.

2 The Project in the Australian and Vietnamese Contexts

Pigs are extremely important in Vietnam. Pork is estimated to provide about 70% of the animal protein intake of the Vietnamese. Pork is a basic part of the meat diet of the Vietnamese. Pig hides are also of value and, in the countryside, pig manure is an important source of fertiliser for crops, especially rice (Hoffman et al. 2001). Vietnam's pig population far exceeds those of buffalo and cattle which have, in the past, been mainly used for draught purposes.

Despite the relative importance of pork in the meat component of the diet of Vietnamese people, Vietnamese per capita annual consumption of pork for 1994 by weight (13 kg) was only a little over two-thirds of its consumption by Australians (19.3 kg). However, by 1998 Vietnamese consumption had risen to an average of 15.7 kg per head whereas Australian consumption had fallen to a little under 19 kg. Thus, by 1998, Vietnamese per capita consumption of pork was 80% of the Australian level. Convergence in the levels of Vietnamese and Australian consumption of pork occurred during the period of this ACIAR project. There was stagnant or slightly falling demand for pork in Australia (*partially* due to greater dietary concerns and the perceived fattiness of pork), whereas demand for, and supplies of, pork both rose rapidly in Vietnam.

When this ACIAR project commenced, the average carcass weight of Vietnamese pigs slaughtered was around 90% that of Australian pigs. The relative carcass weight between these countries has fluctuated, with greater year-to-year stability in growth evident for Australia compared with Vietnam. By 2000 (according to FAO statistics), the average carcass weight of Vietnamese pigs was still only around 90% of that of the Australian pigs slaughtered. Nevertheless, both Vietnam and Australia recorded significant increases in carcass weights of slaughtered pigs in the period of this project. In 1993, the average carcass weight of Australian slaughtered pigs was 65.2 kg compared with 59.1 kg for Vietnam. For 2000, the comparable figures were 75.6 kg and 67.3 kg, respectively. This is an increase of around 16% and 13.9% for Australia and Vietnam, respectively.

Vietnam's stock of pigs is much larger than that of Australia. In 2000, Australia's stock consisted of 2.364 million head, and showed virtually no growth in the 1990s. By comparison, Vietnam had a stock of 19.584 million pigs in 2000, a figure slightly more than eight times the Australian

level of stock. The total level of Vietnam's pig stock expanded substantially throughout the 1990s. It rose from a stock level of not much more than 12 million head in the early 1990s to almost 20 million by 2000. Nevertheless, the relative differences in total number of pigs slaughtered and in the quantity of pork supplied by Australia and by Vietnam are much less. In 2000, Australia slaughtered 4.8 million pigs and produced 363,000 tonnes of pig meat whereas Vietnam slaughtered 19.584 million and produced 1,318,196 tonnes of pig meat. Consequently, Vietnam's slaughter rate was just over four times that for Australia but its production of pig meat was only about 3.63 times that of Australia, the latter figure being less than the previous one because of the higher carcass weight of Australian pigs.

On the face of it, the Australian stock of pigs is more effectively used to produce pig meat than is Vietnam's stock. Nevertheless, there was an average rise in both the number of pigs slaughtered per year in relation to stock, and the weight of pork produced per animal in the stock during the period of this project (Table 1). In 1994, Australia slaughtered 1.87 pigs per year in relation to its stock, but by 2000 this had risen to just over two. The comparable figures for Vietnam are 0.99 and 1. Thus, the Australian slaughter rate is about twice that in Vietnam. Differences in the amount of pork production on average in relation to pig stocks are revealing. In 1994, Australia produced 121 kg of pork annually per pig in its stock whereas Vietnam produced 61.8 kg, around half that of Australia. By 2000, as can be seen from Table 1, Australia's annual supply of pork in relation to its stock of pigs was 137.5 kg per member of its pig population, and that for Vietnam 67.3 kg. Consequently, Australia's production of pork relative to its pig population remained at about twice the Vietnamese level. Thus, on this basis, Australia has been a highly efficient producer of pork compared with Vietnam, and remains so despite increased productivity in pork production in Vietnam.

Table 1. Number of pigs slaughtered and weight of pork produced per member of the pig stock for Australia and Vietnam, 1994 and 2000.

	1994	2000
Pigs slaughtered in relation to the stock		
Australia	1.87	2.03
Vietnam	0.99	1.00
Weight (kg) of pork produced per member of the pig population		
Australia	121	137.5
Vietnam	61.4	67.3

Source: Estimated from FAO Livestock Statistics at <www.fao.org>.

Given the large pre-project differences between Australia and Vietnam in the use of pig stocks for pork production, significant scope existed for Vietnam to benefit from the transfer of Australian knowledge in pig production and, as will become apparent later, for the transfer of genetic material (breeding stock) from Australia. However, it should be borne in mind that the structure of the Vietnamese pig industry is very different to that in Australia. A large proportion of production in Vietnam is accounted for by farmers with just a few pigs kept as a sideline (Gallacher 1997). For these farmers, pig manure is a significant product used to fertilise crops, including rice (Hoffmann et al. 2001). Also, pigs provide a source of value and often act as indicators of a family's prosperity (Lehane 2000). Consequently, these farmers do not keep pigs solely for commercial pork sales. Nevertheless, specialised commercial pig-farming is on the increase in Vietnam. Most commercial producers are located near and in large urban areas. They are providing extra supplies of pork for Vietnam's expanding urban population. The traditional village system of pig production in Vietnam is hard pressed to meet Vietnam's growing urban demand for pork. As a result of structural changes due to its economic development, Vietnam is becoming increasingly urbanised and urban incomes are rising. There is thus an increasing urban demand for food, including pork.

Australia and Vietnam have had an overlapping interest in this project. Both had an interest in increasing pork yields and in reducing production costs via better nutrition of pigs and genetic improvements. Furthermore, both wanted to reduce the fattiness of pork produced. Although Australian pork is much leaner than Vietnamese pork, the growing health consciousness of Australia has resulted in increasing demand for even leaner pork in Australia. Particularly at the commencement of this project, Vietnamese pig meat was regarded as being of low quality because of its fattiness. In fact, it was reported to be so fatty that it could not find an export market (ACIAR Project Proposal Document, 1994, p. 26). Even within Vietnam, a substantial demand exists for leaner pork, with a price premium of up to 30% being paid for lean pigs compared with those with considerable back-fat.

The benefits of this research to Australia and Vietnam arise partly from the knowledge gained from the scientific research and training completed and, in Vietnam's case, to a large extent from the transfer of Australian Yorkshire (also known as Australian Large White) and Duroc pig genotypes to Vietnam. It is unlikely that this genetic transfer would have occurred without this project. Successful experimental results with these Australian genotypes in Vietnam, especially Australian Large Whites

from Queensland, have resulted in their rapid spread in Vietnam. This spread has been facilitated by five new artificial insemination (AI) centres in Vietnam, partly funded by the Australian Agency for International Development (AusAID). The AI centres have multiple uses and they remain as long-term assets for Vietnam. They are therefore not costed against the project.

3 Approach to Assessing Benefits/Impacts

The project proposal documentation listed several benefits or outputs that could be expected to accrue to the pig industries in Australia and Vietnam. Table 2 lists benefits obtained by Australia and Vietnam from this project.

Table 2. List of benefits/outputs obtained by Australia and Vietnam from this project in relation to pig-farming.

High lean-meat growth of pigs	Better diet formulation
Adaptation of pigs to high temperature	Alternative feed knowledge
Stress resistance of pigs	Enhanced technical knowledge
Nutrient optimisation	Training of scientists
Potential genetic gains	Training of industry personnel

Project benefits arising from the factors listed in Table 2, and resulting in economic gains, include improved feed-conversion ratios, higher rates of successful reproduction of pigs and, because of improved composition of pig feed, reduced feed costs per unit of pork produced. New sources of feed for Australian pigs, based on tropical crops such as pearl millet, have been developed as a consequence of this project. The training given to Vietnamese scientists will provide long-term benefits to Vietnam as that country continues to improve the quality of its pigs and their management. For example, Vietnam continues to import new pig genotypes to assess their potential to further improve the quality of its pig stocks.

The review of the returns to this project proceeds by outlining general benefits for Australia. More detailed quantitative results are provided for Vietnam, using benefit–cost or investment analysis. It is found that economic benefits to Vietnam provide an exceptionally large economic return on the total investment in this project, even if Australia's economic benefits are not taken into account. The high rate of economic return in Vietnam is largely due to the rapid diffusion of superior genotypes, mostly Australian Yorkshire stock (hereinafter called 'AY') from Queensland, and to the comparatively rapid adoption of more cost-effective pig feed mixtures.

We first consider the general impacts of the project in Australia. Because of the paucity of data available these could not be quantified. More detailed quantitative analysis follows for Vietnam which, according to the original proposal document, was expected to be the major economic beneficiary.

4 Significance and General Impacts of this Project in Australia

Economic benefits for Australia were achieved from this project through research outcomes involving pig genetics, nutrition and new sources of feed for pigs.

Dr Cam McPhee (pers. comm., May 2001) reported that 'The Large White [AY] herd bred in Queensland for the project delivered a believed-to-be world first in selecting pigs that wasted less energy (0.4 MJ/d) in maintenance, possibly due to less physical activity. This made more energy available for growth and improved the pigs' resistance to stress of high temperature and long-distance transport. A lack of increased muscle pH at slaughter, normally observed in lines selected for rapid, lean growth, indicated no increase in stress during transport and no increase in the level of dark, firm, dry pork.' Thus, the advantages of these selected genotypes for Australia are the leanness of their meat, increased conversion of feed to meat, and better quality pork when pigs have to be transported.

In Australia, genetic material from the herd utilised in this project is being used by a breeding stock supplier and is available from a commercial AI centre in Queensland.

At the beginning of this project, herds of AY and Duroc pigs were introduced into Vietnam from Queensland, and AY in particular have proven to be popular in Vietnam. As discussed later, a substantial fraction of Vietnam's pig stock is now based on AY genetic material. However, in order to avoid inbreeding, it will be necessary for Vietnam to import additional breeding stock from Australia in the future. Vietnam is interested in this possibility and its demand will add to commercial demand for Queensland pig-breeding stock.

In relation to the nutrient requirements and feed evaluation components of this project, several findings have benefited Australia. Research carried out at Binh Thang Animal Research and Training Center of the Institute of Agricultural Science of South Vietnam determined the relationship between meat yield and quality (degree of fattiness) for different pig genotypes, for pigs of different ages, and for variations in the energy to lysine (protein) ratios in pig feed. This has enabled more profitable diets to be formulated for pigs; diets which vary according to the age and genotype of pigs. Since the Vietnamese studies include AY and Durocs, the results of this nutritional research are also applicable in Australia.

The project has enabled QDPI to evaluate several new feed ingredients for Australian pigs, such as varieties of cassava and pearl millet, grain legumes and rice by-products, some of which are used in Vietnam. This has resulted in 'flow-on' research being supported. Information obtained as a result of this project enabled a grant to be obtained by QDPI for a research project on the use of pearl millet as a potential new feed grain for Australia's livestock industries. That project is being funded by the Grains Research and Development Corporation.

The research has shown that energy in relation to protein requirements usually varies with genotype and age of pigs. A 'short-cut' method of determining these requirements would be advantageous, would benefit the Australian pig industry and could be used for evaluating the nutritional requirements of a variety of pig genotypes, including new genotypes. It would be also of value to Vietnam because it has a variety of genotypes and continues to import new exotic genotypes. Collaborative research with James Cook University has had the aim of identifying such a method.

QDPI (Danny Singh, pers. comm., May 2001) reports:

> The objective of the muscle metabolism studies being conducted in collaboration with James Cook University is to identify a relatively simple method to estimate nutrient requirement of pigs. It will be possible to quickly determine the requirements for energy and protein for a particular genotype for optimum productivity and hence less output of nitrogenous material to the environment [can be expected]).

The latter could be a particular environmental advantage.

In summary, the main benefits for Australia from the research in project AS2/1994/023 have been:

1 improved feed-conversion ratios for pigs due to genetic selection and nutrient research;

2 better quality pork—lean pork with low damage due to stress;

3 diets which increase productivity in relation to cost;

4 potential new sources of feed for Australian livestock e.g. pearl millet;

5 potential for some future commercial exports of Australian pigs to Vietnam for breeding purposes; and

6 reduced environmental wastes, e.g. nitrogenous wastes, from piggeries.

5 Significance and General Impact of this Project in Vietnam

Vietnam has long had the goal of increasing the productivity of its pig industry, its volume of pork production and the quality of its pork. From 1961 to 1981, its supply of pig meat was relatively static. During that period, the carcass weight of its slaughtered pigs tended to decline, the number of pigs slaughtered annually was relatively constant and pig stocks showed only a small increase. Its per capita pig meat consumption fell from about 7 kg per head in the 1960s to around 5 kg per head for most of the 1970s. Thus, the already low level of animal protein in the Vietnamese diet in the 1960s was reduced even further by the poor performance of its pig industry in the 1970s.

