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Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts

IMPACT ASSESSMENT SERIES **52**





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Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts

Hayden Fisher and Jenny Gordon

Centre for International Economics, Canberra and Sydney

May 2008

Australian Government

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The Australian Centre for International Agricultural Research (ACIAR) operates as part of Australia's international development cooperation program, with a mission to achieve more productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

ACIAR seeks to ensure that the outputs of its funded research are adopted by farmers, policymakers, quarantine officers and other beneficiaries.

In order to monitor the effects of its projects, ACIAR commissions independent assessments of selected projects. This series reports the results of these independent studies.

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Foreword

This impact assessment study continues ACIAR's focus on better understanding and quantifying the impact of the capacity-building contribution from its research and development funding.

In addition, the study updates the estimates of the impact provided in Impact Assessment Series Report No. 17 published in 2001.

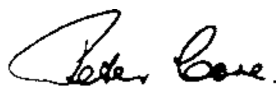
The study highlights two important issues. First, the total benefits from this research activity and subsequent follow-up activities have increased substantially, from a net present value of benefits of nearly $500 million to nearly $2.0 billion. While part of this increase in benefits is due to the significant follow-up development funding, the study estimates that the ACIAR project impacts have more than doubled over the original estimates to around $1.1 billion. This provides a benefit-to-cost return of over 250:1 and an internal rate of return of 74%.

Second, the capacity building included as an important component of the original project has been crucial in sustaining the original impact of the research and in significantly extending this impact. Without the enhanced skills of the research team, the productivity gains for the pig industry would have diminished soon after the project was completed. In addition, through this enhanced capacity, the Vietnamese research team was able to attract significant follow-up funding which expanded the original breeding program and has more than doubled the adoption and spread of the pig industry with improved productivity.

This study estimates that the contribution to the total benefits of the capacity-building activities has been substantial. While attribution of the benefits to this capacity building is a complex issue, the study concludes that this impact was $424 million of the total benefits. The return on the funds invested in the capacity building was estimated to provide a benefit:cost ratio of 250:1 and an internal rate of return of 25%.

This study adds further quantitative evidence demonstrating the importance and complexity of capacity building and stock-of-knowledge generation to ACIAR's partnership research and development activities.

This is a complex area and I congratulate the Centre for International Economics group for developing it further.



Peter Core
Chief Executive Officer
ACIAR

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Summary

This report forms part of ACIAR's Impact Assessment Series (IAS). It revisits a previous impact assessment (Tisdell and Wilson 2001: *Breeding and feeding pigs in Australia and Vietnam,* IAS No. 17), but assesses, in addition, the impacts of the capacity-building aspects of the activities.

ACIAR Project AS2/1994/023 on *Breeding and feeding pigs in Australia and Vietnam* was estimated to have delivered significant benefits to Vietnam. Tisdell and Wilson (2001) estimated that, over the period from 1995 to 2010, the internal rate of return on the project was around 900%. Using a discount rate of 5%, the project was estimated to have a net present value of $496 million and a benefit:cost ratio of 159:1 (using 1995 as the base year). They estimated that around 92% of the benefits accrued from the breeding component of the project, with the remaining 8% attributed to the feed-formulation component.

As with most ACIAR projects, capacity building was an important focus. This impact assessment extends the work of Tisdell and Wilson by focusing on the benefits that can be attributed to the capacity-building activities. This includes a share of the impacts of the subsequent investments that were a consequence of the development of skills and knowledge. Benefits are attributed to the ACIAR capacity building on a cost share basis, as the capacity building was necessary but not sufficient to deliver the full impact of the ACIAR project and the follow-on research and development (R&D). As the initial impact assessment was completed in 2001, it was also an opportunity to verify the assumptions about adoption and observe actual productivity improvements.

Motivation for the ACIAR project

Pigs are an integral part of Vietnam's rural economy, and pig meat accounts for more than 70% of total meat production in Vietnam. Native pig breeds tend to have lower feed-conversion ratios and lean-meat percentages than exotic breeds. Consequently, local breeds are gradually being replaced or crossbred with exotic breeds. However, many of the exotic breeds that had been introduced into Vietnam had adapted poorly to local conditions and the breeding stock was of low genetic quality. Furthermore, the diets fed to exotic pigs in Vietnam were found to be deficient (La Van Kinh et al. 2002).

ACIAR Project AS2/1994/023 aimed to enhance the productivity of the pig industry in Vietnam through improved genetics and the formulation of least-cost diets (ACIAR 2001). Over a number of years, the Queensland Department of Primary Industries (QDPI) has bred high-yielding pigs that adapt well to tropical conditions. QDPI was commissioned to undertake the research in collaboration with James Cook University (JCU) and the Institute of Agricultural Science of South Vietnam (IAS).

Research undertaken

In 1995, 12 gilts and 21 boars of the Yorkshire and Duroc breeds were imported into Vietnam from Australia. The research focused on comparing the performance of these pigs in Vietnamese conditions with that of the existing exotic species in Vietnam. The project also aimed to develop least-cost diet recommendations, based on locally available feed material.

The project involved significant investment in capacity building through formal training of Vietnamese researchers as well as collaboration with Australian researchers. The formal training included the Genetic Improvement and Pig Production Essentials Training (GIPPET) course, which was attended by 19 Vietnamese researchers, over a 3-week period. Some researchers also undertook longer-term training in Australia.

In a follow-up project to facilitate the spread of the superior genes, AusAID provided funding to five artificial insemination (AI) centres throughout Vietnam.

The results of the project

Technical outputs

The project delivered improved genetics and production systems. The major focus appears to be on technology transfer and working with Vietnamese researchers to adapt Australian R&D methods to Vietnamese conditions. The project generated considerable new knowledge of breeding and feed conversion under these conditions.

Capacity built and utilised

The project successfully built the capacity of Vietnamese collaborators to undertake further research in areas such as genetic improvement, nutrient digestibility, AI, chemical analysis and computer-aided diet formulation. The AusAID-funded project also contained a significant capacity-building element, providing training to technicians at the AI centres.

Researchers interviewed stated that they were able to utilise the skills and knowledge developed during the project to maintain the genetic improvements in breeder herds and to continue to produce optimised feed. Furthermore, as a direct result of the project, the IAS was able to attract additional funding from the Ministry of Agriculture and Rural Development and the governments of the Netherlands and Belgium to continue the research.

Impact—the difference the R&D is making

Productivity was raised through increasing the live weight of pigs at slaughter, increasing the lean-meat percentage, improving the reproductive performance of breeding pigs and lowering feeding costs. This has significantly reduced the unit cost of pig-meat production for farmers utilising the superior breeds and/or the feed recommendations. Tested breeding pigs of superior genetic quality have been distributed to breeding farms, AI centres and commercial breeding farms throughout Vietnam. The superior genes have then multiplied and been transferred to commercial pig farms. It is estimated that around 10% of pigs in Vietnam are of superior genetic quality from the Binh Thang Animal Husbandry Research and Training Centre (BTRC), an applied research centre of the IAS. Over the next 10 years this share is expected to increase to around 20%. Of these superior-quality pigs, it is estimated that around 40% will be the progeny of the pigs imported into Vietnam under the ACIAR project.

When all sources of funding are taken into account, it is estimated that the breeding R&D that began under the ACIAR project will deliver benefits of around $1.6 billion to Vietnam (in present value 2006 dollars and using a discount rate of 5%). The feeding R&D is estimated to result in benefits worth around $0.4 billion. The benefits of the breeding R&D to 2007 are estimated at about $89 million, while over the same period the feeding R&D is estimated to have generated benefits of around $60 million.

Of these total benefits, approximately $1.1 billion (present value discounted at 5%) can be attributed to the ACIAR project. The internal rate of return on the project is estimated at 74%, with a benefit:cost ratio of 257:1. Based on cost-share attribution, ACIAR funding is expected to generate benefits of $387 million.

Attribution of benefits to capacity building

The benefits attributable to capacity building depend on the counterfactual scenario; what would have happened in the absence of the capacity-building components of the project. In the absence of the capacity-building and research components of the project, it is likely that the pigs imported under the project would have been distributed to breeding farms immediately. This would have yielded significant benefits but, without careful selection and maintenance of the nucleus herd, it is unlikely that these benefits would have been sustained. Thus, capacity building is responsible for the maintenance of the improved genetics at the level delivered by the ACIAR project. Furthermore, since the skills and knowledge developed under the ACIAR project were used in subsequent projects funded by other organisations, a share of those benefits can also be attributed to the capacity-building activities that formed part of the ACIAR project. For improvements arising from subsequent R&D the capacity built was necessary but not sufficient for delivering the benefits. In such circumstances the approach to estimating the impact of the capacity building alone is to use a cost share basis, unless a case can be made that the capacity-building component's impact was disproportionately greater than those of other essential inputs.

On the feeding side, the capacity building was necessary but not sufficient to deliver the benefits associated with the least-cost diet recommendations. Benefits could therefore also be attributed on a cost-share basis.

The capacity-building component is estimated to have been around 40% of the effort in the project. Based on the project returns, this implies that the capacity-building return is $424 million. The internal rate of return on the capacity-building activities is estimated at 24.5%, with a benefit:cost ratio of 256:1. Given that this component of the ACIAR project was the enabling factor that allowed subsequent R&D investment to be undertaken, the return may well be higher.

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1 Introduction

This report revisits a previous impact assessment (Tisdell and Wilson 2001: *Breeding and feeding pigs in Australia and Vietnam,* IAS No. 17), but with a focus on capacity-building aspects of the research and development (R&D) activities. The project aimed to improve the productivity of pig raising in Vietnam through improved genetics and nutrition (ACIAR 2001).

Tisdell and Wilson identified four major channels through which the project improved the productivity of pig production in Vietnam:

- increased slaughter weight of fattening pigs
- increased lean-meat percentage of fattening pigs
- improved reproductive performance of breeding pigs
- lower feeding costs.

Assessing the impacts of the project over the 1995–2010 period, Tisdell and Wilson (2001) estimated that the internal rate of return (IRR) on the project was around 900%. Using a discount rate of 5%, the project was estimated to have a net present value of $496 million and a benefit:cost ratio of 159:1 (Table 1). Around 92% of the benefits were attributed to the breeding component of the project and the remaining 8% to the feeding component.

As with most ACIAR projects, capacity building was an important focus. However, the benefits of the capacity-building activities were not fully followed through in the initial analysis. This impact assessment extends the work of Tisdell and Wilson by focusing on the benefits flowing from the capacity-building activities. Given the initial impact assessment was completed in 2001, it was also an opportunity to verify the assumptions about adoption and assess actual productivity improvements.

Pig production in Vietnam

Pigs are an integral part of Vietnam's rural economy, and pig meat accounts for more than 70% of total meat production. Most farms keep at least one pig. Vietnam's pig population has increased at an annual rate of nearly 6% since the early 1990s and was estimated at 27 million in 2005 (FAO livestock database at <http://faostat.fao.org/default.aspx>, accessed February 2007). In line with the increase in the number of pigs slaughtered, as well as higher slaughter weights, pig-meat production has also grown strongly through this period (Figure 1). There is little cross-border trade in Vietnam, owing to the large tariffs on imports. However, a small amount of high-quality pork is imported into Vietnam to meet demand from luxury hotels and some supermarkets in urban areas (Dinh Xuan Tung et al. 2005).

Table 1. Estimated benefits from ACIAR-funded project in 2001

	Net present value $m	Benefit:cost ratio	Internal rate of return %
Breeding component	457.2	429	2,644
Feeding component	39.0	20	56
Total	496.2	159	900

Note: Assuming a 5% discount rate

Source: Tisdell and Wilson (2001, pp. 30–33).

Breeds

In Vietnam, local breeds are gradually being replaced or crossbred with higher-yielding exotic breeds. Local breeds tend to be smaller and have lower feed-conversion and lean-meat ratios than exotic breeds (La Van Kinh et al 2002). However, local breeds have a number of favourable characteristics, particularly for smallholder farmers. They include better adaptation to local conditions and low-input production systems, ability to thrive on poor-quality feed, and lower susceptibility to disease (Le Thi Huyen et al. 2005). The more productive local breeds include Mong Cai and Lang Hong.

Exotic pig breeds were first introduced into Vietnam in 1920. During the period of French colonial administration, exotic breeds were imported by individual farms, mainly from France and the US. Following the division of Vietnam in 1954, exotic pigs were imported into South Vietnam through the Phat Ngan Animal Husbandry Corporation, mainly to meet demand from the US Army. In the north, exotic species from the Soviet Union, China and Cuba were imported into state farms through the National Institute of Animal Husbandry (NIAH). These were mainly exotic boars for mating with local sows (Le Thi Huyen et al. 2005).

More recently, exotic breeds have been imported largely through research institutes such as the NIAH in the north and the Institute of Agricultural Science of South Vietnam (IAS) in the south, as well as by foreign-owned companies.

Thus, there were exotic breeds present in Vietnam before the start of the ACIAR-funded project, but these tended to be of low genetic quality. The contribution of the ACIAR project was to improve the genetic quality of the exotic breeds.

Pig production systems

There are four levels of pig production in Vietnam (Nguyen Thi Vien et al. 2001a):

- *State level.* Most state farms raise exotic breeds such as Yorkshire, Landrace, Duroc and Pietrain. They keep mainly great grandparent (GGP) and grandparent (GP) stock. GGP stock is generally used as a nucleus herd and for research. These farms produce piglets to sell to commercial breeding farms. State farms therefore play an important role in improving the quality of the breeding herd.