However, 1981 marked a turning point in the performance of Vietnam's pig industry. Vietnamese supplies of pig meat rose from 5.4 kg to 15.7 kg per capita in 1998 at a relatively constant rate (see Figure 1 and Table 3). A combination of rising carcass weights (Figure 2) and increased pig stocks (Figure 3 and Table 3), as well as growing numbers of pigs slaughtered annually (Figure 4), contributed to this improved situation. Beginning in 1981, Vietnam made extra efforts to import exotic pigs to improve the pig genotypes available to it, and its feeding and housing of pigs were improved, all of which contributed to greater supplies of pig meat. Nevertheless, as indicated earlier, the Vietnamese pig industry is not yet nearly as meat productive as the Australian pig industry.

Continuing research, genetic improvements and dissemination of new techniques have been necessary for Vietnam to continue increasing its pork supplies. It is important for Vietnam to raise the productivity of its pig industry given that it has a relatively low level of consumption of animal protein and that the Vietnamese have a strong preference for pork as a meat. In addition, Vietnam's population continues to grow at a relatively rapid rate. In 1999, its population was approaching 80 million, more than double that in 1965. Vietnam is also experiencing increased urbanisation, so those involved in agriculture must, relatively speaking, feed many more people.

Given these circumstances, Vietnam is under continual pressure to increase its food supplies to meet growing domestic demand. By helping to raise the productivity of the pig industry, this project has made a significant contribution to increasing food supplies for Vietnam. Without it, significantly less growth in pig meat supplies in Vietnam might have been expected. In addition, the project has improved the quality of

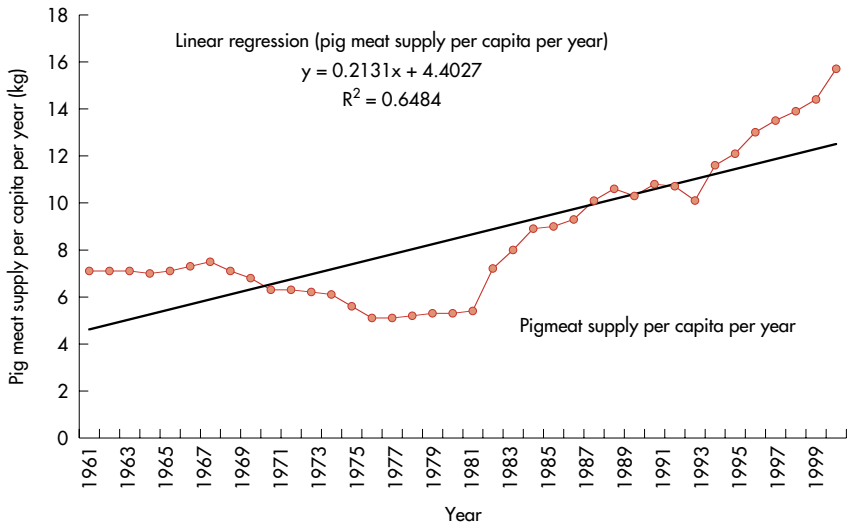

Figure 1. Per capita supply of pig meat, Vietnam, 1961–2000 (data from Table 3).

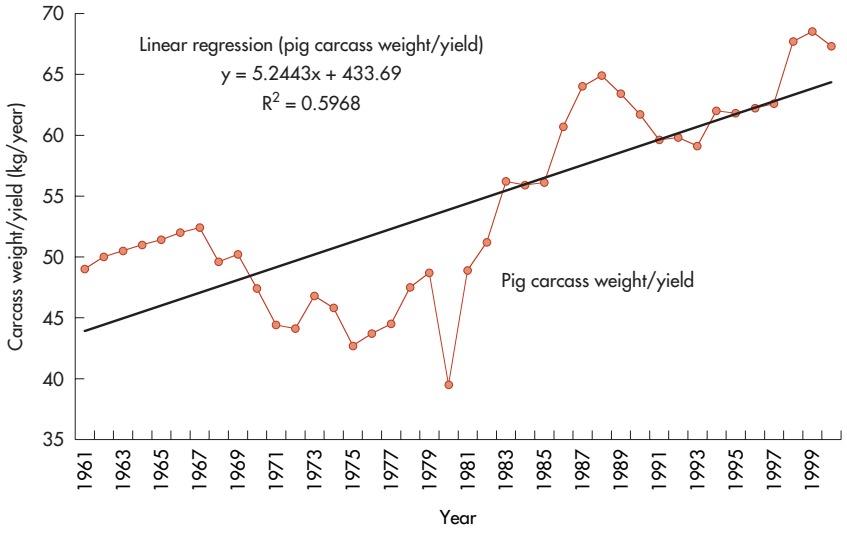

Figure 2. Carcass weight/yield per pig, Vietnam, 1961–2000 (data from Table 3).

Vietnamese pork. It has helped to reduce its excessive fattiness. This makes for greater acceptability of the pork by consumers, may have associated health benefits and could make it easier in the future for Vietnam to export pork. Vietnam is neither a significant exporter nor importer of pig meat at present. Furthermore, lean pig meat sells in Vietnam at a price up to 30% higher than that of fatty pork.

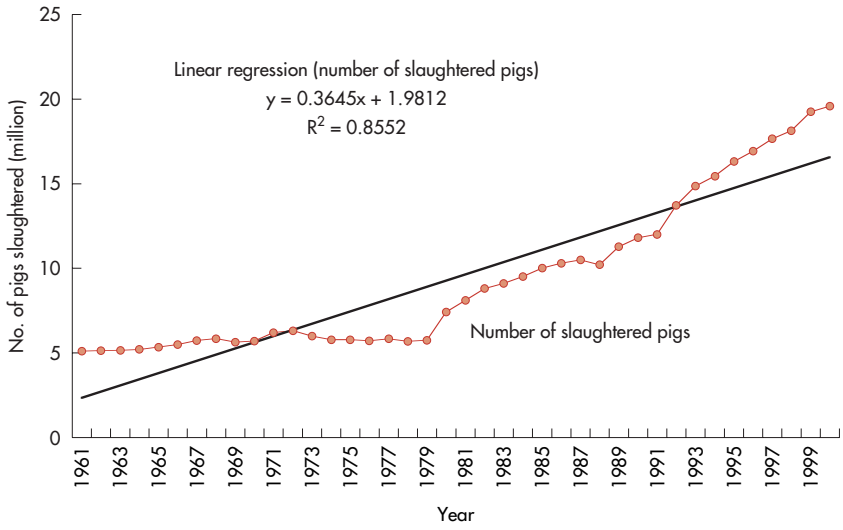

Figure 3. Numbers of pigs slaughtered in Vietnam, 1961–2000 (data from Table 3).

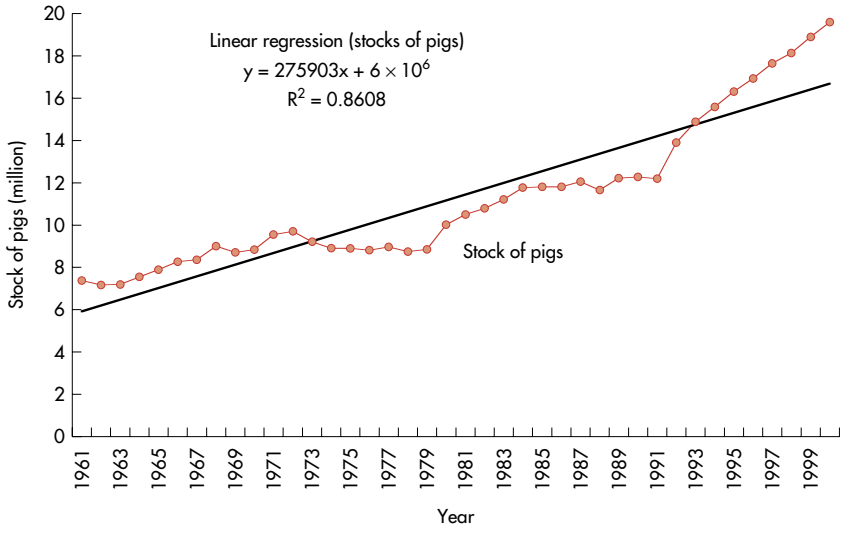

Figure 4. Stocks of pigs in Vietnam, 1991–2000 (data from Table 3).

Regional differences in the average live weight price of pigs in Vietnam are considerable. In 1997, they varied from a low of VND[1]9,133/kg in the northeast to a high of VND14,983/kg in the south. The average price per live-weight kg of pigs over the whole country was VND11,948/kg in 1999. There are various reasons for these regional differences in prices—they are influenced by costs and difficulties of transport and by differences in the fattiness of the pigs offered for sale.

[1] In April 1996 ca VND8,700 = A$1.

Table 3. Per capita supply of pig meat, carcass weight of pigs, number of pigs slaughtered and size of pig stocks in Vietnam, 1961–2000.

Year	Pig meat supply (kg/person/year)	Carcass weight (kg)	Number of pigs slaughtered	Number of pigs in stock
1961	7.1	49.0	5,102,000	7,371,000
1962	7.1	50.0	5,140,000	7,161,200
1963	7.1	50.5	5,150,000	7,191,900
1964	7	51.0	5,200,000	7,539,200
1965	7.1	51.4	5,350,000	7,885,000
1966	7.3	52.0	5,480,000	8,263,600
1967	7.5	52.4	5,725,000	8,354,000
1968	7.1	49.6	5,850,000	9,000,000
1969	6.8	50.2	5,640,000	8,700,000
1970	6.3	47.4	5,700,000	8,831,000
1971	6.3	44.4	6,198,000	9,536,900
1972	6.2	44.1	6,304,000	9,699,000
1973	6.1	46.8	5,980,000	9,200,000
1974	5.6	45.8	5,785,000	8,900,000
1975	5.1	42.7	5,785,000	8,900,000
1976	5.1	43.7	5,720,000	8,800,700
1977	5.2	44.5	5,823,000	8,958,100
1978	5.3	47.5	5,680,000	8,739,200
1979	5.3	48.7	5,745,000	8,838,900
1980	5.4	39.5	7,400,000	10,001,200
1981	7.2	48.9	8,100,000	10,493,400
1982	8	51.2	8,800,000	10,784,900
1983	8.9	56.2	9,100,000	11,201,900
1984	9	55.9	9,500,000	11,759,900
1985	9.3	56.1	10,000,000	11,807,500
1986	10.1	60.7	10,300,000	11,795,900
1987	10.6	64.0	10,484,000	12,050,800
1988	10.3	64.9	10,200,000	11,642,600
1989	10.8	63.4	11,270,000	12,217,300
1990	10.7	61.7	11,800,000	12,260,500
1991	10.1	59.6	12,000,000	12,194,300
1992	11.6	59.8	13,720,000	13,891,700
1993	12.1	59.1	14,850,800	14,873,900
1994	13	62.0	15,443,600	15,587,700
1995	13.5	61.8	16,305,999	16,306,400
1996	13.9	62.2	16,921,000	16,921,700
1997	14.4	62.6	17,635,000	17,635,900
1998	15.7	67.7	18,132,000	18,132,400
1999	n.a	68.5	19,241,604	18,885,772
2000	n.a	67.3	19,584,000	19,584,000

Source: FAO Livestock Statistics at <www.fao.org>.

The average live weight price of pigs in VND/kg for the whole of Vietnam is given in Table 4 for the period 1990–1999 in nominal terms. Compared with 1996, prices were lower in 1997 and 1998, with some recovery evident in 1999.

Table 4. Average live weight price of pigs in Vietnam 1990–1999 in VND/kg (nominal).

1990	2,932
1991	5,536
1992	7,487
1993	7,203
1994	7,761
1995	11,256
1996	11,458
1997	9113
1998	10,373
1999	11,948

Source: Department of Agriculture and Rural Development, Hanoi

The main economic benefits to Vietnam quantified in this study are first, those due to the introduction and diffusion of genetic material from AY animals, and second, gains in profits from research resulting in a more profitable balance of lysine (protein) and energy in pig feed in Vietnam. It is assumed that without this project, AY pigs would not have been introduced into Vietnam. It was the genetic research for the project which resulted in the introduction of AY pigs to Vietnam and the selection of appropriate breeding material.

AY animals were found to have a more favourable feed-conversion ratio than other pig lines in Vietnam and higher growth rates (Hai 2000). Weller (1994) points out that the annual growth rate of animals is highly correlated with their feed efficiency. For the same feed intake, at least a 5% increase in the live weight of pigs containing Australian Yorkshire genes was observed by Vietnamese researchers (Hai 2000). In addition, the meat of AY and AY crosses proved, on average, to be leaner than pork previously available in Vietnam (Hai et al., n.d.). Thus, this pork could command price premium of up to 20–30% compared with fattier pork traditionally supplied to the Vietnamese market. This is an additional economic benefit. In this study, because there are some differences in opinion about the price premium [Jesus (2000) suggests a price premium of 5–10%] and pigs with AY genes may not be uniformly lean, a series of alternative price premiums for lean pork is considered, ranging from 5–20%. Even if the premium for leanness was only 5%, the economic benefits in Vietnam from leaner pork as a result of this project are substantial. However, it is believed that a 10% price premium on average for meat produced by AY pigs and their crosses is most likely.

Research completed at the Binh Thang Center (Hai et al. 2001) indicates that litters of AY genotype sows surviving to weaning are, on average, about one piglet larger than those for other exotics. This is an economic advantage because fewer sows have to be kept to produce the same number of slaughter pigs. Alternatively, the saving in the stock of breeding sows can be used to produce extra pigs for slaughter. Thus, pork production can be increased without increasing costs. Vietnamese scientists estimate that, on average, a breeding sow eats as much feed in a year as four pigs raised for slaughter (advice received by C. Tisdell at the Binh Thang Centre, March, 2001). If the resource-savings from fewer breeding sows being required to produce surviving offspring are used to increase the number of slaughter pigs, the annual economic gains from this can be estimated. The formula of doing this is set out in Section A.3 of Appendix A. In the formula, account is taken of the fact that the extra progeny for slaughter require some sows to be reserved to produce them.