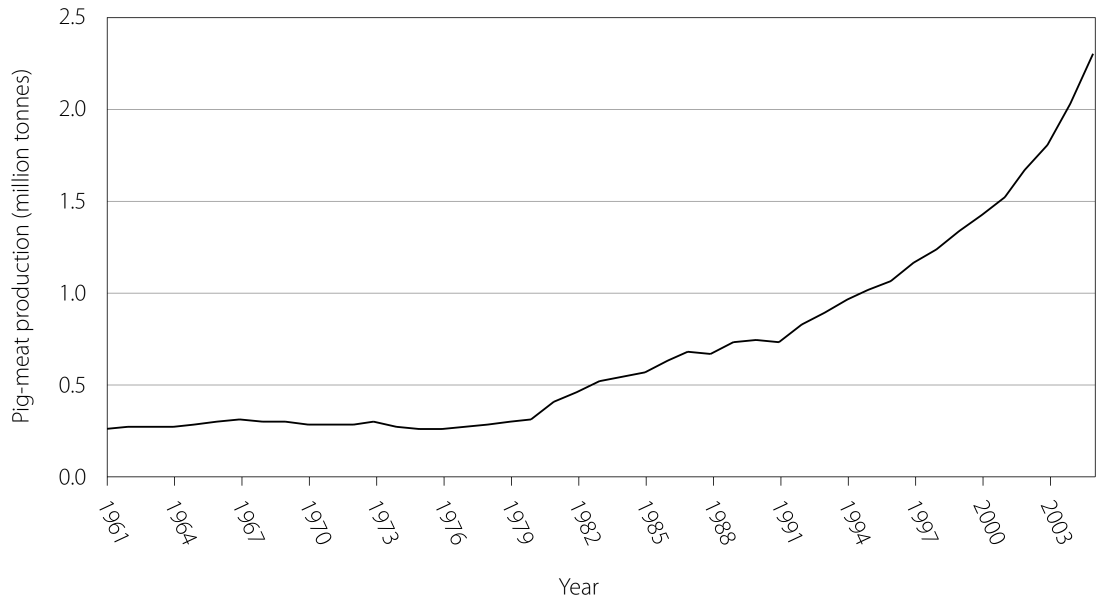

Figure 1. Pig-meat production in Vietnam (carcass weight). Data source: FAO Livestock database at <http://faostat.fao.org/default.aspx>, accessed February 2007

- *Small-scale production level*. Small-scale producers account for more than 64% of the national herd. At the household level, pig herds are mostly a cross between local and exotic breeds. Local breeds are kept mainly in remote areas.
- *Medium-scale production level*. Medium-scale commercial producers keep mainly exotic and crossbreeds.
- *Foreign-invested companies*. Large, foreign-owned companies are clustered mostly around the major urban areas of Hanoi and Ho Chi Minh City to meet the rapidly expanding demand in those markets. These companies tend to have their own programs to improve their breeding stock.

Table 2 shows that the proportion of the pig population held by smallholders has declined over recent years. Growth has mainly been concentrated in small–medium and medium-size farms.

Most smallholder farmers sell live animals to traders at the farm gate. The semi-commercial and commercial farms use a mix of traders and marketing directly to abattoirs.

The ACIAR-funded research project

Background

The production of lean pig meat is affected by the genetic quality of the breeding stock and pig nutrition. Native breeds are small, fat and slow growing. While exotic breeds are leaner, they have often adapted poorly to local conditions and require more expensive feed (ACIAR 2001). A survey of smallholder farms in six provinces showed that the protein concentration of pig diets was often 20–30% lower than recognised feeding standards (La Van Kinh et al. 2002).

The research project

The broad aim of ACIAR Project AS2/1994/023 was to enhance the productivity of pig-meat production in Vietnam and Australia through improved genetics and the formulation of least-cost diets. Pig producers in warmer areas of Australia face similar challenges to those in Vietnam (ACIAR 2001).

Over a number of years, the Queensland Department of Primary Industries (QDPI) has bred high-yielding pigs that adapt well to tropical conditions. In order to capitalise on this expertise, the QDPI Animal Research Institute was commissioned to undertake the research in collaboration with James Cook University (JCU) and the IAS in Vietnam.

The project involved both technical investment (in the provision of equipment and of animals with improved genetic characteristics) and investment in building the capacity of the Vietnamese collaborators, including training in the use of the equipment provided. Equipment provided included:

- two copies of the consultant version of the 'Feedmania' diet-formulation computer package at a cost of $4,250

Table 2. Pig holdings by scale of production

Holding type	Herd size	Share of national herd (1999)	Share of national herd (2006)	Breeds
Smallholders or backyard	1–10 pigs	80%	64%	North: mostly local South: mostly cross with exotic
Small–medium	5–20 sows or 30–100 fattening	10%	20%	Cross and exotic
Medium	20–500 sows or 100–4,000 fattening	5%	10%	Exotic
Large	More than 500 sows or 4,000 fattening	5%	6%	Exotic

Source: La Van Kinh (2007, p. 7)

- two warming stages for semen quality assessment at a cost of $2,365 each
- one amino acid analyser costing $40,000
- one bomb calorimeter nominally costing $10,000.

It is unclear how much of the R&D work was technology transfer (i.e. training of advanced techniques through joint research activities) and how much was new discovery such as adaptation of techniques to Vietnamese conditions. It is clear that new knowledge as to suitability of animal genetics and feed conversion was generated by the project. This knowledge base has been further developed by subsequent research.

There was also a follow-up project funded by AusAID, which provided support to five artificial insemination (AI) centres to facilitate more rapid diffusion of the superior genetic make-up. The project funded the upgrade of each of these facilities, providing new equipment plus 10 tested boars from the Binh Thang Animal Husbandry Research and Training Centre (BTRC) for each centre, together with training in AI techniques for technicians at the centres.

Technical outputs and additions to the stock of knowledge

The main technical investment involved the transfer of the superior genetics of Australian breeding pigs from the QDPI to the IAS. The QDPI scientists developed a selection protocol that, over a number of years, resulted in the development of a pig genotype with a high growth rate, lean carcass, good appetite and high resistance to stress. Initially, 33 breeding pigs of two Australian breeds (Australian Yorkshire and Duroc) were exported to Vietnam. In trials, the Australian stock outperformed the exotic species that were available in Vietnam at the time in terms of growth rate, leanness of the carcass and feed-conversion efficiency.

Working with the Vietnamese researchers, the project also:

- improved understanding of deficiencies in existing feeding practices
- provided increased nutrient information on local feed ingredients
- improved understanding of dietary requirements of pigs in local conditions
- stimulated the development of least-cost feeding recommendations.

Capacity-building activities

The principal ways in which capacity was built during the project were formal training and learning-by-doing activities undertaken in collaboration with the Australian researchers. Formal training provided as part of the project was as follows:

- Nineteen Vietnamese researchers undertook the Genetic Improvement and Pig Production Essentials Training (GIPPET) course. The course was designed by the Australian researchers in consultation with the Vietnamese collaborators to bridge the knowledge gap between pig specialists in Vietnam and Australia and to ensure consistency in research techniques. The course was held in Australia over 3 weeks in May 1996. The group included 14 participants from the IAS as well as participants from other organisations. The GIPPET course covered topics such as (Kopinski and Le Thanh Hai 2001):
  - genetic improvement
  - nutrient digestibility studies
  - artificial insemination
  - chemical analysis
  - computer-aided diet formulation.

- A number of researchers from the IAS undertook longer-term training in Australia for periods ranging from 3 to 6 months (Kopinski and Le Thanh Hai 2001). Topics included:
  - pig selection and breeding by PigBLUP, a computer-based genetic evaluation system
  - in-vitro feed assessment, specifically:
    - bomb calorimetry
    - amino-acid analysis
  - in-vivo feed assessment, specifically:
    - digestible energy assessment in metabolism crates
    - assessment by serial slaughter of digestibility in different gut segments of the pig
    - cannulation of pigs, and other surgical techniques.
- A researcher involved in the project was awarded a John Allwright Fellowship and undertook a PhD in pig genetics at the University of Queensland, supervised by the project leader, Dr C. McPhee.

Capacity building also formed a significant part of the follow-up project funded by AusAID.

Follow-up projects

The capacity built enabled a number of follow-up projects to be undertaken, including:

- pig breeding aid projects funded by the governments of the Netherlands (US$5.4 million over 5 years) and Belgium (10 Pietrain boars)
- the National Breeding Program funded by the Ministry of Agriculture and Rural Development (VND[1]40 billion over 5 years)
- the National Feeding Program also funded by the Ministry of Agriculture and Rural Development (VND1.5 billion over 3 years).

Researchers at the IAS felt that these subsequent projects were a direct result of the capacity developed through the ACIAR-funded project; that is, the capacity built resulted not only in a higher quality of research being undertaken after the project, but also in additional research funding that otherwise would not have come to pig research (see Chapter 2 for a further discussion).

Participants in the capacity-building activities were also able to train other pig-industry stakeholders and thereby build further capacity to conduct research within Vietnam. Many of the participants in the GIPPET course indicated that they subsequently were able to pass on skills and knowledge to other researchers. Technicians from the AI centres who received training through the project were also able to provide training to colleagues. Furthermore, the AI centres conduct regular training courses for local farmers in AI techniques, as well as other aspects of pig raising.

Costs of the research

The ACIAR-funded project was initially planned to run from July 1995 to June 1998, but was subsequently extended and completed in August 2001. ACIAR contributed $1,367,389 over the course of the project, with the partner research organisations contributing $2,135,548 (Table 3). Table 3 also shows the estimated funding provided by AusAID to support the five AI centres.

The estimated Australian dollar cost of the subsequent R&D is shown in Table 4. Converting all to 2006 dollars, the share of the ACIAR projects in the total R&D investment is 10% for the breeding project and 94% for the feeding project. ACIAR funded 36% of the breeding project and 40% of the feeding project.

Figure 2 summarises the project inputs, outputs, outcomes and impacts.

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1 Vietnamese dong; in April 2008, A$1.00 = approximately VND15,000

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Table 3. Nominal cost of research

	ACIAR $'000	QDPI $'000	JCU $'000	IAS $'000	AusAID	Total
Breeding						
1995	136.7	120.0	–	33.0	–	289.7
1996	68.5	120.0	–	31.5	–	220.0
1997	34.4	95.0	–	12.9	–	142.3
1998	34.4	95.0	–	12.9	–	142.3
1999	109.1	110.0	–	46.9	–	266.1
2000	48.5	60.0	–	17.5	92.3	218.3
2001	–	–	–	–	99.3	99.3
2002	–	–	–	–	–	–
2003	–	–	–	–	–	–
2004	–	–	–	–	–	–
2005	–	–	–	–	–	–
Subtotal	431.6	600.0	–	154.6	191.7	1,377.8
Feeding						
1995	271.3	198.9	77.4	33.0	–	580.5
1996	154.6	198.9	77.4	31.5	–	462.3
1997	84.4	64.4	38.7	12.9	–	200.4
1998	84.4	64.4	38.7	12.9	–	200.4
1999	138.5	209.0	–	46.9	–	394.5
2000	202.5	258.7	–	17.5	–	478.6
2001	–	–	–	–	–	–
2002	–	–	–	–	–	–
2003	–	–	–	–	–	–
Subtotal	935.8	994.2	232.2	154.6	–	2,316.8
Total	1,367.4	1,594.2	232.2	309.1	191.7	3,694.6

Note: ACIAR, Australian Centre for International Agricultural Research; QDPI, Queensland Department of Primary Industries, Australia; JCU, James Cook University, Australia; IAS, Institute of Agricultural Science of South Vietnam; AusAID, Australian Agency for International Development

Source: Tisdell and Wilson (2001) and information provided by the IAS

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Table 4. Nominal cost of subsequent research and development[a]

	Ministry of Agriculture and Rural Development, Vietnam $'000	**Netherlands** $'000	**Belgium** $'000	**Total** $'000
Breeding				
1998	–	1,715.9	15.9	1,731.8
1999	–	1,673.6	15.5	1,689.0
2000	–	1,854.6	–	1,854.6
2001	1,043.7	2,086.4	–	3,130.1
2002	964.9	1,985.6	–	2,950.6
2003	792.8	–	–	792.8
2004	691.6	–	–	691.6
2005	662.1	–	–	662.1
Total	4,155.2	9,316.1	31.4	13,502.6
Feeding				
2001	65.2	–	–	65.2
2002	60.3	–	–	60.3
2003	49.6	–	–	49.6
Subtotal	175.1	–	–	175.1
Total	4,330.3	9,316.1	31.4	13,677.7

[a] Amounts provided by the Institute of Agricultural Science (IAS) are converted to Australian dollars using exchange rates from the International Monetary Fund's World Economic Outlook database.

Source: IAS, IMF World Economic Outlook database at <http://www.imf.org/external/pubs/ft/weo/2007/02/weodata/index.aspx>.