AY boars, as selected in Vietnam, also have greater reproductive ability than other exotics, as discussed in Section A.3. This also has positive economic implications. This attribute allows some reduction in breeding stock to occur in relation to the quantity of slaughter pigs produced. Relatively fewer boars (and to some extent sows) are needed in proportion to the number of slaughter pigs produced. While the magnitude of the economic benefit is likely to be much less than that from the increase in the number of surviving pigs born annually to a sow, it is nevertheless a definite economic advantage.

The better reproductive performance of AYs compared with other exotics in Vietnam means that fewer resources have to be tied up in breeding stock. As pointed out earlier, compared with Australia, Vietnam has a low annual slaughter rate of pigs relative to its stock. This partly reflects the low effective reproduction rate of its stock of pigs. Indications are that the introduction and selection of AY genotypes is helping to correct this imbalance.

Economic benefits from this project are also being obtained in Vietnam from improved composition of pig feed in terms of lysine/energy content. Research at the Binh Thang Animal Research and Training Center (BTRC) has resulted in the development of more profitable pig-feed mixes. This has already resulted in significant economic gain for Vietnam and further gains can be expected in the future. Several Vietnamese-owned manufacturers of pig feed have started to use the BTRC formula for producing concentrated pig feed for fattening and finishing pigs. Trials are now being completed by BTRC on manufactured feed for weaners. It is expected that Vietnamese-owned produce mills will soon be using the BTRC formula for weaners. So

far, Vietnamese mills have lacked the know-how to produce suitable concentrated feed for weaners. This scientific advance is expected to bring further economic gains for Vietnam.

Substantial economic gains have been made in Vietnam from the nutrient component of this research, with further gains anticipated. In addition, a number of alternative feeds for pigs have been chemically evaluated and, as part of this project, a major pig industry survey was undertaken for Vietnam of smallholdings, larger pig sheds and feed mills (Gallacher 1997), with particular emphasis on determining the status of feed utilised for pig production in Vietnam. This was completed early in this project and provided a significant reference point not only for pig feed but also for genetics, management and production efficiencies in Vietnam's pig industry. It is difficult to quantify the economic value of such surveys but they are important in determining industry-relevant directions for agricultural research; that is, in managing the direction of research effectively.

While not evaluated here in quantitative economic terms, Vietnam has gained considerably from the international technology transfer component of this research. In particular, the training afforded to Vietnamese scientists as a result of the project should provide long-term economic returns to Vietnam because it has increased the capacity of the country's scientists to continue effective research in this area after completion of Australia's involvement in this project. Furthermore, the project has increased technical capacity in relation to pig husbandry in Vietnam. During the project, 19 persons were sent to Australia from different regions of Vietnam to obtain training at various levels. Two university-level staff were sent to Australia for training and several middle-level staff from BTRC have also benefited from training in Australia. BTRC has conducted several training courses based on experience and knowledge gained from this project. These courses have been of 2–10 weeks duration. Training has been given to farmers and technicians. The technical staff in the five AI centres in Vietnam have been sent to BTRC for training.

In summary, the following are the main economic benefits to Vietnam, from this project:

1 improved pig feed-conversion ratios as a result of genetically improved exotic pig stocks;

2 better quality (less fatty) pork, also an outcome of genetic improvement;

3 greater reproductive efficiency of exotic stocks, again from genetic improvement; and

4 improved nutrient-balance of pig feed resulting in greater profits and lower cost of pork production in Vietnam.

In addition, the project has played a significant role in personnel capacity-building in Vietnam and this will provide long-term economic benefits. Some economic benefits have been obtained or are expected for evaluation of alternative feed sources for pigs in Vietnam. However, these are difficult to assess in quantitative economic terms. On the other hand, quantitative economic evaluation of benefits (1)–(4) above is possible and has been completed. They are used as part of the benefit–cost analysis of this project, the results of which are reported below. This analysis provides internal rates of return for investment in the project, benefit–cost ratios and estimates of the net present value of the investment in this project. The calculations are done on the basis of the economic benefits being captured by Vietnam but, as pointed out previously, there are also economic benefits for Australia. However, even if only Vietnam's economic benefits are considered and estimated in a very conservative fashion, the estimated return on the total investment in this project turns out to be extremely high. The genetic component of the project shows an extraordinarily high rate of economic return. The economic return from the nutrient component of this research is also high.

6 Investment (Benefit–Cost) Analysis

6.1 Project Costs

Table 5 shows the financial year breakdowns of expenditures by ACIAR and other organisations on project AS2/1994/023. The breakdowns were obtained from two project proposal documents, namely McPhee and Hai (1995) and McPhee and Hai (1999). The breakdowns are for five financial years from 1995–1996 to 2000–2001.[2] In order to facilitate the benefit–cost analysis, the expenditure breakdowns have been transformed into calendar years. Tables 6 and 7 show the expenditure breakdowns for the genetics and feeding components of this project, respectively. Dr Cam McPhee provided ACIAR and QDPI with breakdowns of expenditures for the genetic component of the project for the six calendar years. As stated by Dr McPhee, the QDPI components of expenditures are approximate figures only. The ACIAR and QDPI expenditures on genetic research were then deducted from the total ACIAR and QDPI expenditures to arrive at the expenditure components for research on feeding for the six calendar years. These are shown in Table 7. The allocations of expenditure to genetic and nutrition components of research completed by the Institute of Agricultural Sciences of South Vietnam were obtained, as advised by Professor Hai, by allocating half the total expenditure to each component. To convert financial year expenditures to calendar years, the financial year expenditures for each financial year were equally divided. One half was allocated to genetics and the other half to the feeding component. For the financial year 1997–1998, the financial year expenditures were divided by four and each quarter was allocated for 1997 and 1998 for genetic and feeding components to obtain expenditures for calendar years. There was no expenditure incurred by James Cook University for the genetic component of the project. Hence, its expenditure was devoted solely to the feeding component. To obtain the calendar year expenditures incurred by JCU, the financial year expenditures were taken as calendar year expenditures for the first two years. To obtain the calendar year expenditures for 1997 and 1998, the financial year expenditures for 1997–1998 were divided by two. It should be noted here that the pre-herd development costs incurred by QDPI have not been taken into account.

[2] Note that in the financial year 1998–1999, the grant was only for the six months January–June and in the financial year 2000–2001, only for the six months July–December. This came about because two grants were given. The initial one was for three financial years and the grant for extending the project was for two calendar years. For more details see McPhee and Hai (1995, 1999).

They were not specifically incurred for this project and from the viewpoint of this project were sunk costs. Nevertheless, Vietnam has been a major incidental beneficiary from those expenditures.

Table 5. Total expenditure by ACIAR and other organisations on project AS2/1994/023 (nominal A$) by financial years.

	1995–1996	1996–1997	1997–1998	1998–1999[a]	1999–2000	2000–2001[a]	Total
ACIAR	408,007	223,138	237,626	120,515	254,282	123,821	1,367,389
DPI	318,850	318,850	318,850	159,584	318,850	159,264	1,594,248
JCU	77,400	77,400	77,400	–	–	–	232,200
Vietnam	65,900	62,900	51,500	32,950	60,900	34,950	309,100
Total	870,157	682,288	685,376	313,049	634,032	318,035	3,502,937

[a]*Funding in these years was for six months only. For further information see McPhee and Hai (1995, 1999).*

Table 6. Expenditure on project genetic component by ACIAR and other organisations on project AS2/1994/023 (nominal A$) by calendar years.

Year	ACIAR (A$)		QDPI (A$)		Institute of Agricultural Sciences of South Vietnam (A$)	Total costs (A$)
	Vietnam	Australia	Vietnam	Australia	Vietnam	
1995	36,200	100,500	20,000	100,000	32,950	289,650
1996	9,300	59,200	20,000	100,000	31,450	219,950
1997	5,385	29,000	20,000	75,000	12,875	142,260
1998	5,385	29,000	20,000	75,000	12,875	142,260
1999	16,630	92,500	10,000	100,000	46,925	266,055
2000	8,500	40,000	10,000	50,000	17,475	125,975
Total	81,400	350,200	100,000	500,000	154,550	1,186,150

Table 7. Expenditure on project feeding component by ACIAR and other organisations on project AS2/1994/023 (nominal A$) by calendar years.

Year	ACIAR (A$)	QDPI (A$)	JCU (A$)	Institute of Agricultural Sciences of South Vietnam (A$)	Total costs (A$)
1995	271,307	198,850	77,400	32,950	580,507
1996	154,638	198,850	77,400	31,450	462,338
1997	84,428	64,425	38,700	12,875	200,428
1998	84,428	64,425	38,700	12,875	200,428
1999	138,526	209,009	–	46,925	394,460
2000	202,462	258,689	–	17,475	478,626
Total	935,789	994,248	232,200	154,550	2,316,787

Table 8. Estimated expenditure on the genetics and feeding components of project AS2/1994/023 (nominal A$) by calendar years.

Year	Genetics	Feeding	Total
1995	289,650	580,507	870,157
1996	219,950	462,338	682,288
1997	142,260	200,428	342,688
1998	142,260	200,428	342,688
1999	266,055	394,460	660,515
2000	125,975	478,626	604,601
Total	1,186,150	2,316,787	3,502,937

6.2 Procedures Used to Estimate Vietnam's Benefits from Project AS2/1994/023

The procedures and assumptions used to estimate Vietnam's economic benefits from this project are detailed and illustrated in Appendix A. *The benefits are divided into two main categories:*

1 those attributable to the genetic research; and

2 those attributable to the pig-feeding research.

Estimates for the benefits from genetic research involve an allowance for three factors:

- an average increase in the weight of slaughter pigs containing AY genes of 5% (for the same feed consumption compared to other exotic pigs in Vietnam);
- an increase in the price of pork produced with AY stock on account of the greater leanness of the meat on average; and
- a reduction in the number of sows needed for breeding purposes given that the surviving number of progeny of AY stock is larger than for other exotics, on average.

Benefits and net benefits are estimated so as to allow for different assumptions about the price premium paid on average for pork derived from pigs containing AY genes. Price premiums of 5, 10 and 20% are allowed for. For assessing the benefits arising from the larger number of surviving progeny produced annually by sows containing AY genes

compared with other exotics, two combinations are considered: 18 for breeding sows containing AY genes and 16 for other exotics, and 16 for AY stock and 14 for others. Benefits for the feeding component are based solely on those from the improved BTRC formula for the production of concentrated feed for growing and finishing pigs for slaughter. Food based on this formula reduces the cost of the pig diet and raises carcass yields and quality.

6.3 Economic Benefits and Net Benefits to Vietnam—Genetics Component

Table 9 gives the benefits to Vietnam when only the extra value of pigs slaughtered is considered, and the greater reproduction of AY stock is ignored. An average price premium of 10% is allowed in this case for the leanness of pork from AY stock. Vietnamese researchers are inclined towards a higher allowance, but Australian researchers demur, because of the likely degree of variation in pork quality from AY animals and their crosses. Taking account of the different points of view, a 10% premium on average seems most probable. With such an allowance and for a relatively short time-horizon, the benefits are very substantial, particularly in relation to costs. Using a discount rate of 5%, the benefit–cost ratio is 354, as shown in Table 9. If only a 5% price premium for lean meat is allowed, the benefit–cost ratio is 234 (see Table B.1).

Benefits from the genetic component of the research are further increased if allowance is made for the higher reproduction rate of sows containing Australian pig genes. As can be seen from Table 10 (based on the assumption of 16 surviving progeny versus 14 and a 10% price premium for leanness), the benefit–cost ratio is 429. This is considered to be the most probable scenario.

Benefit–cost details similar to those given in Tables 9 and 10 can be found in Appendix B for a variety of possible scenarios. Tables B1–B3 correspond to Table 9, and detail benefit–cost results for price premiums of 5, 10 and 20%. Tables B4–B6 correspond to Table 10 and detail results for the same set of price premiums but allow for an increase in the number of slaughter pigs per sow from 14 to 16 annually. Tables B7–B9 do the same, except they allow for an increase in the number of slaughter pigs per sow from 16 to 18 annually. Table B10 shows the costs and benefits of the feeding (nutrition) research. The remaining tables (B11–B19) in Appendix B combine the results for the nutrition (feeding) research with the benefit–cost scenarios for the genetic research, outlined in Tables B1–B9, to give the benefit–cost possibilities for the whole project.

6.4 Economic Benefits to Vietnam—Feeding Component

The estimated economic benefits for Vietnam based on the results of the feeding research in this project are shown in Table 11. The basis for the estimates is set out in Section A.4 of Appendix A. Once again, even assuming a relatively short horizon, benefits as well as net benefits are substantial, although significantly less than for the genetic component. Using a discount rate of 5%, the benefit–cost ratio for the feeding component is 20 and the estimated internal rate of return is 56%, well above the interest rate of 5%.

Table 9. Extra value of slaughtered pigs (at 10% price premium for lean meat) in Vietnam.