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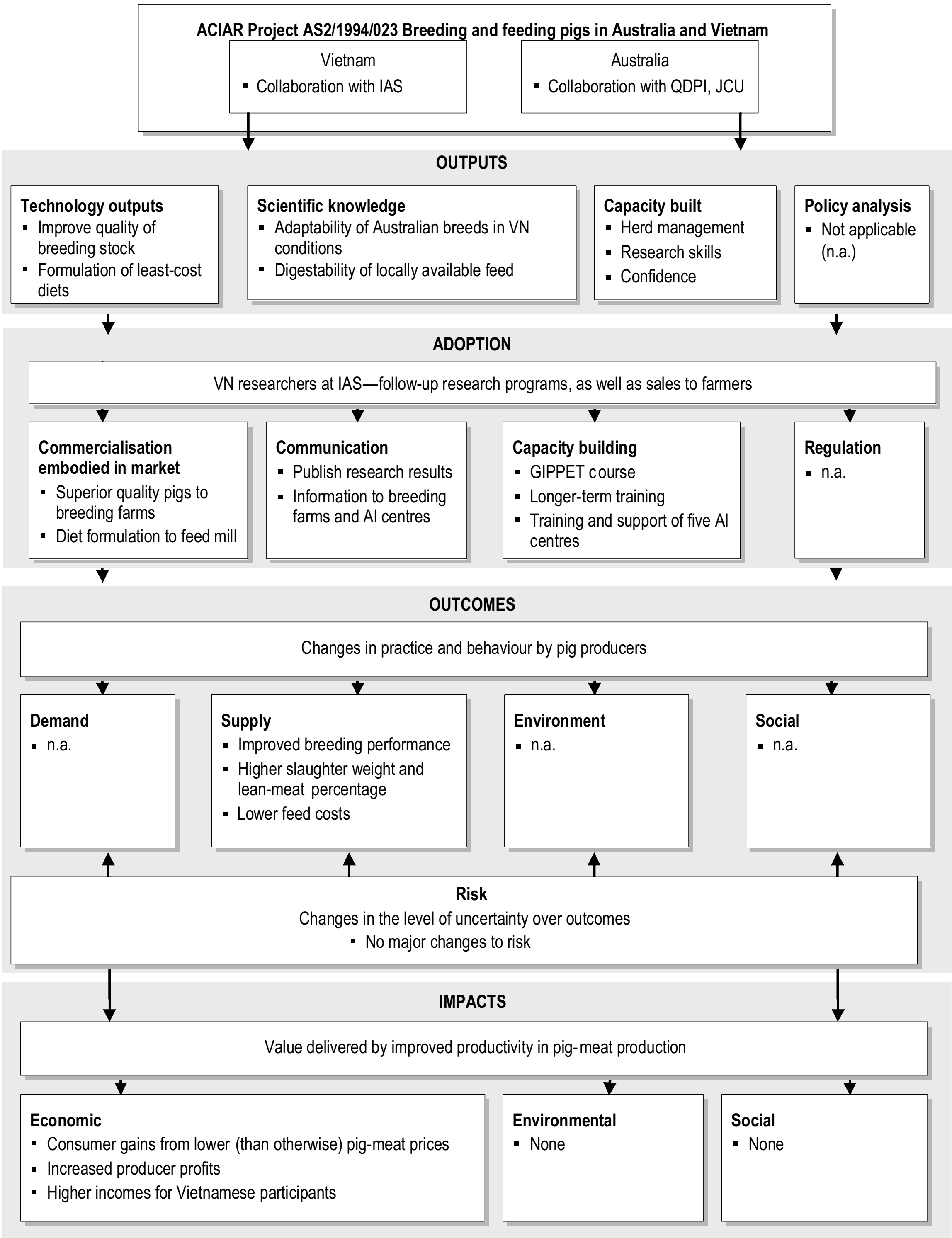


IAS = Institute of Agricultural Science of South Vietnam   QDPI = Queensland Department of Primary Industries

JCU = James Cook University   VN = Vietnamese   AI = artificial insemination

GIPPET = Genetic Improvement and Pig Production Essentials Training

Figure 2. Project summary. Source: Centre for International Economics

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

2 Mapping capacity building to measured benefits

There are two distinct (although related) pathways to measured benefits from the capacity-building activities that formed part of the project. The first is the capacity built during the project that contributed directly to sustaining the project outcomes. The second is the contribution the capacity built made to the subsequent level of investment and to the effectiveness of the ongoing research that is, in turn, improving the genetic selection and feed formulation. Such 'flow-on' effects of enhanced capacity arise because:

- the skills and knowledge gained by the researchers enable them to further their research and improve the quality and/or speed of their results
- organisational capacity to support the research agenda is enhanced both in terms of management understanding and the legacy of systems development from the collaborative work
- the relationships developed continue to encourage international collaboration and sharing of knowledge, enhancing the research quality and effectiveness of all researchers involved.

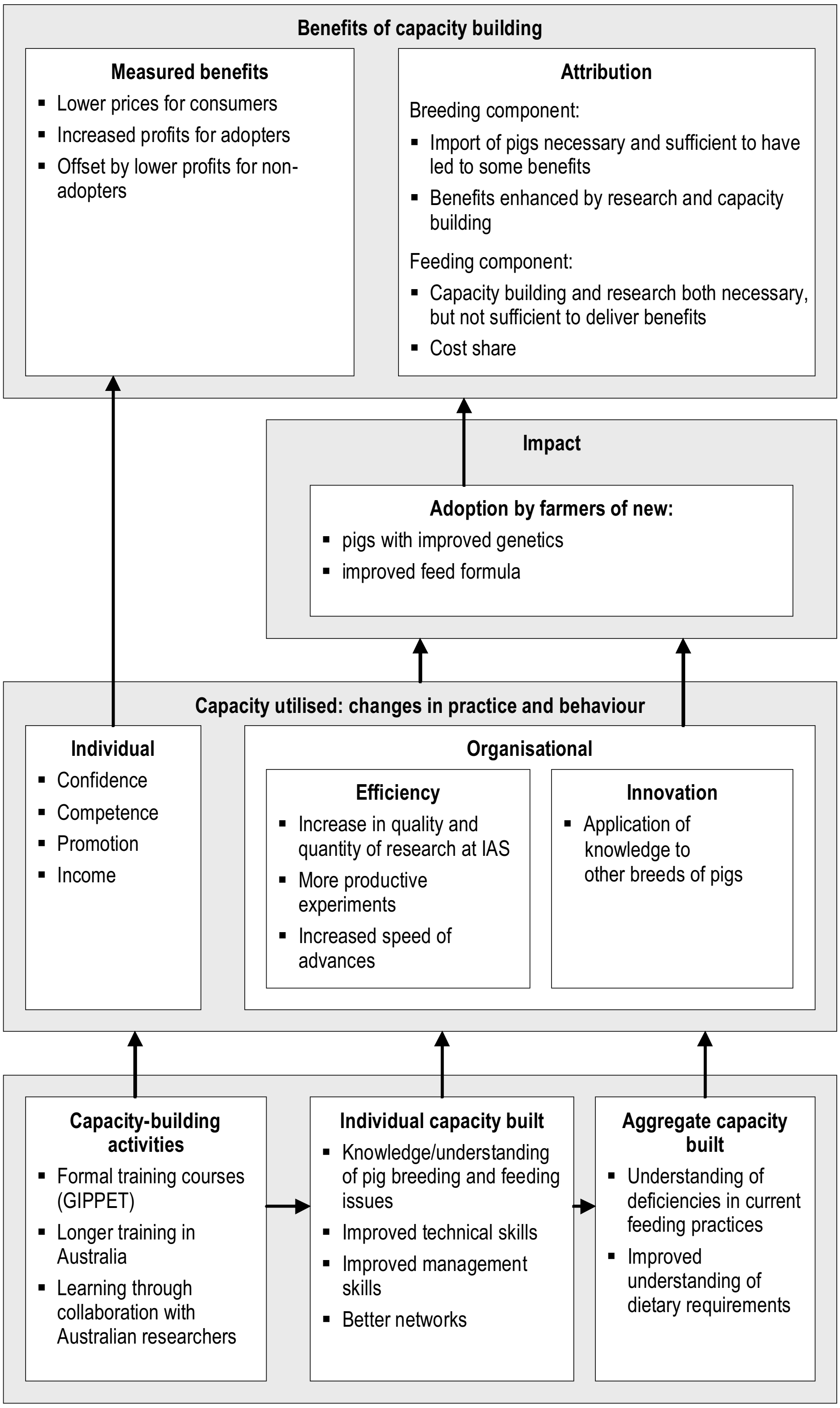
Figure 3 provides a mapping from capacity-building activities through to impacts and benefits following the guidelines for capacity-building evaluation (Gordon and Chadwick 2007).

The strength of these linkages from the capacity-building activities through to the measured benefits was tested using a survey of the researchers involved in the training programs. A survey was conducted in June 2007 through face-to-face interviews and a survey questionnaire. The survey included:

- 11 of the 19 GIPPET trainees who participated in the survey, some of whom also completed longer-term training in Australia
- from four of the five AI centres, at least one technician who received training under the AusAID-funded follow-up project.

The results of the survey are given in the appendix. The aim of the survey was to capture information from those involved in the capacity building to assess the extent to which their skills and knowledge were improved, how that capacity was then utilised and, where possible, the consequences of this application in terms of both personal and organisational outcomes. Respondents provided scores across a number of questions. The average scores yield information on the extent to which the respondents as a group felt that capacity had been built and utilised, and outcomes achieved. For the 11 respondents, the average scores across all areas for both formal training courses were between 'agree' and 'strongly agree' for almost all positive aspects of relevance, quality of training, capacity built, capacity utilised and outcomes. The average score for each category of questions is provided in Table 5.

As the perceptions of the individuals involved in the capacity-building activities may not always be accurate—particularly in regard to organisational outcomes—it is important to verify the survey results. Where possible, the supervisors of the training-course participants were also interviewed to confirm the survey responses. The responses of supervisors have been included in the survey results only if they also participated in the training courses. The high scores reported in the survey were confirmed in discussions with the individuals involved and their supervisors.



IAS = Institute of Agricultural Science of South Vietnam

GIPPET = Genetic Improvement and Pig Production Essentials Training

Figure 3. Pathways from capacity building to benefits. Source: Centre for International Economics

Table 5. Survey responses[a]: summary

Area	GIPPET course	AI technician training
Relevance of training provided	4.6	4.5
Quality of training provided	4.3	4.3
Capacity built	4.3	4.3
Capacity utilised	4.2	4.3
Outcomes—personal	4.1	4.5
Outcomes—organisational	4.2	4.2

[a] Unweighted average of responses: 5 is strongly agree (highly positive), 3 is neutral and 1 is strongly disagree (highly negative)
Source: Centre for International Economics survey conducted June 2007

It is interesting also to look at the correlation between each level of the responses. The correlation matrix of responses from the survey of participants in the GIPPET training course is given in Table 6. The sample of AI technicians was too small to conduct a meaningful correlation analysis. The correlation analysis for GIPPET participants confirms that positive scores at all levels are positively correlated across respondents. The correlation was particularly strong between capacity built and capacity utilised. This shows that where skills were built they were also used, indicating that appropriate people were selected to undertake the course. The correlation between perceptions of the quality of training and capacity built were also relatively strong, suggesting that it is important to provide high-quality training in order to build capacity.

Responses to the relevance question tended to be relatively weakly correlated with capacity utilised and the outcomes for the organisation. The correlation between responses to the quality of training questions and the outcomes for the organisation was also relatively weak.

Table 6. Correlation matrix—Genetic Improvement and Pig Production Essentials Training course survey

	Relevance	Quality	Capacity built	Capacity utilised	Outcomes—personal	Outcomes—organisation
Relevance of training	1.00					
Quality of training	0.68	1.00				
Capacity built	0.50	0.82	1.00			
Capacity utilised	0.39	0.79	0.97	1.00		
Outcomes—personal	0.59	0.76	0.78	0.72	1.00	
Outcomes—organisation	0.37	0.40	0.77	0.72	0.64	1.00

Source: Centre for International Economics, based on survey responses

Capacity built

During the project, capacity was built through:

- formal training
- collaboration with the Australian researchers.

During interviews, the Vietnamese researchers involved in the project felt that formal training was crucial and was the most effective means of building capacity. Learning through collaborations with the Australian researchers was useful in reinforcing and building on the skills and knowledge developed through formal training.

For the GIPPET survey, the average response to the survey questions relating to capacity built was 4.3, indicating that, on average, the participants agreed or strongly agreed that capacity was built through the GIPPET course. The researchers surveyed indicated that, as a direct result of the course, they had increased their capacity to conduct higher quality research, improved their understanding of the issues and principles in relation to pig breeding and nutrition, and acquired new ways to approach work problems. To a lesser extent, participants also acquired new or improved laboratory or other technical skills, gained new skills to manage research projects efficiently and effectively, and learned new or improved ways of communicating with peers.

For the survey of AI technicians, the average response to the survey questions relating to capacity built was also 4.3. This indicates that technicians that participated in this training course also agreed or strongly agreed that capacity was built through this training.

Capacity utilised

The GIPPET course participants were able to apply the knowledge and skills to their work and, in general, continue to do so. The average response to questions relating to capacity utilised was 4.2, indicating that participants agreed or strongly agreed that they were able to utilise the capacity built through the course. They felt that the skills and technologies learned and the contacts made had allowed them to perform better at work. Some, but not all, of the researchers increased their professional collaboration with other organisations, both nationally and internationally.

An important aspect of capacity utilisation was that many of the course participants were able to then provide training to other industry participants. Nine of the 11 participants in the GIPPET survey either agreed or strongly agreed that they had trained others in the skills learned during the course. All of the participants in the survey of AI technicians either agreed or strongly agreed that they had been able to train others in the skills learned during the course. Personnel of the AI centres supported by the AusAID-funded follow-up project indicated during interviews that they regularly provided training to local farmers in AI techniques and other matters relating to pig farming.

Of considerable importance in utilising the capacity built was the ability of the researchers at the IAS to attract funding from other organisations. Ten of the 11 participants surveyed either agreed or strongly agreed that they had been able to secure additional resources to expand or enhance their research. The researchers indicated during interviews that they felt that these subsequent projects were a direct result of the capacity built through the ACIAR project. Through these projects the IAS has been able to import a significant number of exotic pigs with superior genes that continue to improve the genetic quality of the national herd. This included a further 100 GGP (great grandparent) pigs from Australia. It was noted, however, that the second batch of pigs imported from Australia was sourced from a commercial breeding-stock supplier and the genetic quality was lower than the initial batch.

The researcher who received funding to undertake PhD studies in Australia returned to Vietnam only briefly upon completing the doctorate, before securing employment abroad. Consequently, the capacity built through this extensive training was not fully utilised within Vietnam. Nevertheless, there were private benefits that flowed directly to the researcher.

The research outputs of capacity utilisation

The impact of the capacity built by the ACIAR project arises from the consequent technologies developed by the subsequent R&D and continued application of the skills.

Breeding

Using hierarchical breeding structures, research institutes like the IAS play a key role in improving the genetic quality of the national herd. It is therefore important to maintain the genetic quality of the nucleus herd. The superior-quality genetic material is transferred to breeding farms, where it is multiplied and then transferred to commercial pig farms.

Maintaining and improving the genetic quality of the nucleus herd involves ongoing research. The breeding stock must be carefully selected and tested for desirable traits, or the genetic quality will eventually decline. Research that produces high-performing crossbreeds also improves the genetic quality of the breeding stock. The research funding that the IAS was able to attract as a direct result of the capacity built through the ACIAR-funded project enabled the IAS to continue the research program and to import additional pigs of superior genetic quality.

The outcomes of the capacity building are:

- maintenance of the value of the genetics, which would have declined in the absence of the skills to continue to manage the herd
- a share of the further improvements achieved by follow-up R&D.