Year	Benefits (A$)	Costs (A$)	Benefits – costs (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	6,240,465	219,950	6,020,515	0.952	5,731,530
1997	13,007,576	142,260	12,865,316	0.907	11,668,842
1998	20,061,245	142,260	19,918,985	0.863	17,190,084
1999	28,385,208	266,055	28,119,153	0.822	23,113,944
2000	36,112,896	125,975	35,986,921	0.783	28,177,759
2001	39,269,787	–	39,269,787	0.746	29,295,261
2002	42,426,678	–	42,426,678	0.711	30,165,368
2003	45,583,569	–	45,583,569	0.676	30,814,493
2004	48,740,460	–	48,740,460	0.644	31,388,857
2005	51,897,352	–	51,897,352	0.613	31,813,077
2006	51,897,352	–	51,897,352	0.584	30,308,053
2007	51,897,352	–	51,897,352	0.556	28,854,927
2008	51,897,352	–	51,897,352	0.531	27,557,494
2009	51,897,352	–	51,897,352	0.505	26,208,163
2010	51,897,352	–	51,897,352	0.481	24,962,626
Total	591,211,996	1,186,150	590,025,846	–	376,960,828

Note: Totals may not add exactly because of rounding.

Total NPV	$376,960,828
Benefit–cost ratio	354
Internal rate of return	2,187%

6.5 Economic Benefits to Vietnam of the Whole Project (Breeding plus Feeding Components) and Its Benefit–Cost Indicators

The estimated economic benefits from the whole of this project, and the benefit–cost indicators, are estimated on two bases:

(a) the value of increased slaughter pigs with number of breeding sows assumed unaltered but including nutrition (feeding) benefits; and

(b) as in (a) but with a likely reduction in breeding sow numbers taken into account.

Table 10. Extra value of slaughtered pigs (at 10% price premium for lean meat) and slaughter pigs per breeding sow up from 14 to 16 annually.

Year	Benefits (A$)	Costs (A$)	Benefits – costs (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	7,565,524	219,950	7,345,574	0.952	6,992,987
1997	15,769,519	142,260	15,627,259	0.907	14,173,924
1998	24,320,918	142,260	24,178,658	0.863	20,866,182
1999	34,412,338	266,055	34,146,282	0.822	28,068,242
2000	43,780,871	125,975	43,654,896	0.783	34,181,784
2001	47,608,076	–	47,608,076	0.746	35,515,625
2002	51,435,281	–	51,435,281	0.711	36,570,484
2003	55,262,485	–	55,262,486	0.676	37,357,440
2004	59,089,690	–	59,089,690	0.644	38,053,760
2005	62,916,895	–	62,916,895	0.613	38,568,056
2006	62,916,895	–	62,916,895	0.584	36,743,466
2007	62,916,895	–	62,916,895	0.556	34,981,793
2008	62,916,895	–	62,916,895	0.531	33,408,871
2009	62,916,895	–	62,916,895	0.505	31,773,032
2010	62,916,895	–	62,916,895	0.481	30,263,026
Total	716,746,072	1,186,150	715,559,922	–	457,229,022

Note: Totals may not add exactly because of rounding.

Total NPV	$457,229,022
Benefit–cost ratio	429
Internal rate of return	2,644%

Table 12 summarises the situation in relation to approach (a) assuming a 10% price premium for the superior quality of AY meat. Situation (a) results in a benefit–cost ratio of 133 and an internal rate of return of 748%.

If the possibility is also allowed for that sows containing AY genes have, on average, a greater reproductive capacity than other exotics, this further increases the benefits from this research project. The flows of total benefits and net benefits are shown in Table 13 for this project, assuming that sows with Australian genes produce 16 surviving pigs for slaughter each year compared with 14 for other exotics. In this case, the benefit–cost ratio for this project increases to 159 and the internal rate of return rises to 900%.

Table 11. Extra benefits from nutrition (feeding) research.

Year	Benefits (A$)	Costs (A$)	Benefits – costs (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	580,507	–580,507	1	–580,507
1996	–	462,338	–462,338	0.952	–440,146
1997	–	200,428	–200,428	0.907	–181,788
1998	–	200,428	–200,428	0.863	–172,969
1999	–	394,460	–394,460	0.822	–324,246
2000	2,785,024	478,626	2,306,398	0.783	1,805,910
2001	3,298,545	–	3,298,545	0.746	2,460,715
2002	3,870,955	–	3,870,955	0.711	2,752,249
2003	4,502,263	–	4,502,263	0.676	3,043,530
2004	5,192,461	–	5,192,461	0.644	3,343,945
2005	5,993,151	–	5,993,151	0.613	3,673,802
2006	7,071,172	–	7,071,172	0.584	4,129,564
2007	7,967,286	–	7,967,286	0.556	4,429,811
2008	8,922,292	–	8,922,292	0.531	4,737,737
2009	9,936,190	–	9,936,190	0.505	5,017,776
2010	11,008,980	–	11,008,980	0.481	5,295,319
Total	70,548,319	2,316,787	68,231,532	–	38,990,702

Note: Totals may not add exactly because of rounding.

Total NPV	$38,990,702
Benefit–cost ratio	20
Internal rate of return	56%

6.6 A Comparative Summary of the Benefit–Cost Outcomes for the Individual Components of this Project

Table 14 summarises the benefit–cost results for the genetics and feeding subcomponents of ACIAR Research project AS2/1994/023 for a limited number of alternative scenarios, relying on the approach outlined in Appendix A and the tables detailed in Appendix B. Alternative price premiums of 5, 10 and 20% for pigs containing Australian genes are considered (a consequence of the better quality pork produced on average by these pigs) although a 10% premium is most likely. Similarly, sows containing AY genes produce a larger number of surviving pigs annually.

Table 12. Extra value of slaughtered pigs (at 10% price premium for lean meat) plus nutrition (feeding).

Year	Total benefits (A$)	Total costs (A$)	Benefits – costs (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	6,240,465	682,288	5558,177	0.952	5,291,384
1997	13,007,576	342,688	12,664,888	0.907	11,487,053
1998	20,061,245	342,688	19,718,557	0.863	17,017,115
1999	28,385,208	660,515	27,724,693	0.822	22,789,698
2000	38,897,920	604,601	38,293,319	0.783	29,983,669
2001	42,568,332	–	42,568,332	0.746	31,755,976
2002	46,297,633	–	46,297,633	0.711	32,917,617
2003	50,085,832	–	50,085,832	0.676	33,858,023
2004	53,932,921	–	53,932,921	0.644	34,732,801
2005	57,890,503	–	57,890,503	0.613	35,486,878
2006	58,968,524	–	58,968,524	0.584	34,437,618
2007	59,864,638	–	59,864,638	0.556	33,284,739
2008	60,819,644	–	60,819,644	0.531	32,295,231
2009	61,833,542	–	61,833,542	0.505	31,225,939
2010	62,906,332	–	62,906,332	0.481	30,257,945
Total	661,760,315	3,502,937	658,257,378	–	415,951,529

Note: Totals may not add exactly because of rounding.

Total NPV	$415,951529
Benefit–cost ratio	133
Internal rate of return	748%

We consider the alternative possibilities that their surviving numbers rise from 14 to 16 per year, and from 16 to 18 per year, on average. The former possibility seems most likely even though, under relatively controlled experimental conditions, the latter result can be achieved. The most probable benefit–cost outcomes for the various subcomponents of the project are shown in bold in Table 14.

It is apparent from Table 14 that the benefit–cost ratios from the genetic component of this research are high. There are several reasons for this. First, the genetic material transferred as a part of the research package, namely AY genes from the Queensland herd of QDPI, was most appropriate to Vietnamese tropical conditions and was capable of adding both to the quantity and quality of pig production in Vietnam.

Table 13. Extra value of slaughtered pigs (at 10% price premium for lean meat), flowing from an increase in slaughter pigs per breeding sow from 14 to 16 annually and nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefits – costs (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	7,565,524	682,288	6,883,236	0.952	6,552,841
1997	15,769,519	342,688	15,426,831	0.907	13,992,136
1998	24,320,918	342,688	23,978,230	0.863	20,693,212
1999	34,412,337	660,515	33,751,822	0.822	27,743,998
2000	46,565,895	604,601	45,961,294	0.783	35,987,693
2001	50,906,621	–	50,906,621	0.746	37,976,339
2002	55,306,236	–	55,306,236	0.711	39,322,733
2003	59,764,748	–	59,764,748	0.676	40,400,970
2004	64,282,151	–	64,282,151	0.644	41,397,705
2005	68,910,046	–	68,910,046	0.613	42,241,858
2006	69,988,067	–	69,988,067	0.584	40,873,031
2007	70,884,181	–	70,884,181	0.556	39,411,604
2008	71,839,187	–	71,839,187	0.531	38,146,608
2009	72,853,085	–	72,853,085	0.505	36,790,808
2010	73,925,875	–	73,925,875	0.481	35,558,346
Total	787,294,390	3,502,937	783,791,453	–	496,219,725

Note: Totals may not add exactly because of rounding.

Total NPV	$496,219,725
Benefit–cost ratio	159
Internal rate of return	900%

Table 14. Benefit–cost indicators of the impact of components of ACIAR research Project AS2/1994/023.

Component and assumptions	Benefit–cost indicators		
	Net present value (A$)	Internal rate of return (%)	Benefit–cost ratio
GENETICS			
1. Extra value of slaughter pigs only			
1.1 5% price premium	249,242,785	1,459	234
1.2 10% price premium	**376,960,828**	**2,187**	**354**
1.3 20% price premium	63,239,691	3,643	593
2. Extra value of slaughter pig plus extra reproductive capacity of sows			
• Increase in surviving slaughter pigs per sow per year from 14 to 16			
2.1 5% price premium	325,861,896	1,896	306
2.2 10% price premium	**457,229,022**	**2,644**	**429**
2.3 20% price premium	719,963,286	4,142	675
• Increase in surviving slaughter pigs per sow per year from 16 to 18			
2.4 5% price premium	310,324,587	1,807	292
2.5 10% price premium	440,951,732	2,552	414
2.6 20% price premium	702,206,021	4,041	658
FEEDING			
Nutrition only	**38,990,702**	**56**	**20**

Note: Details for the above calculations are contained in Tables B.1–B.10 in Appendix B, and these correspond to the above order of coverage. The most likely values are in bold.

Second, the transfer of this genetic material was not a commercial transaction but essentially an aid item. Third, the considerable costs involved in developing the pig herd of QDPI (now sold to private interests in Australia) are not assigned as a cost of this project. They are treated as a sunk cost because they were incurred before this ACIAR project. Fourth, there was an extremely short time lag or gestation period before the flow of benefits or results from this subcomponent in Vietnam. Benefits could be obtained almost immediately. Fifth, effective mechanisms were quickly put into place to diffuse the superior genes. These included their adoption on state farms and the construction or reconstruction of five regional AI centres and associated improvement in their facilities and the skills of their staff so as to promote the genetic diffusion process. The latter initiatives were supported by ACIAR as a part of this project, and by AusAID, but are not costed against the project since the AI centres have multiple uses and they remain as long-term assets for Vietnam.

By comparison, the research into the feeding of pigs, by its very nature, made it less likely that high returns would be achieved in a relatively short period. Much more development work was necessary at the

Vietnamese end. A longer research gestation period could not be avoided. While Vietnamese researchers could draw on the knowledge of Australian scientists, considerable product development was necessary at their end. In this case, a ready-made product, such as improved genetic material, could not be imported. After development of new feed mixtures for pigs by BTRC, care was needed not to release these commercially without adequate testing. This slowed adoption. Furthermore, diffusion of these research results was dependent on the BTRC convincing Vietnamese millers of livestock feeds, and state farms, to adopt their formulas. Nevertheless, even for this component the benefit–cost ratio is 20. This is quite high considering that an assessment period of only 16 years is considered. A longer period could raise the estimate for this component significantly.

It may be of interest to point out that the bulk of the economic benefits from the genetic component of this project derives from improvements in the quality of Vietnamese pork. However, the magnitudes of the economic benefits from weight gains by pigs and from greater reproductive performance when use is made of AY genes in Vietnam are also significant.

6.7 Sensitivity Indicators of the Benefit–Cost Results for the Whole Project

Table 15 provides sensitivity estimates of economic benefits in relation to cost of the whole of ACIAR research project AS2/1994/023. It draws on detailed tables in Appendix B of this report and uses the methodologies outlined in Appendix A. Note that while the costs of the whole project (whether the money was spent in Australia or Vietnam) are included in these calculations, the only the benefits for Vietnam are taken into account. This is because insufficient data were available to quantify the economic benefits to Australia from the project even though a qualitative list of these benefits is given in Section 4. Furthermore, it was not possible to quantify the economic benefits from the training component of this project and these could be considerable in the long term. The latter evaluation would be possible only over a longer period and with more resources for evaluation. Thus, the benefits of the project provided here are conservative.

Table 15. Benefit–cost indicators of the whole of ACIAR research project AS2/1994/023.