Feeding

The skills and knowledge built through the research and capacity-building activities enabled the Vietnamese researchers to undertake the research that delivered the technical outputs discussed above. Following the completion of the ACIAR-funded project, the research on the use of local feed ingredients to formulate least-cost diets was continued, with the recommendations subsequently transferred to various feed mills.

Capacity building made a contribution to the total impact of the combined research. This total impact depends on adoption of the superior genetic stock and the feed developed, as well as how much these contribute to improved productivity. These are estimated in the next chapter.

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3 Outcomes and adoption

Utilisation of the capacity built has resulted in positive outcomes for both the individuals who participated in the course and the IAS as an organisation. At the personal level, 8 of the 11 participants in the GIPPET survey either agreed or strongly agreed that they were offered a promotion as a direct result of the training course. All course participants reported getting greater satisfaction from their work. Such personal income benefits are relatively small compared with the impact flowing from utilisation of their additional capacity. From an organisational perspective, all participants indicated that the training provided under the project increased the quality and quantity of the research produced by the IAS.

Utilisation of the capacity built played a major role in achieving the outcomes attributable to the project. The knowledge and skills learned through the training program enabled the Vietnamese researchers to breed pigs with superior characteristics for sale to commercial breeding farms. This increased the overall genetic quality of the national herd. This research continued after the project was completed. As regards the feeding component of the project, the techniques learned during the training program allowed the Vietnamese researchers to develop least-cost diet recommendations.

The outcomes of an improved breeding stock

Tisdell and Wilson (2001) identified three main outcomes from improving the genetic quality of the breeding stock:

- improved reproductive performance
- increase in the average weight of pigs slaughtered
- higher lean-meat percentage.

Improved reproductive performance

Research undertaken as part of the ACIAR-funded project found that the Australian pigs and their progeny adapted well to Vietnamese conditions and displayed superior breeding performance to the pre-existing exotic species in Vietnam.[2] The Australian Yorkshires performed better than the Durocs, and the majority of the pigs provided to breeding farms, AI centres and commercial pig farms under the project were Yorkshires. So, following Tisdell and Wilson, the focus was on the performance of the Australian Yorkshire breed. The assumptions used for this impact assessment on the improvement in the breeding performance of Australian pigs compared with the existing exotic breeds available in Vietnam are shown in Table 7. These assumptions are based on the research undertaken as part of the project and are discussed below.

Piglets per litter

The improvement in the number of piglets per litter varied. Research undertaken by Le Thanh Hai et al. (2001) at the BTRC found that Australian Yorkshire sows had more piglets per sow (10.1 per litter) than did the existing Yorkshire sows in Vietnam (9.6 per litter). Crosses between Australian and Vietnamese pigs performed as well or better than the Australian breeds. Nguyen Ngoc Hung (2001) found that, in Binh Thuan province, crossbred sows inseminated by tested Australian Yorkshire boars had 9.8 piglets per litter compared with 9.2 piglets per litter when the sows were inseminated by Vietnamese Yorkshire boars. However, Nguyen Thi Vien et al. (2001b) found that, on commercial pig farms in the Cao Lanh district of Dong Thap province, sows inseminated by Australian boars

2 See Le Thanh Hai et al. (2001) and Nguyen Thi Vien et al. (2001b)

Table 7. Breeding performance

	Vietnamese Yorkshire	Australian Yorkshire sow	Australian Yorkshire boar
Piglets per litter	9.5	10.1	10.1
Survival rate to weaning (%)	88.0	90.0	90.0
Surviving piglets per litter	8.4	9.1	9.1
Litters per year	1.9	2.0	1.9
Surviving piglets per litter per year	16.0	18.2	17.3
Conception rate (%)	84.0	84	88

Source: Le Thanh Hai et al. (2001) and Nguyen Thi Vien et al. (2001b)

had slightly fewer (10.2) piglets per litter than sows inseminated by the existing boars in the district (10.3). The same study found that, at Kieng Phuoc commune in Go Cong East district (Tien Giang province), using Australian rather than the existing boars increased the number of piglets per litter from 8.6 to 10.1. For the purposes of this impact assessment, we assume that the number of piglets per litter increases from 9.5 to 10.1 for both Australian Yorkshire sows and boars. These estimates are close to the findings of Le Thanh Hai et al. (2001) and Nguyen Ngoc Hung (2001).

Survival rate

Piglets containing the Australian Yorkshire genotype also tended to have a higher survival rate to weaning. Le Thanh Hai et al. (2001) found that 90% of piglets from Australian Yorkshire sows survived to weaning compared with 87% of piglets from Vietnamese Yorkshire sows. Nguyen Thi Vien et al. (2001b) found that, in Cao Lanh district, 96% of piglets from sows inseminated by Australian Yorkshire boars survived to weaning compared with 94% of piglets from sows inseminated by other boars. At Kieng Phuoc commune, using Australian boars increased the survival rate from 88% to 90%.

Surviving piglets per sow per year

Discussions with AI centres suggested that the Australian Yorkshire sows also produced more litters per year (2.0) than the pre-existing exotic sows in Vietnam (1.9). This implies that each Australian sow produces around 18.2 surviving piglets per year compared with 15.2 for Vietnamese Yorkshire sows. Vietnamese sows inseminated by Australian Yorkshire boars produce around 16.2 surviving piglets per year. This is broadly consistent with the assumption of Tisdell and Wilson (2001) that using Australian Yorkshire pigs increased the number of surviving piglets from 16 to 18. Discussions with some local farmers confirmed that these results were broadly in line with the improvements achieved on farms.

Conception rate

Australian Yorkshire pigs also tended to have higher conception rates. Nguyen Ngoc Hung (2001) found that using Australian Yorkshire boars in Binh Thuan province increased the conception rate from 84% to 88%. Nguyen Thi Vien et al. (2001b) found that, in Cao Lanh district, sows artificially inseminated by Australian Yorkshire boars had a conception rate of 80% compared with a conception rate of 73% achieved when the sows were inseminated naturally by other boars. Use of Australian Yorkshire boars at the Kien Phuoc commune in Tien Giang province increased the conception rate to 90% compared with 80% when local boars were used.

Slaughter weight and lean-meat ratio

Fattening pigs carrying the Australian Yorkshire gene have a higher average daily weight gain and a higher lean-meat percentage than the existing Vietnamese stock. The assumptions used in this impact assessment are shown in Table 8 and are discussed below.

Average daily weight gain

A higher average daily weight gain results in either higher live weight at normal slaughter age or pigs being slaughtered at a younger age. Following Tisdell and Wilson, we will assume pigs are slaughtered at the same age, at around 145 days. The results of different researchers on the improvement in the average daily weight gain from using Australian Yorkshire pigs varied significantly. In research conducted at the BTRC, Le Thanh Hai et al. (2001) found that the average daily gain of Australian Yorkshire pigs was 627 grams compared with 555 grams for Vietnamese Yorkshire pigs. Crosses between Australian Yorkshire and Vietnamese Yorkshire pigs had an average daily gain of 605 grams. Le Pham Dai et al. (2001) also conducted research at the BTRC. They found that the average daily weight gain of Australian Yorkshires was 655 grams and of Vietnamese Yorkshires 601 grams, while for crosses between Australian Yorkshire and Vietnamese Yorkshire it was 625 grams. Nguyen Ngoc Hung (2001) found that Australian Yorkshire pigs in Binh Thuan province had an average daily weight gain of 550 grams, while Vietnamese Yorkshire pigs gained 503 grams per day on average. In research conducted at the BTRC and Phu Son farm, Nguyen Thi Vien et al. (2001b) found that pure Australian Yorkshires had an average daily gain of 602 grams compared with 597 grams for Vietnamese Yorkshires. However, the average daily gain of Australian Yorkshire pigs crossed with Vietnamese Landraces was 639 grams compared with 585 grams from a Vietnamese Yorkshire crossed with a Vietnamese Landrace. Nguyen Van Duc and Le Thanh Hai (2001) inseminated Vietnamese Yorkshire sows with Australian Yorkshire semen at the Thanh To (Hai Phong province) and Cau Dien (Ha Noi province) piggeries. At Thanh To, this increased the average daily weight gain from 575 to 650 grams, and at Cau Dian from 572 grams to 646 grams.

The improvement in average daily weight gain reported in the research varies from 0.8% to around 13%. The daily weight gain assumed has a large impact on the estimated benefits. The sensitivity of this assumption is examined in Chapter 4. It is considered more realistic to compare the pre-existing Yorkshire pigs in Vietnam with a cross between Australian and Vietnamese, since purebred Australian Yorkshire pigs are likely to be used to produce breeding stock rather than fatteners. For the purposes of this impact assessment, we therefore use the results of Le Pham Dai et al. (2001) who found that the average daily weight gain of Vietnamese Yorkshires was 601 grams compared with an Australian/Vietnamese Yorkshire cross of 625 grams. This is an improvement of around 4%. It is important to use a conservative estimate of the improvement in the average daily gain since it is assumed that the improvement from all tested pigs from the BTRC matches the improvement of the Australian pigs initially provided under the project. Assuming the pigs are slaughtered at 145 days, this implies a slaughter weight of around 87 kg for the pre-existing Yorkshire breeds and around 90 kg for the pigs containing the Australian Yorkshire genotype. This is broadly in line with the slaughter weights assumed by Tisdell and Wilson (2001), which were around 89 kg for pre-existing Yorkshire pigs in Vietnam and around 94 kg for pigs containing the Australian Yorkshire genotype.

Table 8. Growth performance

	Vietnamese exotic breeds	Australian pigs
Average daily weight gain (g)	601	625
Live weight at slaughter (kg)	87.1	90.6
Carcass weight (%)	72.9	72.3
Carcass weight (kg)	63.5	65.5
Lean-meat percentage (%)	50.2	52.0
Lean meat (kg)	31.9	34.1
Equivalent carcass weight (kg)	63.5	67.9
Equivalent live weight at slaughter (kg)	87.1	93.9

Source: Nguyen Thi Vien et al. (2001b).

Carcass weight

In this impact assessment, it is assumed that the carcass weight of a fattening pig containing the Australian Yorkshire genotype was 72.3% of the slaughter weight, as compared to 72.9% for Vietnamese Yorkshire pigs. This assumption was based on the findings of Nguyen Thi Vien et al. (2001b) from research at the BTRC and Phu Son farm. It implies a carcass weight of 65.5 kg for Australian Yorkshire pigs and 63.5 kg for Vietnamese Yorkshire pigs.

Tisdell and Wilson (2001) assumed the carcass weight was 80% of the slaughter weight.

Lean-meat percentage

Pigs are sold to slaughterhouses (via traders) by the live-weight kilogram. As noted in Tisdell and Wilson (2001), slaughter pigs from Australian breeding stock sell at a premium to other exotics because of the higher lean-meat percentage. Tisdell and Wilson treated this as a quality improvement, implying that, ultimately, consumers are willing to pay a higher price for better-quality meat. Quality differences should be analysed as two separate markets. However, industry participants indicated that the quality of the meat is actually the same. Rather, higher prices are paid for pigs containing the Australian gene because a greater quantity of lean meat can be produced for each live-weight kilogram. While the technology to measure the lean-meat percentage with precision is not available to Vietnamese slaughterhouses, the premium paid for pigs with Australian genes is effectively a proxy for the higher quantity of lean meat per live-weight kilogram.

It is not appropriate to analyse the market for Australian pigs as a separate market because there is not a true improvement in the quality of the meat. We therefore deal with the issue of the greater lean-meat percentage of Australian pigs by converting to a live-weight equivalent (Table 8). This shows the slaughter weight that would yield the same quantity of lean meat if the lean-meat percentage of Australian Yorkshires were the same as the Vietnamese Yorkshires.

The research undertaken as part of the project suggests that the improvement in the lean-meat percentage can vary. Le Thanh Hai et al. (2001) estimated that the lean-meat percentage of Australian Yorkshires at the BTRC was around 57.3 compared with 50.2 for Vietnamese Yorkshires. Crosses between the two had a lean-meat percentage of 52.0. Nguyen Thi Vien et al. (2001b) estimated that the lean-meat percentage of Australian Yorkshires was 56.5, 2.4 percentage points higher than Vietnamese Yorkshires. When crossed with Vietnamese Landrace pigs, Australian Yorkshires had a lean-meat percentage of 55.7 compared with 53.7 for Vietnamese Yorkshires. In Cao Lanh district, pigs from Australian boars had a lean-meat percentage of 49.2 compared with 46.2 for pigs from other boars. At Thanh To piggery, Nguyen Van Duc and Le Thanh Hai (2001) found that use of Australian Yorkshire boars increased the lean-meat percentage of fattening pigs from 55 to 59. A similar increase was reported at Cau Dien piggery.

Given that purebred Australian Yorkshires are unlikely to be used as fattening pigs, it is appropriate to compare the lean-meat percentage of a cross between an Australian and a Vietnamese Yorkshire with Vietnamese Yorkshires. The results of Le Thanh Hai et al. (2001) are therefore used. This is equivalent to a price premium of around 3.6%. By comparison, Tisdell and Wilson (2001) used a price premium of 10% as their central case estimate.

The outcomes of the feeding research

Feeding costs make up a large percentage of the total cost of pig production. The feeding recommendations developed as part of the ACIAR project are estimated to reduce feeding costs by 5–10% relative to feed currently available in Vietnam (La Van Kinh 2007). The quantity fed to each sow depends on the stage of the reproductive cycle. It is estimated that each sow consumes around 476 kg of feed per litter. This is equivalent to around 57 kg per surviving piglet for Vietnamese Yorkshire sows. Each commercial pig then consumes around 17 kg of feed during the weaning period and 250 kg of feed during the fattening period. It is therefore estimated that around 324 kg of feed is required to produce each fattening pig (Table 9).

Table 9. Daily feed requirements

	Feed requirement (kg/day)	Total (kg)
Gestation:		
– first phase (conception to 90 days)	1.8	162.0
– second phase	3.5	84.0
Lactation	5.0	140.2
Non-productive days[a]	1.8	90.2
Total sow feed per litter		476.2
Total sow feed per surviving piglet[b]		57.0
Weaner		17.0
Fattener		250.0
Total feed per fattener		**324.0**

[a] Vietnamese exotic sows have, on average, 1.9 litters per year, which implies 50 non-productive days per litter.