Assumption	Benefit–cost indicators		
	Net present value (NPV) (A$)	Internal rate of return (%)	Benefit–cost ratio
1. Extra value of slaughter pigs (with no allowance for increased reproduction) plus feeding benefits			
– 5% price premium	288,233,484	506	93
– 10% price premium	415,961,529	748	133
– 20% price premium	671,387,615	1,232	214
2. Extra value of slaughter pig plus feeding benefits and with surviving slaughter pigs per sow per year up from 14 to 16			
– 5% price premium	364,852,596	651	117
– 10% price premium	**496,219,725**	**900**	**159**
– 20% price premium	758,953,987	1,399	242
3. Extra value of slaughter pigs plus feeding benefits and with surviving slaughter pigs per sow per year up from 16 to 18			
– 5% price premium	349,315,288	622	112
– 10% price premium	479, 942,435	869	154
– 20% price premium	741,196,722	1,365	237

Note: Details for the above calculations are contained in Tables B.11–B.19 in Appendix B and these correspond to the above order of coverage.

Scenario 2 in Table 15, for the case involving a 10% price premium on average for pigs containing AY genes, which give superior meat, is the most probable. This results in a 900% return (internal rate of return) on the investment in this project, or a benefit–cost ratio of 159. This is a high level of economic benefit which can be explained by the factors outlined in the previous section. In particular, there is a high rate of return on the pig genotypes transferred from Queensland to Vietnam, due partly to strong Australian assistance at the Vietnamese end. Furthermore, slower but significant progress in research into pig feed formulation in Vietnam led to important scientific breakthroughs and to product innovation and diffusion of results to Vietnamese produce mills supplying pig meals. The latter process is continuing and may yield benefits well beyond the 16-year project assessment period considered here. For example, at the time of this assessment, an improved feed formula for weaners had been developed by BTRC and testing had progressed to the stage where this formula was about to be offered to Vietnamese-owned mills. As a result, Vietnamese-owned mills will be able to produce formulated feed for weaner pigs for the first time. So far, production of this feed in Vietnam has been the exclusive domain of foreign-owned mills. This is because domestic millers had insufficient knowledge to produce such feed effectively. Thus, while an additional economic benefit will flow from the project in the near future, this could not be allowed for in Table 15.

From Table 15, it should be observed that, even if the least attractive scenario prevailed, economic returns from this project would remain high, as indicated by the first row of entries in the table. In this case, no allowance is made for the higher reproductive efficiency of breeding sows containing AY genes and a price premium of only 5% is allowed for the higher quality pork produced on average. It is also clear from this entry that the costs assessed could be increased by an extremely high amount and the net present value of the project would remain positive. This is because the benefits are very large.

Nevertheless, it needs to be mentioned that the genetic benefits from the original importation of AY stock from Queensland may not be sustained beyond 2010. If further genetic stock is not imported from Australia by Vietnam, inbreeding could occur in Vietnam's AY stock with some loss in genetic benefits for Vietnam. However, this does not affect the benefit–cost analysis here because no account is taken of benefits after 2010. This is partly because of the high degree of uncertainty of evaluations for the more distant future and the fact that there is no need to speculate on further benefits to establish that the net economic value of this project is extremely high.

Acknowledgments

This assessment has benefited greatly from the help and suggestions of Dr Cam McPhee (project leader in Australian and Senior Principal Geneticist, QDPI) and Dr Le Thanh Hai, project leader in Vietnam and retiring Director of the Binh Thang Animal Research and Training Institute, Institute of Agricultural Sciences of South Vietnam (IAS). Dr Cam McPhee and Danny Singh of QDPI provided background data and specific suggestions. Dr Le Thanh Hai provided data for Vietnam and arranged an informative itinerary for Clem Tisdell during his visit to Vietnam in late March. He arranged several meetings with IAS staff at BTRC to provide information on genetics, feeding and training aspects of this project. The staff of IAS at BTRC gave valuable feedback and this is much appreciated. Visits were made to private pig farms and private AI centres in Dong Nai and Binh Thuan provinces near Ho Chi Minh City and the cooperation of the farmers is much appreciated, especially farmer Vu Ngoc Ninh. In addition, the AI unit in Binh Duong Province located at Phan Thiet was visited and the considerable assistance provided by Director Nguyen Ngoc Hung was of great value. A visit was also made to a rural village between Phan Thiet and Binh Thang to see improvements in village husbandry of pigs and the cooperation of villagers is appreciated. The timely assistance of Dr Greg Banova, ACIAR Country Manager, Vietnam, in arranging contacts in Vietnam was beneficial. While the above-mentioned assistance is gratefully acknowledged, the final responsibility for the assumptions and analysis of this impact assessment rests with the senior author.

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Additional references are provided at the end of Appendix A.

Appendix A

Procedures Used to Estimate Economic Benefits for Vietnam

A.1 Introduction

This appendix outlines and illustrates the procedures which have been used to estimate economic benefits to Vietnam from Project AS2/1994/023. It outlines the procedures to estimate economic benefits from the following items:

- extra value of slaughtered pigs due to the genetic component;
- reduction in required stock of breeding sows due to the genetic component; and
- improvements in the feeding of pigs due to the nutrition component of this research.

A.2 Genetics: Procedure to Estimate Benefits—Extra Value of Slaughtered Pigs

Prices and the exchange rate between the Vietnamese Dong (VND) and the Australian dollar are standardised on 2000. The average exchange rate in this year was VND8,257.34079 to A$1.00 (Oanada.com, n.d.). This will be rounded to VND8,250 to the Australian dollar.

The price for live-weight pigs in Vietnam in 1999 on average amounted to VND11,948 per kg but varied considerably by regions of the country according to data supplied by the Department of Agriculture and Rural Development, Hanoi. The average for 2000 was not available but is said to be little changed on that for 1999.

From 1995 onwards, some decline in the real price of live-weight pigs occurred, with some recovery in the price evident in 1999 (see Table 4). The unweighted average for 1996–2000 is VND10,967. Thus, a conservative estimate of the price of live-weight pigs in this period might

be VND11,000 (A$1.33) per kg. This is used for standardising the price of pig meat. No substantial change in Vietnamese pig prices is anticipated at present.

Heavier weight—benefit

It has been found that the infusion of Australian Yorkshire (AY) genes into current exotic pig lines (as well as others) in Vietnam increases the live weight of pigs by at least 5% (Hai 2000).

The average carcass weight of pigs for 1966–2000 in Vietnam was 71.384 kg. Therefore, the average estimated live weight is 71.384 × 1.25 = 89.175 kg. The factor 1.25 is derived from the assumption that usually the carcass weight of a live pig is 80% of its live weight. For pigs with AY genes, their average weight should be 93.64 kg (89.175 × 1.05). The extra weight per pig is therefore worth 4.5 kg × A$1.33 = A$5.99 (rounding). The 4.5 kg indicates the heavier weight of the Australian pig for the same feed intake compared with the Vietnamese average.

For 2000, it is estimated (by Dr Hai and colleagues) that about 12.5% of the pigs slaughtered in Vietnam contained AY genes. However, to be conservative let us assume that it is 10%. In 2000, 19,584,000 pigs were slaughtered in Vietnam. Thus, at least 1,958,400 of these had AY genes. Therefore, the value of the extra weight of slaughter pigs due to the improved feed-conversion ratio of AY pigs was

1,958,400 × A$5.99 = A$11,730,816

Leaner meat—benefit and quantity plus quality benefit

Meat from AY and AY crosses is relatively lean. A price premium of 20–30% prevails for lean live pigs, according to Vietnamese researchers. This price premium should be allowed for as a benefit of introducing AY genes to Vietnam. However, account must be taken of the fact that pork from AY pigs and their crosses is not uniformly lean, due to natural variations. Hence, an allowance of 10% price premium on average seems appropriate. Nevertheless, estimates of economic benefits are also given in this report for price premiums of 5% and 20% on average (see Appendix B).

As specified above, the average price per kg for a live-weight pig in Vietnam in the period 1996–2000 was A$1.33 and the average weight of AY and AY-cross pigs for slaughter is estimated to be 93.64 kg. Therefore, on average, the price premium per kg for these pigs amounts to

13.3 cents Australian and results in the following extra value for such a pigs on average:

A$0.133 × 93.64 = A$12.45

Therefore, since the 1,958,400 slaughtered pigs in Vietnam were either AY or AY crosses in 2000, this extra economic benefit to Vietnam for 2000 is

1,958,400 × A$12.45 = A$24,382,080

Thus, the increased economic benefit from the genetic component of this project for 2000 in terms of extra value of slaughtered pigs in Vietnam consists of economic benefits from more pork plus better quality pork. This amounted to:

A$11,730,816 + A$24,382,080 = A$36,112,896

Note that the economic gains from the quality increase exceed those from quantity increases by a wide margin. Even if only a 5% price premium prevailed for better quality pork from AY pigs and their crosses, the economic benefit from the quality effect would be more than double that from the quantity impact.

Spread or diffusion functions

We shall assume the spread function of AY genes as a percentage of the Vietnamese pigs slaughtered annually indicated in Table A.1 in the second column. It implies a linear increase from 0% to 10% between 1995 and 2000.

Table A.1. Estimates of presence of AY genes in pigs slaughtered in Vietnam, 1995–2000.

Year	Percentage of pigs slaughtered containing AY genes	Total number of pigs slaughtered in Vietnam	No. with AY genes[a]
1995	0	16,305,999	0
1996	2	16,921,000	338,420
1997	4	17,635,000	705,400
1998	6	18,132,000	1,087,920
1999	8	19,241,604	1,539,328
2000	10	19,584,000	1,958,400

[a] *column 2 times column 3*

The Vietnamese target production of pigs for 2005 is 25 million. Whether this will be achieved or not is unclear. The growth rate in number of pigs slaughtered fell in 2000 compared with 1999.

To be conservative, let us assume that the annual growth rate in numbers of all pigs (exotic and non-exotic) slaughtered will be approximately that for 1999–2000. This would suggest the number of pigs slaughtered would be around 21.3 million in 2005. All or most of this growth will be accounted for by exotic pigs. Suppose that half the growth in numbers of exotic pigs slaughtered by 2005 have AY genes. Thus, it is assumed that an extra 342,000 pigs are slaughtered each year between 2001 and 2005 and that pigs with AY genes will account for half of the annual increase, namely 171,000. This means that the proportion of pigs containing AY genes remains at about half the number of exotic pigs slaughtered.

Flow of benefits

Extra benefits for each year compared with 2000 are as set out in Table A.2. This table shows the extra number of Vietnamese pigs expected to contain AY genes. The benefit per pig consists of $5.99 on account of the heavier average weight of pigs with AY genes and $12.45 on account of the 10% price premium allowed for improved pork quality. This makes a total benefit of $18.44 per pig.

Table A.2. Estimated incremental benefit from increased value of slaughtered pigs with AY genes, Vietnam, 2001–2005, compared with 2000.

Year	Number of extra pigs with AY genes	Benefit per pig with AY genes	Total extra benefit[a] A$
2001	171,198	$18.44	3,156,891
2002	342,396	$18.44	6,313,782
2003	513,594	$18.44	9,470,673
2004	684,792	$18.44	12,637,564
2005	855,990	$18.44	15,784,457

[a]*Column 2 times Column 3. Entries are rounded.*

Note that to obtain the *total economic benefits* from the above pig husbandry impacts for Vietnam for each year in the period 2001–2005, A$36,112,896, or approximately A$36.1m, should be added to the figures in the last column of Table A.2.

The situation beyond 2005 is uncertain but we shall assume that beyond that and up to and including 2010 the situation is the same as in 2005 for

the total number of pigs slaughtered containing AY genes. This is a conservative assumption but could be warranted if inbreeding occurs in the Vietnamese herd without further importation of AY genes from Australia. So the benefit flow will be like the relationship shown in Figure A.1. This is purely the benefit flow from infusion of AY genes into Vietnamese pig herds allowing for heavier pigs and better quality meat only. It does not allow for breeding advantages.

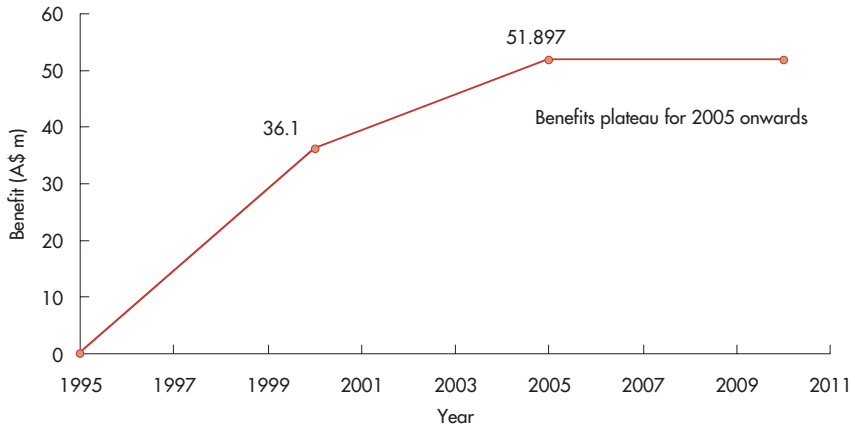

Figure A.1. Estimated annual economic benefits to Vietnam from increased value of slaughtered pigs containing AY genes, 1995–2010.