[b] With surviving litter size of 8.4 piglets

Source: Centre for International Economics estimates based on consultation with researchers

Cost of production

The improved reproductive performance, higher slaughter weight and lean-meat percentage, and reduced feeding costs all reduce the unit cost of production. Agrifood Consulting International (2001) showed that the cost structure across different livestock producers varies depending on the scale of production. The change in production costs therefore depends on what type of farmer adopts the research outputs. Table 10 shows the estimated production costs for a medium-size farm keeping sows that are artificially inseminated from boars from an AI centre. A medium-size farm has been chosen because farms of that size are the most likely to adopt the research outputs. Large, foreign-owned farms tend to have their own breeding programs, while the relatively higher costs associated with raising exotic breeds means that many smallholders with limited access to credit continue to keep local breeds which suit poorer quality feeds. The Australian-sow column in Table 10 assumes a superior-quality Australian sow is inseminated by a lower-quality exotic boar, while the Australian boar column assumes a lower-quality exotic sow is used but is inseminated by a superior-quality Australian boar.

Using a superior-quality Australian sow is estimated to reduce production costs by VND2,030 per live-weight kg, or around 10%, while using an Australian boar for artificial insemination is estimated to reduce production costs by VND1,869 per live-weight kg, or around 9% (Table 10). Using the feeding recommendations developed under the project is estimated to reduce production costs by around VND743 per live-weight kg, or around 4%.

Adoption

Pathways to adoption

For the research into pig breeding and feeding to deliver benefits, it is essential that the research outputs produced either directly or through capacity building are adopted by pig farmers.

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

Table 10. Production costs

	Vietnamese exotic breeds VND'000[a]	**Australian sow** VND'000	**Australian boar** VND'000	**Improved feed** VND'000
Costs per sow per year				
Cost of parent-stock sow[b]	1,399	1,462	1,399	1,399
Artificial insemination[c]	45	48	43	45
Housing costs[d]	1,480	1,480	1,480	1,480
Feeding costs[e]	20,705	23,066	22,044	19,670
Labour costs[f]	5,187	5,719	5,480	5,187
Total cost per sow per year	**28,816**	**31,775**	**30,446**	**27,781**
Cost per fattening pig produced	1,801.2	1,749.7	1,764.8	1,736.5
Cost per live-weight kilogram	20.7	18.6	18.8	19.9
Change in costs per kilogram	–	–2.0	–1.9	–0.7

a Vietnamese dong; in April 2008, A$1.00 = approximately VND15,000

b Each parent-stock sow costs around VND4 million and has a working life of 6 litters. A cost of capital of 10% is assumed.

c Artificial insemination typically costs VND20,000 per dose. This is multiplied by the number of litters per year and divided by the conception rate.

d Researchers estimated that housing for exotic pigs costs VND10 million per sow and lasts for 10 years. A cost of capital of 10% is assumed.

e Feed suitable for exotic pig species currently costs around VND4,000 per kilogram. The feeding recommendations developed under the ACIAR-funded project are estimated to reduce feeding costs by 5%.

f Agrifood Consulting International (2001) estimated that labour (including household labour) makes up 18% of total costs for medium-size livestock farmers.

Source: Agrifood Consulting International (2001) and Centre for International Economics estimates. based on discussions with researchers and industry stakeholders

Breeding

The genetic quality of the Vietnamese pig population was improved by introducing the Australian genotype to breeding farms and AI centres. In turn, these breeding farms and AI centres multiply the improved genotypes and pass them on to commercial farmers and, to a lesser extent, smallholders.

A key advantage of AI is that superior genes can be dispersed more rapidly than through natural mating. Discussions with AI centres suggest a single boar can service around 200 sows per year using AI compared with around 30–40 using natural methods. The aim of the follow-up project funded by AusAID was to facilitate wider adoption of the Australian pig genotype. The training provided to these centres was a key aspect of this project. The AI centres have conducted many training courses for farmers, which has increased the use of AI in those provinces.

Feeding

The low-cost-feeding recommendations developed through the project are adopted by farmers via feed mills. From 1999 to 2002, the low-cost-feeding recommendations were transferred to the following feed mills (La Van Kinh 2007):

- Vina (Dong Nai province)
- Thanh Binh (Dong Nai province)
- Vitaga (Dong Nai province)
- Lai Thieu (Binh Duong province)
- Thanh Loi (Binh Duong province)
- Vifaco (Binh Duong province)
- Dai Hung (Ho Chi Minh City)

- Binh Dinh (Binh Dinh province)
- Con Voi (Ha Noi).

Adoption by final users

Breeding

From the 33 Australian pigs imported into Vietnam in October 1995, the herd maintained at the BTRC had expanded to 104 by 2000. This comprised 91 gilts and 13 boars, which were progenies from the original herd. In addition, 689 sows and 686 boars were supplied to breeding farms, AI centres and commercial pig farms in 18 provinces (Le Thanh Hai et al. 2001). These tested pigs are largely GP or parent stock, which then multiply through breeding farms and commercial pig farms. Furthermore, purebreeds are often crossed with other exotic or local breeds. There have been a number of other high-quality exotic breeds imported into Vietnam under subsequent projects that occurred as a direct result of the capacity built through the ACIAR-funded project. This included a further 100 GGP pigs from Australia. These pigs have also been bred selectively, tested and distributed throughout Vietnam. Currently, around 40% of the herd kept at the BTRC originates from the original batch of Australian pigs.

Researchers estimated that currently around 10% of the current breeding stock are tested pigs from the BTRC, or their progeny. This is expected to increase to around 20% over the next 10 years. This maximum adoption rate is based on the maximum capacity of the BTRC. Since 40% of the herd maintained at the BTRC were the progeny of the original batch of pigs imported under the ACIAR-funded project, this implies that the maximum adoption that can be directly attributed to that project is around 8%. Adoption typically follows an S-shaped curve, where adoption initially occurs at an increasing rate, before slowing as maximum adoption is approached. These estimated adoption profiles are shown in Figure 4.

Feeding

The pig-feeding recommendations developed under the ACIAR-funded project are estimated to reduce feeding costs by 5–10%. The feed mills that adopted the recommendations produce more than 1.5 million tonnes of feed per year (La Van Kinh 2007). It is estimated that, on average under Vietnamese conditions, it takes around 324 kg of feed to produce a single fattening pig. This implies around 4.6 million fattening pigs per year can be produced using the ACIAR-project feeding recommendations. This was around 12% of total pig production.

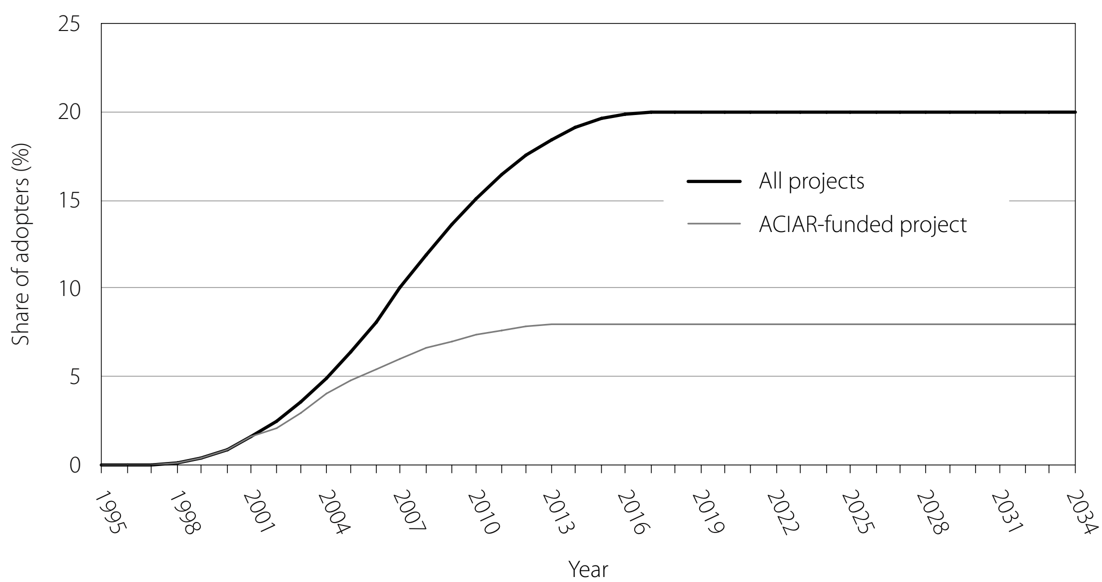

Figure 4. Breeding adoption profiles. Data source: Centre for International Economics estimates based on consultation with researchers.

The feeding recommendations were transferred to feed mills from 1999 to 2002. While the IAS has not transferred the feeding recommendations to additional feed mills since 2006, it is assumed that the feed mills that have adopted the recommendations maintain their share of total pig-feed production. An S-shaped adoption profile is assumed, with maximum adoption reached in 2006. The feed recommendations apply only to exotic breeds and some crossbreeds. Adoption of the recommendations is therefore limited by the proportion of these breeds in the total herd. Estimates suggest that around half the suitable breeds are fed using the recommendations. Why not 100%? This may be due to location of the animals and location of the mills and transport costs involved in shipping the food, as well as cost of the ingredients in different mill areas. The cost of multiple production runs if there is a wide variety of breeds in a region might also limit expansion to other mills. The adoption rate over time is shown in Figure 5.

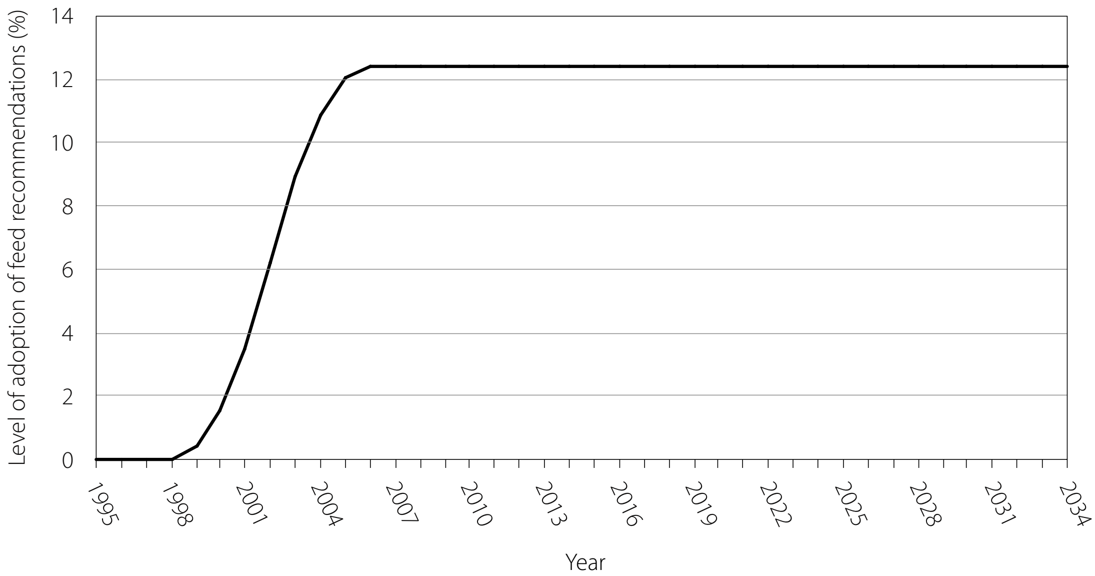

Figure 5. Feeding adoption profile (share of total feed production). Data source: Centre for International Economics estimates based on consultation with researchers

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

4 Impact assessment

The focus of this impact assessment is on the benefits flowing from the capacity-building activities that formed part of the ACIAR-funded project. In estimating the benefits attributable to this capacity building, it is therefore important to consider the benefits of all projects that utilised that capacity built. That includes the benefits that flowed directly from that project, as well as a share of the benefits from subsequent research that utilised the skills and knowledge the researchers built.

The benefits of the R&D are estimated using an economic surplus framework and then allocated to capacity building using the cost-share method described in Gordon and Chadwick (2007).

Approach to estimation

Modelling the benefits of the R&D projects requires an analysis of the relevant markets. There tends to be little substitution between the different markets for pig meat in Vietnam. Smallholders tend to produce meat for their own consumption or sale at local markets. Small–medium and medium-size producers supply wet markets, while the large, foreign-owned producers supply the big supermarkets in the main urban centres of Hanoi and Ho Chi Minh City. There tends to be little competition between markets. As the research outputs are most likely to be adopted by small–medium and medium-size producers, the analysis focuses on this market.

Surveys showed that the share of the national herd held by smallholders declined significantly between 1999 and 2006, with the shift largely towards small–medium and medium-size producers (Table 2). Since this shift is likely to continue in the longer term, the trend implied by the surveys is extrapolated over the period of the analysis (Figure 6).

The shares in Figure 6 can be applied to actual data and future projections of total pig-meat production to obtain an estimate of pig meat produced by small–medium and medium-size producers over the assessment period (Figure 7). The projections to 2020 are from Quirke et al. (2003). The growth rate is then extrapolated over the remainder of the assessment period.