A.3. Benefits from Reduction in the Stock of Breeding Sows Required

AY sows generally have large litters that have a higher survival rate than alternative exotics. On average, about one more pig survives in the AY case per litter (Hai et al. 2001). The exact surviving litter size on average is not certain. It may either be 9 rather than 8, or 8 rather than 7. The results of Hai et al. (2001) suggest the former. However, this is achieved under experimental conditions and possibly indicates more the potential than what would actually be achieved in the field. Therefore, we shall take the more conservative figures for surviving litter sizes. This implies that if AY sows are used for breeding, they can be expected to produce 16 slaughter pigs in two litters per year compared with 14 produced by other exotics. Thus, to produce the same number of pigs for slaughter in a year fewer sows are needed if AY sows or if AY-cross sows are used for breeding than in the case of other exotics.

In 2000, for instance, it is estimated that 1,958,400 pigs containing AY genes were slaughtered in Vietnam. Theoretically, the required number of AY sows was:

1,958,400/16 = 122,400

Using other exotics,

1,958,400/14 = 139,885.71 = 139,886 (rounded)

sows would be needed. Therefore, the use of AY stock reduces the number of breeding sows needed to produce 1,950,400 slaughter pigs by 17,486 head.

Each sow annually eats as much feed as four pigs being reared for slaughter, according to the estimates of BTRC staff. The opportunity cost of not having AY sows is the number of pigs for slaughter forgone by having a larger sow population for breeding.

Estimating the number of extra slaughter pigs possible if AY sows are used for breeding

One possible way to estimate benefits from the reduced stock of breeding sows is to estimate the net value of the extra number of slaughter pigs made possible by using the extra sows. This requires the use of a formula because account must be taken of the extra sows needed to produce the extra slaughter pigs. The formula is:

$$Y = c(A - B) \qquad \text{(A.1)}$$

in which

c = number of slaughtered pigs that could be produced annually with the resources provided for one breeding sow;

A = the reduction in the number of breeding stock of sows made possible by increased surviving litter size if, say, AY genes are present;

B = the number of breeding sows needed to produce the maximum number of extra slaughter pigs made possible by a positive value of A; and

Y = extra pigs for slaughter annually.

To find the value of B, it is necessary to solve

$$sB = c(A - B) \tag{A.2}$$

where

s = number of surviving pigs produced by a sow in a year.

This occurs for

$$B = \frac{cA}{s + c} \tag{A.3}$$

For example, if the opportunity cost of a breeding sow is four slaughtered pigs forgone annually (as Vietnamese estimates indicate), and if the surviving litter size for Australian Yorkshires is 16,

$$B = \frac{4}{18 + 4} A = \frac{2}{11} A \tag{A.4}$$

For 2000, as estimated above

$$A = 13{,}600 \tag{A.5}$$

In this case, A is the *reduction* in breeding sows possible if the same number of surviving offspring annually are to be produced as would have been produced by other exotic pigs with an average surviving litter size of 14.

However, if the extra resources made available by reducing the number of sows needed for breeding are used to maximise the additional number of slaughter pigs, the following number of sows will have to be reserved for producing these extra slaughter pigs:

$$B = \frac{2}{11} \times 13{,}600 = 2{,}472.726 \tag{A.6}$$

Consequently, after allowing for the increase in required breeding sows

$$Y = 4(13{,}600 - 2472.726) \tag{A.7}$$

$$= 44{,}510 \text{ (rounding)} \tag{A.8}$$

Consequently, 55,954 extra pigs are made available for slaughter in 2000 by the infusion of AY genes. The value of these slaughter pigs can be estimated in the same manner as before, and an example follows.

Estimating the extra value of extra slaughter pigs able to be produced because fewer breeding sows are needed

On average in 2000, a slaughtered pig in Vietnam was worth

$$89.175 \times A\$1.33 = A\$118.6$$

However, the value of AY progeny in comparison, given a 10% price premium for leanness, would be worth A$118.60 + A$18.44 = A$137.04. The sum of A$18.44 consists of A$5.99 for extra weight plus A$12.41 for improved quality as explained in Section A.2.

Therefore, for 2000, the saving by having AY sows, assuming that AY sows have 16 surviving progeny compared with 14 for other exotics, is:

$$A\$149.5 \times 55{,}954.272 = A\$8{,}365{,}163.66$$

A similar procedure can be used to estimate cost savings for other years, and for the assumption that pigs with Australian genes have 18 surviving slaughter pigs per year compared with 16 for other exotic pigs.

Note that the opportunity costs of having exotics other than AY are higher if surviving litter size is assumed to be 8 for AY and 7 for other exotics; that is if the alternatives are 16 and 14 surviving pigs respectively per year rather than 18 and 16.

The greater conception rates and larger number of semen doses provided by AY boars compared to others (Hai et al. 2000) also implies that their use reduces the required number of boars to produce the same quantities of pigs for slaughter. Also, the higher conception rates allow some further small reduction in breeding sow numbers for the same production of pigs for slaughter. Thus, opportunity cost calculations could also be done for these benefits. However, they will be much smaller than the other genetic benefits specified here and will not be estimated.

While the benefits from reduced sow numbers are less than from slaughter pig benefits outlined in the previous section, they are still considerable. As compared with Australia, Vietnam overall has a large breeding stock compared with the number of pigs slaughtered, or with that in most higher income countries.

A.4. Procedure Used to Estimate Vietnam's Benefits From Improved Feeding of Pigs Due to Better Nutrition

The nutrition research involved in this project has resulted in advances on two fronts:

1 the formulation of feed for weaners (according to BTRC (see McPhee, Hai et al. 2001)) which is 95–100% as effective as that produced by foreign-owned mills in Vietnam; and

2 the formulation of feed which is more economical for fattening and finishing pigs.

At present, all formulated feed for feeding weaners in Vietnam is produced by foreign-owned mills. Lack of appropriate knowledge by domestic mills has been a barrier to their production of such feed. In the future, it is possible that several domestic mills will begin producing feed for weaners using the BTRC formula. However, BTRC is still testing its feed for weaners on selected commercial farms. So it is too early yet to estimate its commercial uptake and resulting benefits.

However, commercialisation of BTRC-formulated feed for fattening and finishing pigs for markets is well advanced. BTRC found that the lysine/energy ratio of pig feed produced on state farms and by domestically-owned commercial mills was too high for maximum growth of exotic pigs being fattened and finished. A lower ratio was found to increase growth and improve meat quality, and to be more profitable than feed being produced using the higher ratio of lysine to energy (Singh et al. 2001).

BTRC estimates the economic benefit from using its feed formula compared with the alternative one for fattening and finishing pigs to be around VND71,000 per pig. This amounts to an extra economic benefit of A$8.60 per pig marketed, using the 2000 exchange rate of VND8,250 =A$1.00.

Production of formulated feed for livestock in Vietnam is estimated to be 5 million tonnes. Of this, 2.6 million tonnes is supplied directly by livestock producers and 2.4 million by commercial millers. Of this latter amount, foreign-owned mills supply 1.4 million tonnes and Vietnamese-owned mills supply 1 million tonnes. Therefore, the division of formulated livestock feed supplies in Vietnam using 2000 as an indicator is as in Table A.3.

Table A.3. Sources of formulated feed for livestock in Vietnam.

	Quantities (Mt)	%
Direct production by growers	2.6	52
Foreign-owned mills	1.4	28
Domestically-owned mills	1.0	20
TOTAL	5.0	100

BTRC reached agreement with several Vietnamese-owned mills to use its formulas for fattening and finishing pigs. These mills accounted for 25% of production of livestock feed by Vietnamese commercial mills in 2000, or 5% of total production. Mostly, it is exotic pigs which are fed completely on formulated feed.

In 2000, exotic pigs were estimated to account for 20% of the total pigs slaughtered. This amounts to 0.2 × 19,584,000 = 3,916,800.

If the feeding of such pigs is in proportion to supplies of formulated livestock feed in Vietnam, 20% would be fed by pig feed from domestically-owned mills.

In 2000, 5% of all exotic pigs would have been fed by domestically-owned mills using the BTRC formula. This amounts to 195,840 pigs. This would have resulted in a net benefit for Vietnam of 195,840 × A$8.60 = A$1,684,224. In addition, several state farms produce their own pig feed for fattening and finishing and have excessive lysine-to-energy ratios for their pig feed. It is estimated by BTRC that state farms in Ho Chi Minh City and its environs have about 8,000 sows producing, on average, 128,000 pigs for slaughter each year. By 2000, these farms (which produce their own formulated pig feed) had adopted the BTRC feed formula for fattening and finishing pigs. The economic benefit from this in 2000 would therefore have been 128,000 × A$8.60 = A$1,100,800. Therefore, the total economic benefit achieved in 2000 is estimated to be A$2,785,024.

The proportion of Vietnamese-owned mills adopting the BTRC formula is expected to rise in the future. BTRC estimates that, by 2005, it will reach agreement with Vietnamese-owned mills accounting for 50–100% of livestock feed. To be conservative, assume 50% and suppose that by 2010 that this rises to 75%. Suppose that the share of livestock feed production, accounted for by Vietnamese mills using the BTRC formula, rises by 1% per year and, as estimated above, assume that total exotic pig numbers from 2000 onwards rises by 342,396 per year.

Table A.4. Flow of benefits to Vietnam from adoption of the BTRC feed formula by Vietnamese-owned commercial mills.

Year	Percentage of food supply using BTRC formula	No. of exotic pigs	No. of pigs fed on formula	Benefit in A$
2000	5	3,916,800	195,840	1,684,224
2001	6	4,259,196	255,552	2,197,745
2002	7	4,601,592	322,111	2,770,155
2003	8	4,943,988	345,519	3,401,463
2004	9	5,286,384	475,775	4,091,661
2005	10	5,688,780	568,878	4,892,351
2006	11	6,311,176	694,229	5,970,372
2007	12	6,653,572	798,429	6,866,486
2008	13	6,995,968	909,476	7,821,492
2009	14	7,338,364	1,127,371	8,835,390
2010	15	7,680,760	1,152,114	9,908,180

The economic benefits received from the use of improved BTRC formula by Vietnam can then be seen from Table A.4, if it is assumed that shares in supply remain unaltered until 2010, and if only Vietnamese-owned commercial mills are considered. But to this benefit should be added any benefits obtained by growers of pigs directly formulating their own pig feed, if they have access to the formula. Except for state farms, the degree of likely access is not known. We can conservatively assume that 128,000 head of slaughtered pigs will benefit each year on state farms.

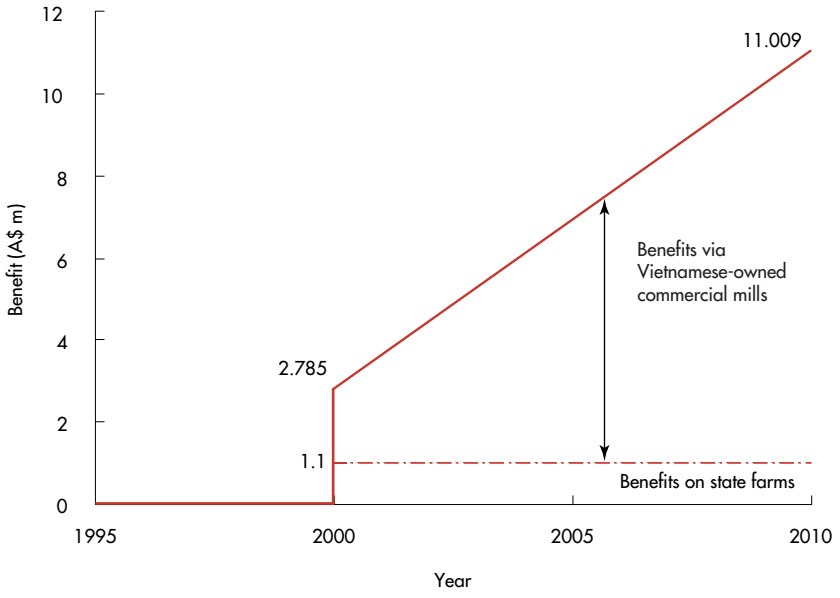

Figure A.2. Estimated flow of improved pig nutrition benefits for Vietnam.

Considering state farms as the only farms directly producing their own concentrated pig feed using the BTRC formula, an annual benefit of A$1,100,800 should be added to the figures in Table A.4. The benefit function when graphed would be as shown in Figure A.2.

References for Appendix A

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APPENDIX B

Detailed Tables for the Benefit–Cost Analysis of Research Project AS2/1994/023[3]

Table B.1. Extra value of slaughtered pigs (at 5% price premium for lean meat) in Vietnam.

Year	Benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	4,132,108	219,950	3,912,158	0.952	3,724,375
1997	8,612,934	142,260	8,470,674	0.907	7,682,901
1998	13,283,503	142,260	13,141,243	0.863	11,340,893
1999	18,795,195	266,055	18,529,140	0.822	15,230,953
2000	23,912,064	125,975	23,786,089	0.783	18,624,508
2001	26,002,392	–	26,002,392	0.746	19,397,784
2002	28,092,719	–	28,092,719	0.711	19,973,923
2003	30,183,047	–	30,183,047	0.676	20,403,740
2004	32,273,374	–	32,273,374	0.644	20,784,053
2005	34,363,702	–	34,363,702	0.613	21,064,949
2006	34,363,702	–	34,363,702	0.584	20,068,402
2007	34,363,702	–	34,363,702	0.556	19106,218
2008	34,363,702	–	34,363,702	0.531	18,247,126
2009	34,363,702	–	34,363,702	0.505	17,353,669
2010	34,363,702	–	34,363,702	0.481	16,528,941
Total	391,469,548	1,186,150	390,283,398	–	249,242,785

Note: Totals may not add exactly because of rounding.