Analysis of the market

While pigs and pig meat are tradeable products, the market is modelled using a partial equilibrium analysis as a closed market. Vietnam's pig-meat industry is currently protected from import competition by tariffs. Fresh, chilled and frozen pig meat currently attracts a tariff of 30% (World Trade Organization 2006). As a result, Vietnam imports only a small quantity of pork, mainly to meet the demand of luxury hotels and supermarkets in urban areas (Dinh Xuan Tung et al. 2005). Under Vietnam's WTO commitments, these tariffs will be reduced to 25% for fresh and chilled pig meat and 15% for frozen pig meat by 2012, but these tariffs are likely to continue to limit competition from imports. If there were a sharp increase in prices, imported pig meat could become competitive, but this is not expected in the longer term if current policy settings remain in place.[3] Vietnam is also not expected to become a major pork exporter, owing to high production costs, low meat quality and the lack of bilateral zoosanitary

3 See Quirke et al. (2003)

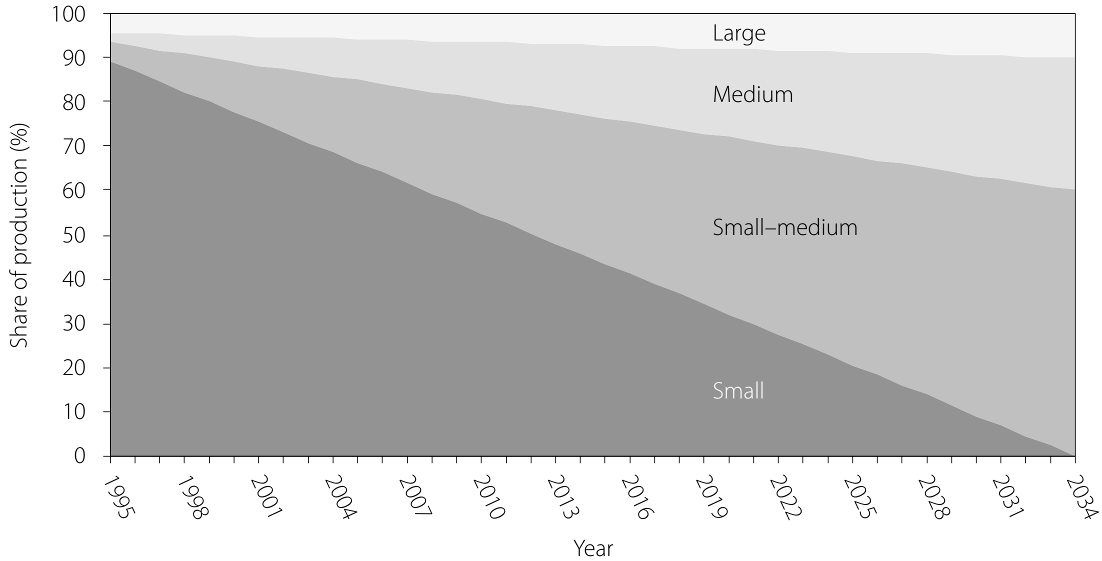

Figure 6. Pig production by scale of operation. Data source: La Van Kinh (2007) and Centre for International Economics

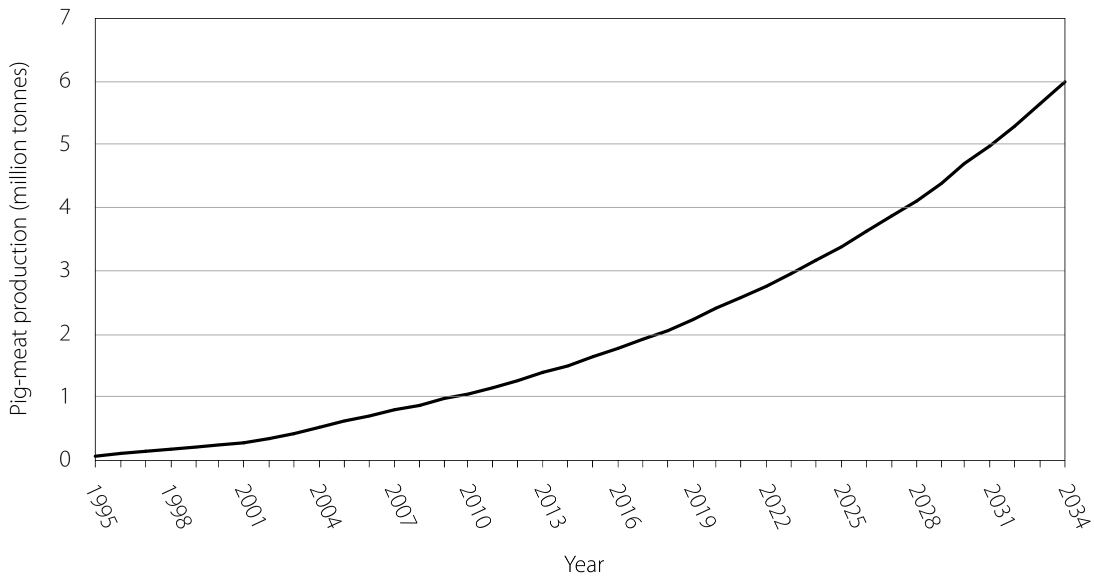

Figure 7. Pig-meat production by small–medium and medium-size producers. Data source: FAO Livestock database, accessed February 2007 at <http://faostat.fao.org/default.aspx>; Quirke et al. (2003) and Centre for International Economics

agreements with other countries. Consequently, most of the anticipated increase in pork production will be consumed domestically (Dinh Xuan Tung et al. 2005).

Using a standard, static supply (S in Figures 8 and 9) and demand (D in Figures 8 and 9) model, the productivity improvements resulting from the research can be represented as a parallel downward shift in the supply curve of those producers that adopt (Figure 8). The supply curve of non-adopters does not change. The market supply curve is the horizontal sum of the supply curves of adopters and non-adopters. The shift in the supply curve of adopters therefore also shifts the market supply curve downwards, reducing the market price. Consumers benefit from the lower price, which also encourages them to consume more. The increase in consumer surplus is represented by the shaded area (*d*) in Figure 8. Adopters also benefit from lower production costs. The increase in the producer surplus of adopters is represented by the shaded area (*b* – *a*). The lower price, however, reduces the producer surplus of non-adopters. The loss of producer surplus by non-adopters is represented by the shaded area (*c*). The change in economic surplus is therefore (*b* + *d* – *a* – *c*).

The change in consumer surplus is given by:

$$\Delta CS = (\Delta P \times Q_0) + (0.5 \times \Delta P \times \Delta Q)$$

where

- ΔCS is the change in consumer surplus
- ΔP is the decrease in the market price resulting from the lower cost of production
- ΔQ is the increase in the quantity of pig meat consumed as a result of the lower cost of production.

The change in producer surplus of adopters is given by:

$$\Delta PS^A = (\Delta S \times Q^A_p) + (0.5 \times \Delta S \times (Q^A_1 - Q^A_p)) - (\Delta P \times Q^A_p) - (0.5 \times \Delta P \times (Q^A_0 - Q^A_p))$$

where

- ΔPS^A is the change in the producer surplus of adopters
- ΔS is the shift in the supply curve of adopters
- Q^A_p is the quantity adopters would have produced at the current price if the supply curve had not shifted
- Q^A_1 is the amount produced by adopters
- Q^A_0 is the amount that would have been produced by producers that adopted the research if they had not done so.

The change in the producer surplus of non-adopters (which will be negative) is given by:

$$\Delta PS^N = -(\Delta P \times Q^N_1) - (0.5 \times \Delta P \times \Delta Q^N)$$

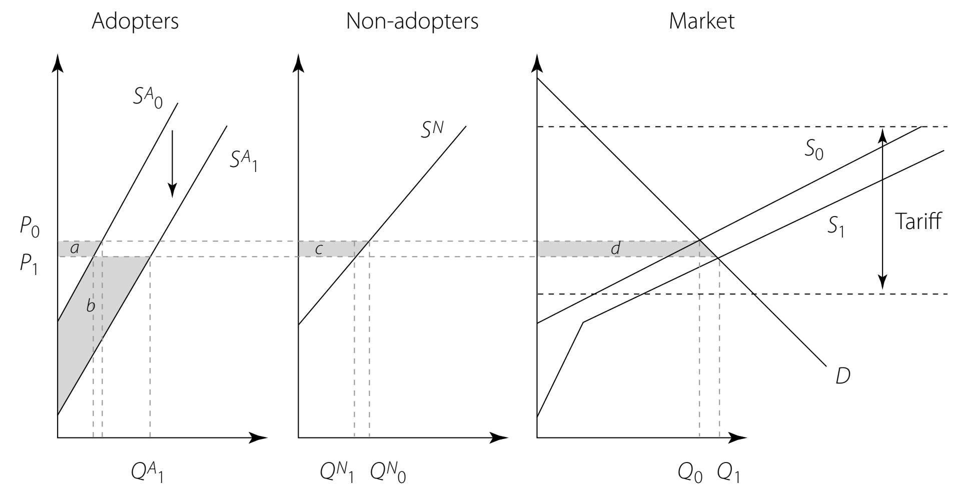

Figure 8. Change in economic surplus

where

- $Q^N{}_1$ is the amount of pig meat produced by non-adopters
- ΔQ^N is the decrease in the quantity of pig meat produced by non-adopters as a result of the price change.

The total change in economic surplus is given by:

$$\Delta ES = \Delta CS + \Delta PS^A + \Delta PS^N$$

Estimating the benefits

The static supply and demand model shows the increase in economic surplus in a single period. It is important to recognise that over the period of the impact assessment there are many other significant factors shaping the market for pig meat in Vietnam. These include rapidly increasing demand as a result of population growth and rising household incomes, as well as changing production costs. Productivity is a major determinant of costs, and productivity improvements independent of the ACIAR-funded research would be expected. Other sources of productivity improvements in Vietnam include the ongoing shift from local to exotic breeds, high-quality exotic breeds imported by foreign-owned companies and research from other research institutions. The implication of these background developments is that the quantity produced under the counterfactual scenario (i.e. q_0) changes in every period. This is shown in Figure 9, where both demand and supply have shifted. In these circumstances, the increase in the quantity produced can be only partly attributed to adoption of the research outputs. The quantity produced changes from q_0 to q_1, but only the shift from q_{cf} to q_1 can be attributed to the shift in supply. The shift in demand changes the counterfactual quantity produced from q_0 to q_{cf}.

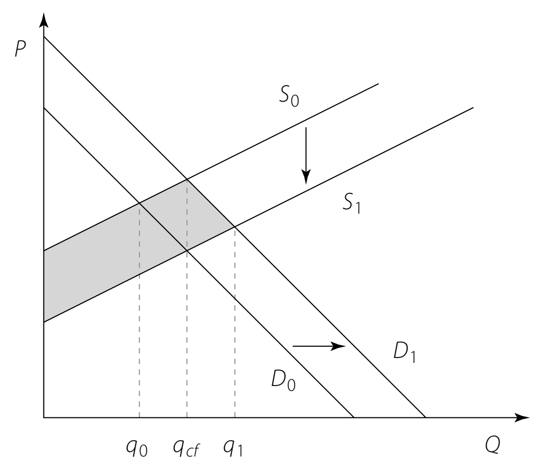

Figure 9. Change in economic surplus with rising demand and productivity improvements

The projections produced by Quirke et al. (2003) take account of these background developments. Important assumptions underlying this projection include annual real income growth of 5% and annual productivity growth in the pig-meat industry of 2%. Based on these assumptions, production of pig meat in Vietnam is projected to increase by 3.8% annually between 2005 and 2020.[4]

It is assumed that the productivity improvements achieved by the ACIAR-funded research and related projects contribute to this annual productivity improvement. The projections produced by Quirke et al. are therefore treated as the quantity produced with the ACIAR and other R&D and sources of productivity growth. The quantity produced under a without-the-ACIAR R&D scenario (the counterfactual) is estimated by subtracting the increase in production attributable to the project from the projection provided by Quirke et al.

To estimate the change in price and quantity attributable to the project, information is needed on the shape of the supply and demand curves and the shift in the supply curve of adopters. The supply and demand curves are assumed to be linear (i.e. constant slope). The slope can be estimated using an initial price and quantity and reasonable estimates of the own-price elasticities of supply and demand at that equilibrium.

Agrifood Consulting International (2001) estimates the elasticity of demand for pig meat in Vietnam is –0.85. This is relatively low, reflecting the strong preference for pig meat relative to other meat in Vietnam. Quirke et al. (2003) use elasticities of supply for pig meat in countries in the Asian region ranging between 0.2 and 0.7. Using the midpoint of 0.45 implies that the elasticity of supply

4 This growth rate is used to extrapolate pig-meat production to 2034.

is also quite low. The supply curve captures the opportunity cost of alternative uses of resources. In the short term, it is relatively difficult to shift from pig production to alternative livestock production because intensively farmed pigs require relatively little land compared with other livestock production. The initial equilibrium price and quantity used in order to estimate the slopes of the supply and demand curves are VND25,000 per kg and 791,357 tonnes, based on the price prevailing in 2007 and the estimated quantity produced by small–medium and medium-size farms in 2007. This implies that the slope of the market supply curve is 57.4 and the slope of the demand curve 37.2.

The shift in the supply curve of adopters of the research can be approximated by the change in the unit cost of production, which was estimated in Table 10.

The assumptions used in modelling are summarised in the accompanying box.

Benefits

The estimated benefits from the projects over the 40-year period from 1995 to 2034 are shown in Table 11. Following Gordon and Davis (2007), once steady-state benefits are reached the benefits in subsequent years are converted to an annuity value to calculate the summary indicators. The benefits are converted to

Box. Major assumptions used in modelling

This box outlines the major assumptions used in modelling the costs and benefits attributable to the project.

- Pig markets in Vietnam are closed.
- Only small–medium and medium-size producers adopt the research.
- There is no substitutability between village-level wet markets, commercial wet markets and large supermarkets. Small–medium and medium-size producers supply commercial wet markets.
- The trend shift in the share of production from smallholders to small–medium and medium-size producers observed between 1999 and 2006 continues over the assessment period.
- Real incomes in Vietnam increase at an annual rate of 5%.
- Productivity in the pig-meat industry increases at an annual rate of 2%. The projects discussed in this report contributed to this annual increase.
- In the absence of the research projects, the farmers who adopted the research outputs would have continued to raise inferior exotic breeds.
- Without the research and capacity-building components of the project, the benefits provided by the superior-quality Australian pigs imported into Vietnam would not have been sustained.
- Without the ACIAR-funded project, the subsequent projects would not have occurred.
- The supply and demand curves are linear.
- Adoption of the research outputs results in a vertical, parallel shift in the supply curve of the adopters.
- The price per live-weight kg was VND25,000 in 2007. At that price, 0.791 million live-weight tonnes were produced in 2007. At that equilibrium, the elasticity of demand is assumed to be –0.85 and the elasticity of supply to be 0.55. This implies that the slope of the market supply curve is 57.4 and the slope of the demand curve 37.2. It is also assumed that the price remains at VND25,000 in real terms.

Table 11. Estimated total net benefits (A$ million, 2006 values), comparing the results from this study with those of Tisdell and Wilson (T&W) (2001)[a]

	Breeding T&W	Breeding ACIAR	Breeding Other	Breeding Total	Feeding T&W	Feeding ACIAR	Feeding Other	Feeding Total	Total R&D
1995	–	–	–	–	–	–	–	–	–
1996	10.1	0.0	–	0.0	–	0.0	–	0.0	0.0
1997	20.7	0.0	–	0.0	–	0.0	–	0.0	0.0
1998	31.8	0.3	–	0.3	–	0.0	–	0.0	0.3
1999	44.7	1.2	–	1.2	–	0.4	–	0.4	1.6
2000	54.6	3.1	–	3.1	3.5	2.0	–	2.0	5.1
2001	57.1	6.3	–	6.3	4.0	5.0	0.1	5.2	11.5
2002	60.2	8.1	1.8	9.9	4.5	8.8	0.4	9.2	19.2
2003	62.6	10.4	2.3	12.7	5.1	11.1	0.7	11.8	24.5
2004	64.7	13.8	3.1	16.9	5.7	13.2	0.9	14.1	30.9
2005	65.8	17.8	6.1	23.9	6.3	15.9	1.1	16.9	40.8
2006	62.9	21.2	10.3	31.5	7.1	17.1	1.2	18.2	49.7
2007	60.9	23.3	15.1	38.4	7.7	16.9	1.1	18.0	56.4
2008	59.9	25.9	20.9	46.8	8.5	17.3	1.2	18.5	65.3
2009	58.4	28.7	26.8	55.5	9.2	18.0	1.2	19.2	74.7
2010	57.0	31.3	32.6	63.8	10.0	18.7	1.3	19.9	83.7
2011	–	33.7	38.2	71.9	–	19.4	1.3	20.7	92.6
2012	–	35.8	43.7	79.6	–	20.1	1.4	21.4	101.0
2013	–	37.8	49.1	86.8	–	20.9	1.4	22.3	109.1
2014	–	39.4	54.2	93.5	–	21.6	1.5	23.1	116.6
2015	–	40.8	58.7	99.6	–	22.5	1.5	24.0	123.6
2016	–	42.4	62.6	104.9	–	23.3	1.6	24.9	129.8
2017	–	44.0	65.5	109.5	–	24.2	1.6	25.8	135.3
2018	–	45.6	68.0	113.6	–	25.1	1.7	26.8	140.4
2019	–	47.3	70.6	117.9	–	26.0	1.8	27.8	145.7
2020	–	49.1	73.3	122.4	–	27.0	1.8	28.8	151.2
2021	–	50.9	76.0	127.0	–	28.0	1.9	29.9	156.9
2022	–	52.8	78.9	131.7	–	29.1	2.0	31.1	162.8
2023	–	54.8	81.9	136.7	–	30.2	2.0	32.2	168.9
2024	–	56.9	85.0	141.8	–	31.3	2.1	33.4	175.2
2025	–	59.0	88.2	147.1	–	32.5	2.2	34.7	181.8
2026	–	61.2	91.5	152.7	–	33.7	2.3	36.0	188.6
2027	–	63.5	94.9	158.4	–	35.0	2.4	37.3	195.7
2028	–	65.8	98.5	164.3	–	36.3	2.4	38.7	203.1

Table 11. (continued)

	Breeding T&W	Breeding ACIAR	Breeding Other	Breeding Total	Feeding T&W	Feeding ACIAR	Feeding Other	Feeding Total	Total R&D
2029	–	68.3	102.2	170.5	–	37.6	2.5	40.2	210.7
2030	–	70.9	106.0	176.9	–	39.1	2.6	41.7	218.6
2031	–	73.5	110.0	183.5	–	40.5	2.7	43.3	226.8
2032	–	76.3	114.1	190.4	–	42.0	2.8	44.9	235.2
2033	–	79.1	118.4	197.5	–	43.6	2.9	46.6	244.1
2034	–	82.1	122.8	204.9	–	45.2	3.1	48.3	253.2

[a] Adjusted to 2006 values for comparability
Source: Tisdell and Wilson (2001) and Centre for International Economics estimates

Australian dollars using the average annual exchange rate from the 'World economic outlook' database of the International Monetary Fund (IMF). For 2007 and 2008, the IMF's forecasts are used. In subsequent years, the exchange rate is assumed to remain constant at 12,747 Vietnamese dong per Australian dollar, as per the IMF's 2008 forecast.

For the breeding component, the benefits attributed to the ACIAR-funded project are based on the estimated adoption profile in the counterfactual scenario where the subsequent research did not occur (see Figure 4). For the feeding component, the benefits attributable to the ACIAR project are estimated on a cost-share basis. This is because, unlike with the superior breeds, it is not clear that the feeding research would have delivered significant benefits without the subsequent funding. Both the ACIAR-funded feeding project and the subsequent feeding R&D were therefore necessary but not sufficient to deliver benefits.

The benefits attributable to the ACIAR-funded project are also compared with the estimates reported in Tisdell and Wilson (2001) in the initial impact assessment, converted to 2006 dollars. The estimated benefits of the breeding component in this study are initially significantly lower than those of Tisdell and Wilson, while the estimated benefits of the feeding component are higher. The main reason why the estimated benefits are much higher in this impact assessment is because they have been estimated over a much longer period.

Since the capacity built during the ACIAR-funded project was utilised in the subsequent projects, final attribution of benefits to the ACIAR-funded project includes a share of the benefits from those subsequent projects (see below).

Costs

The nominal research costs of all the projects are presented in Table 12. They are converted to real 2006 dollars using the Australian GDP deflator, obtained from the IMF database.

Returns on the R&D investments

Overall, the series of research investments initiated by the ACIAR-funded project delivered significant benefits to Vietnam (Table 13). This is consistent with the findings of the initial impact assessment (Tisdell and Wilson 2001). When the benefits of capacity building, including subsequent projects that occurred as a direct result of the ACIAR-funded project, are considered, the internal rate of return on the total investment is estimated to be around 65.3%. Using a discount rate of 5%, the net present value of the investments is estimated to be around $2.0 billion, which equates to around $119 worth of benefits for every dollar spent.

Investments in both the breeding and feeding components delivered significant benefits. The internal rates of return on the breeding (65.8%) and feeding (64.8%) components are similar. Using a discount rate of 5%, the net present values of the breeding and

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

Table 12. Research costs (A$'000)

	Nominal cost of breeding projects A$'000	**Nominal cost of feeding projects** A$'000	**Total nominal cost of projects** A$'000	**GDP deflator** (2006=100)	**Cost of breeding projects (2006 dollars)** A$'000	**Cost of feeding projects (2006 dollars)** A$'000	**Total cost of projects (2006 dollars)** A$'000
1995	289.7	580.5	870.2	73.7	393.2	788.1	1,181.3
1996	220.0	462.3	682.3	75.2	292.4	614.6	907.0
1997	142.3	200.4	342.7	76.3	186.6	262.8	449.4
1998	1,874.1	200.4	2,074.5	76.6	2,447.9	261.8	2,709.7
1999	1,955.1	394.5	2,349.6	77.0	2,538.0	512.1	3,050.1
2000	2,072.9	478.6	2,551.5	80.1	2,586.7	597.3	3,184.0
2001	3,229.5	65.2	3,294.7	83.3	3,875.8	78.3	3,954.1
2002	2,950.6	60.3	3,010.9	85.4	3,454.8	70.6	3,525.4
2003	792.8	49.6	842.4	88.3	897.4	56.1	953.4
2004	691.6	–	691.6	91.4	756.7	–	756.7
2005	662.1	–	662.1	95.6	692.8	–	692.8

Source: Tisdell and Wilson (2001), International Monetary Fund, and Centre for International Economics / Institute of Agricultural Science discussions

feeding components are estimated to be $1.6 billion and $423 million, respectively. The benefit:cost ratios were estimated to be around 113:1 for the breeding R&D and 148:1 for the feeding R&D.

Attribution of benefits

The framework developed in Gordon and Chadwick (2007) is used to establish what impacts can be attributable to capacity building. The breeding and feeding components of the project are considered separately.

Breeding component

The breeding component of the ACIAR-funded project involved:

- *technology transfer*—superior-quality Australian pigs were imported into Vietnam under the project
- *research that improved the stock of knowledge*—the research completed under the project improved the knowledge of how the Australian pigs adapt to and perform in Vietnamese conditions
- *capacity building*—the capacity built through the project was utilised in the ACIAR-funded project as well as in subsequent R&D projects.

The technology transfer was necessary for the project to deliver benefits. The research and capacity building would not have delivered benefits without the introduction of superior genetic material into Vietnam. It is also likely that the importation of the Australian pigs would have delivered benefits to Vietnam even without the research and the capacity-building activities. However, without careful selection, the genetic quality of the breeding stock, and therefore the benefits, would have eventually declined. The technology transfer was therefore both necessary and sufficient to deliver some benefits to Vietnam. The benefits attributable to the gene transfer can be estimated by considering what would have happened in the absence of the research and capacity-building components of the project.

Table 13. Summary measures: total investment ($A, 2006 values)

	1% discount rate	5% discount rate	10% discount rate
Breeding			
Present value of benefits ($m)	16,492.0	1,579.7	390.9
Present value of costs ($m)	17.2	13.9	11.0
Net present value ($m)	16,474.8	1,565.7	380.0
Benefit:cost ratio	960.9:1	113.3:1	35.7:1
Internal rate of return (%)	65.8	65.8	65.8
Feeding			
Present value of benefits ($m)	3,968.3	425.4	124.9
Present value of costs ($m)	3.2	2.9	2.6
Net present value ($m)	3,965.2	422.6	122.3
Benefit:cost ratio	1,255.7:1	148.0:1	48.2:1
Internal rate of return (%)	64.8	64.8	64.8
Total			
Present value of benefits ($m)	20,460.3	2,005.1	515.8
Present value of costs ($m)	20.3	16.8	13.5
Net present value ($m)	20,440.0	1,988.3	502.3
Benefit:cost ratio	1,006.7:1	119.3:1	38.1:1
Internal rate of return (%)	65.3	65.3	65.3

Source: Centre for International Economics estimates

It is assumed that, without the research and capacity building, the Australian pigs would have multiplied through the hierarchical breeding structure. The number of fattening pigs that would have been produced by the pigs imported into Vietnam under the project can be estimated from the following information:

- Each Australian sow has around two litters per year (Le Thanh Hai et al. 2001).
- Around 9.1 piglets per litter survive to weaning (see Table 7).
- Each sow has a working life of six litters.
- A boar can service around 40 sows per year using natural mating.
- Australian boars have a conception rate of around 88%.
- It is assumed that 50% of each litter are boars and 50% are gilts.
- It is assumed that, without careful selection, the genetic quality of each generation declines: great grandparent stock produces grandparent stock, grandparent stock produces parent stock and parent stock produces fatteners.

Under these assumptions, it is estimated that a maximum of around 7.6 million fattening pigs could have been produced (Figure 10). Because AI centres reported strong demand for the superior-quality Australian pigs, full adoption of the Australian pigs available is assumed.

The research and capacity building were considered necessary but not sufficient to deliver the full benefits. Following Gordon and Chadwick (2007), the remaining benefits (those not attributed to gene transfer) flowing from the ACIAR-funded project are therefore allocated on a cost-share basis between capacity building and the increase in the stock of knowledge.

The capacity-building components of the ACIAR-funded project also led to further investment in R&D in pig-breeding projects funded by other aid organisations and the Ministry of Agriculture and Rural Development. Since the skills and knowledge developed through the ACIAR-funded project were utilised in the subsequent projects, it is appropriate to attribute some of the benefits flowing from those subsequent projects to the capacity-building activities undertaken as part of the ACIAR-funded project. This is also attributed, on the basis of the cost of the capacity-building activities undertaken as part of the ACIAR-funded project, as a share of the total investment in breeding R&D. The benefits attributable to the ACIAR-funded project are therefore greater than shown in Table 11.

Feeding component

The cost reduction attributed to the feeding component of the project was a direct outcome of the research and capacity-building activities. The capacity building was considered necessary but not sufficient to deliver the benefits. To a large extent, the research and the diet recommendations developed by the project were specific to Vietnamese conditions. The project gave the Vietnamese researchers the knowledge and techniques to undertake the research. The research begun under the ACIAR-funded project was continued under the National Feeding Program. This program adopted the methods developed by the Vietnamese researchers. The capacity-building component of this was a substantial share of the total costs of this research. Thus, a cost-sharing approach to attributing the benefits is appropriate.

Private benefits to researchers involved in the project

As a rule of thumb, Gordon and Chadwick (2007) suggest that a worker's lifetime income is higher, on average, by around 10% for each additional year spent in formal education. An indicative lifetime income is estimated, based on Vietnamese per capita income over the 40 years from 1995 to 2034. Per capita GDP at current prices in local currency from the IMF's World Economic Outlook database is converted to 2006 Australian dollars. The IMF's forecasts are used for 2007 and 2008, while in subsequent years it is assumed that real incomes increase by 5% per year.[5] Using a discount rate of 5% produces an estimate of lifetime income in Vietnam of $23,259 in 2006 dollars.