Total NPV	$249,242,785
Benefit–cost ratio	234
Internal rate of return	1,459%

[3] Based on varied assumptions. Benefits to Vietnam only considered in this quantitative analysis.

Table B.2. Extra value of slaughtered pigs (at 10% price premium for lean meat) in Vietnam.

Year	Benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	6,240,465	219,950	6,020,515	0.952	5,731,530
1997	13,007,576	142,260	12,865,316	0.907	11,668,842
1998	20,061,245	142,260	19,918,985	0.863	17,190,084
1999	28,385,208	266,055	28,119,153	0.822	23,113,944
2000	36,112,896	125,975	35,986,921	0.783	28,177,759
2001	39,269,787	–	39,269,787	0.746	29,295,261
2002	42,426,678	–	42,426,678	0.711	30,165,368
2003	45,583,569	–	45,583,569	0.676	30,814,493
2004	48,740,460	–	48,740,460	0.644	31,388,857
2005	51,897,352	–	51,897,352	0.613	31,813,077
2006	51,897,352	–	51,897,352	0.584	30,308,053
2007	51,897,352	–	51,897,352	0.556	28,854,927
2008	51,897,352	–	51,897,352	0.531	27,557,494
2009	51,897,352	–	51,897,352	0.505	26,208,163
2010	51,897,352	–	51,897,352	0.481	24,962,626
Total	591,211,996	1,186,150	590,025,846	–	376,960,828

Note: Totals may not add exactly because of rounding.

Total NPV	$376,960,828
Benefit–cost ratio	354
Internal rate of return	2,187%

Table B.3. Extra value of slaughtered pigs (at 20% price premium for lean meat) in Vietnam.

Year	Benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	10,457,178	219,950	10,237,228	0.952	9,745,841.1
1997	21,796,860	142,260	21,654,600	0.907	19,640,722
1998	33,616,728	142,260	33,474,468	0.863	28,888,466
1999	47,565,235	266,055	47,299,180	0.822	38,879,926
2000	60,514,560	125,975	60,388,585	0.783	47,284,262
2001	65,804,578	–	65,804,578	0.746	49,090,215
2002	71,094,596	–	71,094,596	0.711	50,548,258
2003	76,384,614	–	76,384,615	0.676	51,635,999
2004	81,674,633	–	81,674,633	0.644	52,598,463
2005	86,964,651	–	86,964,651	0.613	53,309,331
2006	86,964,651	–	86,964,651	0.584	50,787,356
2007	86,964,651	–	86,964,651	0.556	48,352,346
2008	86,964,651	–	86,964,651	0.531	46,178,230
2009	86,964,651	–	86,964,651	0.505	43,917,149
2010	86,964,651	–	86,964,651	0.481	41,829,997
Total	990,696,888	1,186,150	989,510,739	–	632,396,911

Note: Totals may not add exactly because of rounding.

Total NPV	$632,396,911
Benefit–cost ratio	593
Internal rate of return	3,643%

Table B.4. Extra value of slaughtered pigs (at 5% price premium for lean meat) and slaughter pigs per breeding sow up from 14 to 16 annually.

Year	Benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	5,396,929	219,950	5,176,979	0.952	4,928,483
1997	11,249,316	142,260	11,107,056	0.907	10,074,100
1998	17,349,526	142,260	17,207,266	0.863	14,849,871
1999	24,548,323	266,055	24,282,268	0.822	19,960,025
2000	31,231,444	125,975	31,105,469	0.783	24,355,582
2001	33,961,612	–	33,961,612	0.746	25,335,363
2002	36,691,780	–	36,691,780	0.711	26,087,855
2003	39,421,948	–	39,421,948	0.676	26,649,237
2004	42,152,116	–	42,152,116	0.644	27,145,962
2005	44,882,283	–	44,882,283	0.613	27,512,840
2006	44,882,283	–	44,882,283	0.584	26,211,254
2007	44,882,283	–	44,882,283	0.556	24,954,550
2008	44,882,283	–	44,882,283	0.531	23,832,493
2009	44,882,283	–	44,882,283	0.505	22,665,553
2010	44,882,283	–	44,882,283	0.481	21,588,378
Total	511,296,692	1,186,150	510,110,542	–	325,861,896

Note: Totals may not add exactly because of rounding.

Total NPV	$325,861,896
Benefit–cost ratio	306
Internal rate of return	1896%

Table B.5. Extra value of slaughtered pigs (at 10% price premium for lean meat) and slaughter pigs per breeding sow up from 14 to 16 annually.

Year	Benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	7,565,524	219,950	7,345,574	0.952	6,992,987
1997	15,769,519	142,260	15,627,259	0.907	14,173,924
1998	24,320,918	142,260	24,178,658	0.863	20,866,182
1999	34,412,338	266,055	34,146,282	0.822	28,068,242
2000	43,780,871	125,975	43,654,896	0.783	34,181,784
2001	47,608,076	–	47,608,076	0.746	35,515,625
2002	51,435,281	–	51,435,281	0.711	36,570,484
2003	55,262,485	–	55,262,486	0.676	37,357,440
2004	59,089,690	–	59,089,690	0.644	38,053,760
2005	62,916,895	–	62,916,895	0.613	38,568,056
2006	62,916,895	–	62,916,895	0.584	36,743,466
2007	62,916,895	–	62,916,895	0.556	34,981,793
2008	62,916,895	–	62,916,895	0.531	33,408,871
2009	62,916,895	–	62,916,895	0.505	31,773,032
2010	62,916,895	–	62,916,895	0.481	30,263,026
Total	716,746,072	1,186,150	715,559,922	–	457,229,022

Note: Totals may not add exactly because of rounding.

Total NPV	$457,229,022
Benefit–cost ratio	429
Internal rate of return	2,644%

Table B.6. Extra value of slaughtered pigs (at 20% price premium for lean meat) and slaughter pigs per breeding sow up from 14 to 16 annually.

Year	Benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	11,902,715	219,950	11,682,765	0.952	11,121,992
1997	24,809,926	142,260	24,667,666	0.907	22,373,573
1998	38,263,701	142,260	38,121,441	0.863	32,898,803
1999	54,140,365	266,055	53,874,310	0.822	44,284,683
2000	68,879,726	125,975	68,753,751	0.783	53,834,187
2001	74,901,004	–	74,901,004	0.746	55,876,149
2002	80,922,283	–	80,922,282	0.711	57,535,743
2003	86,943,560	–	86,943,560	0.676	58,773,847
2004	92,964,839	–	92,964,839	0.644	59,869,356
2005	98,986,117	–	98,986,117	0.613	60,678,490
2006	98,986,117	–	98,986,117	0.584	57,807,893
2007	98,986,117	–	98,986,117	0.556	55,036,281
2008	98,986,117	–	98,986,117	0.531	52,561,628
2009	98,986,117	–	98,986,117	0.505	49,987,989
2010	98,986,117	–	98,986,117	0.481	47,612,322
Total	1,127,644,821	1,186,150	1,126,458,670	–	719,963,286

Note: Totals may not add exactly because of rounding.

Total NPV	$719,963,286
Benefit–cost ratio	675
Internal rate of return	4142%

Table B.7. Extra value of slaughtered pigs (at 5% price premium for lean meat) and slaughter pigs per breeding sow up from 16 to 18 annually.

Year	Total benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	5,140,391	219,950	4,920,441	0.952	4,684,260
1997	10,714,454	142,260	10,572,194	0.907	9,588,980
1998	16,525,027	142,260	16,382,767	0.863	14,138,328
1999	23,381,812	266,055	23,115,757	0.822	19,001,152
2000	29,747,236	125,975	29,621,261	0.783	23,193,448
2001	32,347,713	–	32,347,713	0.746	24,131,394
2002	34,948,189	–	34,948,189	0.711	24,848,162
2003	37,548,665	–	37,548,665	0.676	25,382,898
2004	40,148,712	–	40,148,712	0.644	25,855,770
2005	42,749,188	–	42,749,188	0.613	26,205,252
2006	42,749,188	–	42,749,188	0.584	24,965,526
2007	42,749,188	–	42,749,188	0.556	23,768,549
2008	42,749,188	–	42,749,188	0.531	22,699,819
2009	42,749,188	–	42,749,188	0.505	21,588,340
2010	42,749,188	–	42,749,188	0.481	20,562,359
Total	486,997,327	1,186,150	485,811,177	–	310,324,587

Note: Totals may not add exactly because of rounding.

Total NPV	$310,324,587
Benefit–cost ratio	292
Internal rate of return	1,807%

Table B.8. Extra value of slaughtered pigs (at 10% price premium for lean meat) and slaughter pigs per breeding sow up from 16 to 18 annually.

Year	Total benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	7,296,769	219,950	7,076,819	0.952	6,737,132
1997	15,209,184	142,260	15,066,924	0.907	13,665,700
1998	23,457,151	142,260	23,314,891	0.863	20,120,751
1999	33,190,269	266,055	32,924,214	0.822	27,063,704
2000	42,225,976	125,975	42,100,001	0.783	32,964,301
2001	45,917,312	–	45,917,312	0.746	34,254,315
2002	49,608,648	–	49,608,648	0.711	35,271,749
2003	53,299,984	–	53,299,984	0.676	36,030,789
2004	56,990,871	–	56,990,871	0.644	36,702,121
2005	60,682,208	–	60,682,208	0.613	37,198,194
2006	60,682,208	–	60,682,208	0.584	35,438,409
2007	60,682,208	–	60,682,208	0.556	33,739,308
2008	60,682,208	–	60,682,208	0.531	32,222,252
2009	60,682,208	–	60,682,208	0.505	30,644,515
2010	60,682,208	–	60,682,208	0.481	29,188,142
Total	691,289,412	1,186,150	690,103,262	–	440,951,732

Note: Totals may not add exactly because of rounding.

Total NPV	$440,951,732
Benefit–cost ratio	414
Internal rate of return	2,552%

Table B.9. Extra value of slaughtered pigs (at 20% price premium for lean meat) and slaughter pigs per breeding sow up from 16 to 18 annually.

Year	Total benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	289,650	–289,650	1	–289,650
1996	11,609,524	219,950	11,389,574	0.952	10,842,874
1997	24,198,643	142,260	24,056,383	0.907	21,819,140
1998	37,321,398	142,260	37,179,138	0.863	32,085,596
1999	52,807,183	266,055	52,541,128	0.822	43,188,807
2000	67,183,456	125,975	67,057,481	0.783	52,506,008
2001	73,056,512	–	73,056,512	0.746	54,500,158
2002	78,929,568	–	78,929,568	0.711	56,118,923
2003	84,802,625	–	84,802,625	0.676	57,326,575
2004	90,675,191	–	90,675,191	0.644	58,394,823
2005	96,548,247	–	96,548,247	0.613	59,184,075
2006	96,548,247	–	96,548,247	0.584	56,384,176
2007	96,548,247	–	96,548,247	0.556	53,680,825
2008	96,548,247	–	96,548,247	0.531	51,267,119
2009	96,548,247	–	96,548,247	0.505	48,756,865
2010	96,548,247	–	96,548,247	0.481	46,439,707
Total	1,099,873,582	1,186,150	1,098,687,432	–	702,206,021

Note: Totals may not add exactly because of rounding.

NPV	$702,206,021
Benefit–cost ratio	658
Internal rate of return	4041%

Table B.10. Extra benefits from nutrition (feeding) research.

Year	Benefits (A$)	Costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	580,507	–580,507	1	–580,507
1996	–	462,338	–462,338	0.952	–440,146
1997	–	200,428	–200,428	0.907	–181,788
1998	–	200,428	–200,428	0.863	–172,969
1999	–	394,460	–394,460	0.822	–324,246
2000	2,785,024	478,626	2,306,398	0.783	1,805,910
2001	3,298,545	–	3,298,545	0.746	2,460,715
2002	3,870,955	–	3,870,955	0.711	2,752,249
2003	4,502,263	–	4,502,263	0.676	3,043,530
2004	5,192,461	–	5,192,461	0.644	3,343,945
2005	5,993,151	–	5,993,151	0.613	3,673,802
2006	7,071,172	–	7,071,172	0.584	4,129,564
2007	7,967,286	–	7,967,286	0.556	4,429,811
2008	8,922,292	–	8,922,292	0.531	4,737,737
2009	9,936,190	–	9,936,190	0.505	5,017,776
2010	11,008,980	–	11,008,980	0.481	5,295,319
Total	70,548,319	2,316,787	68,231,532	–	38,990,702

Note: Totals may not add exactly because of rounding.

Total NPV	$38,990,702
Benefit–cost ratio	20
Internal rate of return	56%

Table B.11. Extra value of slaughtered pigs (at 5% price premium for lean meat) plus nutrition (feeding).

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	4,132,108	682,288	3,449,820	0.952	3,284,229
1997	8,612,934	342,688	8,270,246	0.907	7,501,113
1998	13,283,503	342,688	12,940,815	0.863	11,167,923
1999	18,795,195	660,515	18,134,680	0.822	14,906,707
2000	26,697,088	604,601	26,092,487	0.783	20,430,417
2001	29,300,937	–	29,300,937	0.746	21,858,499
2002	31,963,674	–	31,963,674	0.711	22,726,172
2003	34,685,310	–	34,685,308	0.676	23,447,269
2004	37,465,835	–	37,465,835	0.644	24,127,998
2005	40,356,853	–	40,356,853	0.613	24,738,751
2006	41,434,874	–	41,434,874	0.584	24,197,966
2007	42,330,988	–	42,330,988	0.556	23,536,029
2008	43,285,994	–	43,285,994	0.531	22,984,863
2009	44,299,892	–	44,299,892	0.505	22,371,445
2010	45,372,682	–	45,372,682	0.481	21,824,260
Total	462,017,867	3,502,937	458,514,928	–	288,233,484

Note: Totals may not add exactly because of rounding.

Total NPV	$288,233,484
Benefit–cost ratio	93
Internal rate of return	506%

Table B.12. Extra value of slaughtered pigs (at 10% price premium for lean meat) plus nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	6,240,465	682,288	5,558,177	0.952	5,291,384
1997	13,007,576	342,688	12,664,888	0.907	11,487,053
1998	20,061,245	342,688	19,718,557	0.863	17,017,115
1999	28,385,208	660,515	27,724,693	0.822	22,789,698
2000	38,897,920	604,601	38,293,319	0.783	29,983,669
2001	42,568,332	–	42,568,332	0.746	31,755,976
2002	46,297,633	–	46,297,633	0.711	32,917,617
2003	50,085,832	–	50,085,832	0.676	33,858,023
2004	53,932,921	–	53,932,921	0.644	34,732,801
2005	57,890,503	–	57,890,503	0.613	35,486,878
2006	58,968,524	–	58,968,524	0.584	34,437,618
2007	59,864,638	–	59,864,638	0.556	33,284,739
2008	60,819,644	–	60,819,644	0.531	32,295,231
2009	61,833,542	–	61,833,542	0.505	31,225,939
2010	62,906,332	–	62,906,332	0.481	30,257,945
Total	661,760,315	3,502,937	658,257,378	–	415,951,529

Note: Totals may not add exactly because of rounding.

Total NPV	$415,951529
Benefit–cost ratio	133
Internal rate of return	748%

Table B.13. Extra value of slaughtered pigs (at 20% price premium for lean meat) plus nutrition (feeding).

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	10,457,178	682,288	9,774,890	0.952	9,305,695
1997	21,796,860	342,688	21,454,172	0.907	19,458,934
1998	33,616,728	342,688	33,274,040	0.863	28,715,497
1999	47,565,235	660,515	46,904,720	0.822	38,555,680
2000	63,299,584	604,601	62,694,983	0.783	49,090,172
2001	69,103,123	–	69,103,123	0.746	51,550,930
2002	74,965,551	–	74,965,551	0.711	53,300,507
2003	80,886,878	–	80,886,878	0.676	54,679,529
2004	86,867,094	–	86,867,094	0.644	55,942,408
2005	92,957,802	–	92,957,802	0.613	56,983,133
2006	94,035,823	–	94,035,823	0.584	54,916,921
2007	94,931,937	–	94,931,937	0.556	52,782,157
2008	95,886,943	–	95,886,943	0.531	50,915,967
2009	96,900,841	–	96,900,841	0.505	48,934,925
2010	97,973,631	–	97,973,631	0.481	47,125,317
Total	1061,245,208	3,502,937	1057,742,271	–	671,387,615

Note: Totals may not add exactly because of rounding.

Total NPV	$671,387,615
Benefit–cost ratio	214
Internal rate of return	1,232%

Table B.14. Extra value of slaughtered pigs (at 5% price premium for lean meat), increase in slaughter pigs per breeding sow from 14 to 16 annually and nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	5,396,929	682,288	4,714,640.8	0.952	4,488,338
1997	11,249,316	342,688	10,906,628	0.907	9,892,312
1998	17,349,526	342,688	17,006,838	0.863	14,676,902
1999	24,548,323	660,515	23,887,808	0.822	19,635,778
2000	34,016,468	604,601	33,411,867	0.783	26,161,492
2001	37,260,157	–	37,260,157	0.746	27,796,077
2002	40,562,735	–	40,562,735	0.711	28,840,104
2003	43,924,211	–	43,924,211	0.676	29,692,766
2004	47,344,577	–	47,344,577	0.644	30,489,907
2005	50,875,434	–	50,875,435	0.613	31,186,641
2006	51,953,455	–	51,953,456	0.584	30,340,818
2007	52,849,569	–	52,849,570	0.556	29,384,361
2008	53,804,575	–	53,804,576	0.531	28,570,230
2009	54,818,473	–	54,818,474	0.505	27,683,329
2010	55,891,263	–	55,891,264	0.481	26,883,698
Total	581,845,011	3,502,937	578,342,080	–	364,852,596

Note: Totals may not add exactly because of rounding.

Total NPV	$364,852,596
Benefit–cost ratio	117
Internal rate of return	651%

Table B.15. Extra value of slaughtered pigs (at 10% price premium for lean meat), increase in slaughter pigs per breeding sow from 14 to 16 annually and nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	7,565,524	682,288	6,883,236	0.952	6,552,841
1997	15,769,519	342,688	15,426,831	0.907	13,992,136
1998	24,320,918	342,688	23,978,230	0.863	20,693,212
1999	34,412,337	660,515	33,751,822	0.822	27,743,998
2000	46,565,895	604,601	45,961,294	0.783	35,987,693
2001	50,906,621	–	50,906,621	0.746	37,976,339
2002	55,306,236	–	55,306,236	0.711	39,322,733
2003	59,764,748	–	59,764,748	0.676	40,400,970
2004	64,282,151	–	64,282,151	0.644	41,397,705
2005	68,910,046	–	68,910,046	0.613	42,241,858
2006	69,988,067	–	69,988,067	0.584	40,873,031
2007	70,884,181	–	70,884,181	0.556	39,411,604
2008	71,839,187	–	71,839,187	0.531	38,146,608
2009	72,853,085	–	72,853,085	0.505	36,790,808
2010	73,925,875	–	73,925,875	0.481	35,558,346
Total	787,294,390	3,502,937	783,791,453	–	496,219,725

Note: Totals may not add exactly because of rounding.

Total NPV	$496,219,725
Benefit–cost ratio	159
Internal rate of return	900%

Table B.16. Extra value of slaughtered pigs (at 20% price premium for lean meat), increase in slaughter pigs per breeding sow from 14 to 16 annually and nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	11,902,715	682,288	11,220,427	0.952	10,681,846
1997	24,809,926	342,688	24,467,238	0.907	22,191,785
1998	38,263,701	342,688	37,921,013	0.863	32,725,834
1999	54,140,365	660,515	53,479,850	0.822	43,960,437
2000	71,664,750	604,601	71,060,149	0.783	55,640,096
2001	78,199,549	–	78,199,549	0.746	58,336,864
2002	84,793,237	–	84,793,237	0.711	60,287,992
2003	91,445,823	–	91,445,823	0.676	61,817,377
2004	98,157,300	–	98,157,300	0.644	63,213,301
2005	104,979,268	–	104,979,268	0.613	64,352,291
2006	106,057,289	–	106,057,289	0.584	61,937,457
2007	106,953,403	–	106,953,403	0.556	59,466,092
2008	107,908,409	–	107,908,409	0.531	57,299,365
2009	108,922,307	–	108,922,307	0.505	55,005,765
2010	109,995,097	–	109,995,097	0.481	52,907,642
Total	1,198,193,139	3,502,937	1,194,690,202	–	758,953,987

Note: Totals may not add exactly because of rounding.

Total NPV	$758,953,987
Benefit–cost ratio	242
Internal rate of return	1,399%

Table B.17. Extra value of slaughtered pigs (at 5% price premium for lean meat), increase in slaughter pigs per breeding sow from 16 to 18 annually and nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	5,140,391	682,288	4,458,103	0.952	4,244,115
1997	10,714,454	342,688	10,371,766	0.907	9,407,192
1998	16,525,027	342,688	16,182,339	0.863	13,965,359
1999	23,381,812	660,515	22,721,297	0.822	18,676,906
2000	32,532,260	604,601	31,927,659	0.783	24,999,357
2001	35,646,258	–	35,646,258	0.746	26,592,108
2002	38,819,144	–	38,819,144	0.711	27,600,411
2003	42,050,928	–	42,050,928	0.676	28,426,427
2004	45,341,173	–	45,341,173	0.644	29,199,715
2005	48,742,339	–	48,742,339	0.613	29,879,054
2006	49,820,360	–	49,820,360	0.584	29,095,090
2007	50,716,474	–	50,716,474	0.556	28,198,360
2008	51,671,480	–	51,671,480	0.531	27,437,556
2009	52,685,378	–	52,685,378	0.505	26,606,116
2010	53,758,168	–	53,758,168	0.481	25,857,679
Total	557,545,646	3,502,937	554,042,709	–	349,315,288

Note: Totals may not add exactly because of rounding.

Total NPV	$349,315,288
Benefit–cost ratio	112
Internal rate of return	622%

Table B.18. Extra value of slaughtered pigs (at 10% price premium for lean meat), increase in slaughter pigs per breeding sow from 16 to 18 annually and nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	7,296,769	682,288	6,614,481	0.952	6,296,986
1997	15,209,184	342,688	14,866,496	0.907	13,483,912
1998	23,457,151	342,688	23,114,463	0.863	19,947,782
1999	33,190,269	660,515	32,529,754	0.822	26,739458
2000	45,011,000	604,601	44,406,399	0.783	34,770,211
2001	49,215,857	–	49,215,857	0.746	36,715,030
2002	53,479,603	–	53,479,603	0.711	38,023,998
2003	57,802,247	–	57,802,247	0.676	39,074,319
2004	62,183,331	–	62,183,332	0.644	40,046,066
2005	66,675,359	–	66,675,359	0.613	40,871,995
2006	67,753,380	–	67,753,380	0.584	39,567,974
2007	68,649,494	–	68,649,494	0.556	38,169,119
2008	69,604,500	–	69,604,500	0.531	36,959,990
2009	70,618,398	–	70,618,398	0.505	35,662,291
2010	71,691,188	–	71,691,188	0.481	34,483,461
Total	761,837,730	3,502,937	758,334,794	–	479,942,435

Note: Totals may not add exactly because of rounding.

Total NPV	$479,942,435
Benefit–cost ratio	154
Internal rate of return	869%

Table B.19. Extra value of slaughtered pigs (at 20% price premium for lean meat), increase in slaughter pigs per breeding sow from 16 to 18 annually and nutrition.

Year	Total benefits (A$)	Total costs (A$)	Benefit – cost (A$)	Discount factor at 5%	Net present value (NPV) (A$)
1995	–	870,157	–870,157	1	–870,157
1996	11,609,524	682,288	10,927,236	0.952	10,402,729
1997	24,198,643	342,688	23,855,955	0.907	21,637,351
1998	37,321,398	342,688	36,978,710	0.863	31,912,627
1999	52,807,183	660,515	52,146,668	0.822	42,864,561
2000	69,968,480	604,601	69,363,879	0.783	54,311,917
2001	76,355,057	–	76,355,057	0.746	56,960,873
2002	82,800,523	–	82,800,523	0.711	58,871,172
2003	89,304,888	–	89,304,888	0.676	60,370,104
2004	95,867,652	–	95,867,652	0.644	61,738,768
2005	102,541,398	–	102,541,398	0.613	62,857,877
2006	103,619,419	–	103,619,419	0.584	60,513,741
2007	104,515,533	–	104,515,533	0.556	58,110,636
2008	105,470,539	–	105,470,539	0.531	56,004,856
2009	106,484,437	–	106,484,437	0.505	53,774,641
2010	107,557,227	–	107,557,227	0.481	51,735,026
Total	1,170,421,901	3,502,937	1,166,918,964	–	741,196,722

Note: Totals may not add exactly because of rounding.

Total NPV	$741,196,722
Benefit–cost ratio	237
Internal rate of return	1,365%

IMPACT ASSESSMENT SERIES

No.	Author 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	Centre for International Economics (1998)	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	Ross McLeod (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021

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No.	Author and year of publication	Title	ACIAR project numbers
1	Doeleman, J.A. (1990a)	Biological control of salvinia	8340
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3	Fleming, E. (1991)	Improving the Feed Value of Straw Fed to Cattle and Buffalo	8203 and 8601
4	Doeleman, J.A. (1990b)	Benefits and costs of entomopathogenic nematodes: two biological control applications in China	8451 and 8929
5	Chudleigh, P.D. (1991a)	Tick-borne disease control in cattle	8321
6	Chudleigh, P.D. (1991b)	Breeding and quality analysis of canola (rapeseed)	8469 and 8839
7	Johnston, J. and Cummings, R. (1991)	Control of Newcastle disease in village chickens with oral V4 vaccine	8334 and 8717
8	Ryland, G.J. (1991)	Long term storage of grain under plastic covers	8307
9	Chudleigh, P.D. (1991c)	Integrated use of insecticides in grain storage in the humid tropics	8309, 8609 and 8311
10	Chamala, S., Karan, V., Raman, K.V. and Gadewar, A.U. (1991)	An evaluation of the use and impact of the ACIAR book *Nutritional Disorders of Grain Sorghum*	8207
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12	McKenney, D.W., Davis, J.S., Turnbull, J.W. and Searle, S.D. (1991)	The Impact of Australian Tree Species Research in China	8457 and 8848
	Menz, K.M. (1991)	Overview of Economic Assessments 1–12	