5 This assumption is consistent with the assumptions used by Quirke et al. (2003).

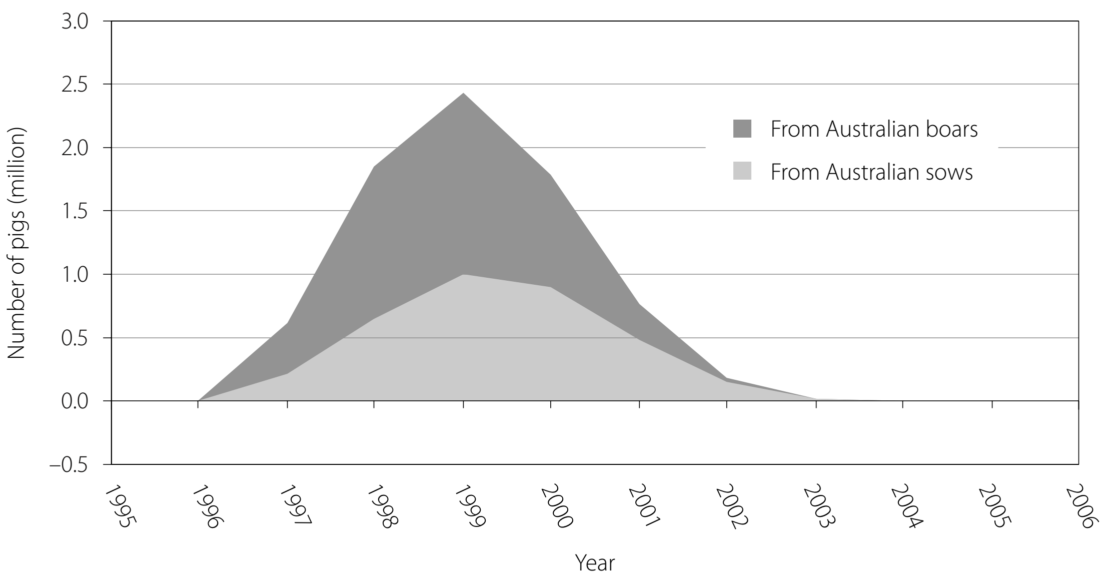

Figure 10. Fattening pigs produced from Australian pigs imported under the project in the absence of research. Data source: Centre for International Economics estimates.

An estimate of the years of full-time education is obtained by multiplying the number of participants involved in each capacity-building activity by its duration. This gives an estimate of 7.8 years of full-time training (based on a 48-week year), implying that the private benefit flowing to the researchers involved in the project was around $25,522 in 2006 dollars. This level of benefit is insignificant compared with the return generated by these and other researchers for the pig-industry producers and consumers. They have nevertheless been included in the total benefits of the projects.

Attribution estimates

The attribution of the benefits, based on the methodologies outlined above, is shown in Table 14. It is notable that the benefits attributed to capacity building and the increase in the stock of knowledge initially appear negative. This is because the benefit attributed to the transfer of superior genes is based on an estimate of what would have happened in the absence of the investment in the research and capacity building. Under this scenario, the superior genes are likely to have been distributed more quickly rather than held for research. One of the costs of undertaking the research was therefore a slower diffusion of the superior genes. However, the research and capacity building ensured that the benefits of the superior genes are sustainable.

Attribution of benefits to capacity building

Researchers estimated that the cost of the capacity-building activities was around 40% of the total budget for both the breeding and feeding components of the ACIAR-funded project.

The importance of R&D as opposed to investments in superior genetics

This impact assessment demonstrates that the benefits that arise from providing new technology without the capacity to maintain and improve on this technology are relatively small. It also points to the value added from ensuring that technology is tailored to the needs of the developing country. While the benefits would have occurred sooner because the animals would have been immediately distributed instead of held for research, the overall benefits are much lower. Table 14 highlights the very big differences between the benefits of the projects with research and capacity building (total benefits column) compared with the benefits from the one-off

Table 14. Attribution of benefits (A$ million and including both the breeding and feeding components)

	ACIAR funding[a]	ACIAR project					Other projects	Total
		Gene transfer	Capacity building — cost share of ACIAR project	Capacity building — benefits to trainees	Capacity building — share of other projects	Increase in the stock of knowledge		
1995	–	–	–	–	–	–	–	–
1996	0.0	–	–	0.001	–	–	–	0.0
1997	0.0	–	–	0.001	–	–	–	0.0
1998	0.1	10.1	−3.9	0.001	–	−5.9	–	0.3
1999	0.6	27.4	−10.3	0.001	–	−15.5	–	1.6
2000	1.8	39.1	−13.6	0.001	–	−20.4	–	5.1
2001	4.0	31.2	−7.9	0.001	–	−11.9	0.1	11.5
2002	6.1	12.4	1.8	0.001	0.1	2.7	2.2	19.2
2003	7.8	2.4	7.6	0.001	0.1	11.4	3.0	24.5
2004	9.7	0.2	10.7	0.001	0.1	16.0	3.9	30.9
2005	12.1	–	13.5	0.001	0.2	20.2	7.0	40.8

Table 14. (continued)

	ACIAR funding[a]	ACIAR project					Other projects	Total
		Gene transfer	Capacity building — cost share of ACIAR project	Capacity building — benefits to trainees	Capacity building — share of other projects	Increase in the stock of knowledge		
2006	13.6	–	15.3	0.001	0.4	23.0	11.1	49.7
2007	14.2	–	16.1	0.001	0.5	24.1	15.7	56.4
2008	15.2	–	17.3	0.001	0.7	26.0	21.3	65.3
2009	16.4	–	18.7	0.001	0.9	28.0	27.1	74.7
2010	17.4	–	20.0	0.001	1.1	30.0	32.7	83.7
2011	18.5	–	21.2	0.001	1.3	31.8	38.2	92.6
2012	19.5	–	22.4	0.001	1.5	33.6	43.6	101.0
2013	20.4	–	23.4	0.002	1.7	35.2	48.8	109.1
2014	21.2	–	24.4	0.002	1.9	36.6	53.7	116.6
2015	22.0	–	25.3	0.002	2.0	38.0	58.2	123.6
2016	22.8	–	26.3	0.002	2.2	39.4	62.0	129.8
2017	23.7	–	27.3	0.002	2.3	40.9	64.9	135.3
2018	24.6	–	28.3	0.002	2.4	42.4	67.3	140.4
2019	25.5	–	29.3	0.002	2.4	44.0	69.9	145.7
2020	26.5	–	30.5	0.002	2.5	45.7	72.6	151.2
2021	27.5	–	31.6	0.002	2.6	47.4	75.3	156.9
2022	28.5	–	32.8	0.002	2.7	49.2	78.1	162.8
2023	29.6	–	34.0	0.003	2.8	51.0	81.1	168.9
2024	30.7	–	35.3	0.003	2.9	52.9	84.1	175.2
2025	31.8	–	36.6	0.003	3.0	54.9	87.3	181.8
2026	33.0	–	38.0	0.003	3.2	56.9	90.6	188.6
2027	34.2	–	39.4	0.003	3.3	59.1	94.0	195.7
2028	35.5	–	40.9	0.003	3.4	61.3	97.5	203.1
2029	36.9	–	42.4	0.003	3.5	63.6	101.2	210.7
2030	38.2	–	44.0	0.004	3.7	65.9	105.0	218.6
2031	39.7	–	45.6	0.004	3.8	68.4	108.9	226.8
2032	41.2	–	47.3	0.004	3.9	71.0	113.0	235.2
2033	42.7	–	49.1	0.004	4.1	73.6	117.3	244.1
2034	44.3	–	50.9	0.004	4.2	76.4	121.6	253.2

[a] Benefits are attributed to ACIAR funding based on the cost share of the total ACIAR project. This column should be excluded when summing across columns to avoid double counting.

Source: Centre for International Economics estimates injection of superior breeding stock (gene transfer column). This demonstrates the importance of working with the researchers in developing countries, tailoring activities to local conditions and building their capacity, to maintain the value of investments in new technology.

Returns to the capacity-building investments

Including a share of the benefits generated by the ACIAR-funded project, as well as a share of the benefits of subsequent R&D that utilised the capacity built, it is estimated that, in present value terms at a 5% discount rate, around $423 million of the total benefit of the breeding and feeding R&D can be attributed to the capacity-building activities undertaken as part of the ACIAR-funded project. The internal rate of return on the investment in capacity building activities was 24.5%, while the benefit:cost ratio was 257:1. The results are summarised in Table 15.

Attribution to ACIAR

The total benefits attributable to the ACIAR-funded project are shown in Table 16. The ACIAR project made up 9.9% of the total investment in the breeding R&D and 93.7% of the feeding R&D investment. The benefits attributable to the ACIAR project are estimated at around $1.1 billion (using a discount rate of 5%). This includes the direct benefits delivered by the project as well as a share of the benefits of the subsequent projects. The internal rate of return on the project is estimated at around 74%, with a benefit:cost ratio of 257:1. ACIAR contributed 32% of the funding for the breeding project and 40% of the funding for the feeding project. Based on cost shares, ACIAR's return on investment is estimated at $385 million. The internal rate of return is estimated at 70.8%, with a benefit:cost ratio of 238:1 (using a discount rate of 5%).

Table 15. Capacity building—summary measures

	1% discount rate	5% discount rate	10% discount rate
Present value of benefits ($m)	4,451.7	424.3	97.7
Present value of costs ($m)	1.8	1.7	1.5
Net present value ($m)	4,449.9	422.7	96.2
Benefit:cost ratio	2,475.2:1	256.5:1	64.8:1
Internal rate of return (%)	24.5	24.5	24.5

Source: Centre for International Economics estimates

Table 16. Attribution of benefits to ACIAR[a]

	ACIAR Project	ACIAR funding
Present value of benefits ($m)	1,109.8	386.6
Present value of costs ($m)	4.3	1.6
Net present value ($m)	1,105.5	385.0
Benefit:cost ratio	257.2:1	238.4:1
Internal rate of return (%)	74.2	70.8

[a] Using a discount rate of 5%

Source: Centre for International Economics estimates.

Distribution of benefits

The economic-surplus framework used for this impact assessment provides some insights into the distribution of benefits among stakeholders in the pig industry. Estimates of the distribution of benefits are sensitive to the elasticity assumptions used.

Consumers benefit from the lower prices resulting from the lower production costs associated with adoption of the research outputs. It is estimated that in present value terms around $821 million, or 52% of the total benefits attributed to the breeding component of the project, flow to consumers.[6] Similarly, around 50% of the estimated benefits from the feeding component of the project flow to consumers through prices lower than would otherwise be the case. This is around $211 million of the total $422 million attributed to the feeding component of the project.

Net benefits flowing to producers are estimated to be around $973 million, comprising around $759 million from the breeding component of the project and $214 million from the feeding component. This was around 49% of the total benefits of the breeding component and 50% of the benefits flowing from the feeding component.

Adopters of the research benefit from the lower costs of production. Benefits flowing to adopters of the outputs of the breeding component of the project are estimated at $1.4 billion. Adopters of the feeding component of the project are estimated to benefit by $383 million. The producers who adopt the outputs of the breeding and feeding components of the project are not necessarily the same. These adopters are small–medium and medium-size commercial pig producers.

The benefits flowing to those producers who adopt the research outputs are partly offset by losses to those producers who do not adopt but compete in the same markets. The losses arise because producers who do not adopt the research face a lower market price but with no reduction in their unit production costs. It is estimated that losses to non-adopters are around $764 million.

[6] Assuming a discount rate of 5%

About $595 million of those losses arise from the breeding component of the project, while the remaining $169 million are a result of the feeding component.

The Vietnamese researchers involved in the project were also direct beneficiaries. All researchers surveyed now get greater satisfaction from their work and many were promoted as a direct result of their involvement with the project. The personal income benefits flowing to the Vietnamese researchers involved in the project were estimated to be around $25,522 (in 2006 dollars, using a discount rate of 5%), and are therefore relatively insignificant in the context of the total benefits.

Sensitivity analysis

The results reported above are sensitive to many of the assumptions used in the modelling. This section examines the effect of varying these assumptions on the estimated net present value of the project. The sensitivities of the following key assumptions are examined:

- the elasticities of supply and demand
- the average daily gain
- the cost reduction resulting from adopting the least-cost diets
- the adoption profiles.

Sensitivity to elasticity assumptions

Quirke et al. (2003) used elasticities of supply for pig meat that ranged between 0.2 and 0.7 for developing Asian economies in the region. The assumed elasticity of supply of 0.45 used in this impact assessment is based on the mid-point of this range. The sensitivity of the results to this assumption is tested by using the extreme ends of the range.

The assumed elasticity of demand for pig meat of –0.85 used in this study was estimated by Agrifood Consulting International (2001). We also vary this assumption using a similar range as for the elasticity of supply. The effects of varying these assumptions are shown in Table 17.

Table 17. Net present value ($ million) of project under various elasticity assumptions

	Elasticity of demand		
Elasticity of supply	−0.60	−0.85	−1.10
0.20	1,983	1,983	1,982
0.45	1,989	1,988	1,988
0.70	1,995	1,994	1,994

Source: Centre for International Economics estimates

The estimated net present value of the projects is relatively insensitive to the elasticity assumptions used, particularly that for the elasticity of demand. However, the distribution of benefits between producers and consumers is more sensitive to these assumptions. Table 18 shows the share of the benefits flowing to consumers and producers when the elasticity assumptions are varied as above.

In general, if demand is more elastic, a greater share of the benefits flows to producers. Conversely, the more elastic is supply, the greater the share of benefits that flows to consumers.

Alternative assumptions

The alternative assumptions used to test the sensitivity of the results to the average daily gain assumption, the adoption profiles and the cost reduction associated with the feeding recommendations are summarised in Table 19 and discussed below.

Average daily gain

The results are sensitive to all the assumptions made about the cost reductions achieved by adopting the research outputs. However, the average daily weight gain reported in the research results varied significantly more than the other parameters. The improvement in the average daily gain varied between 0.8% and 13.0%. This highlights that there is significant variation in performance that is difficult to fully capture when estimating the benefits. The average daily weight gain assumptions are varied based on the extreme ends of the range of results reported in the research.

The central case was based on the findings of Le Pham Dai et al. (2001), who found that superior genetics increases the average daily gain from 601 grams per day to 625 grams per day. The low alternative assumption is based on the findings of Nguyen Thi Vien et al. (2001b). These results suggested that improved genes increase the average daily gain from 597 grams per day to 602 grams per day. The high alternative assumption is based on the results reported in Nguyen Van Duc and Le Thanh Hai (2001). This research suggested that improved genes increase the average daily gain from 575 grams per day to 650 grams per day.

Table 18. Distribution of benefits (%) under various elasticity assumptions

	Elasticity of demand					
Elasticity of supply	−0.60		−0.85		−1.10	
	Consumers	Producers	Consumers	Producers	Consumers	Producers
0.20	40.6	59.4	32.8	67.2	27.5	72.5
0.45	59.7	40.3	51.5	48.5	45.3	54.7
0.70	69.0	31.0	61.6	38.4	55.7	44.3

Source: Centre for International Economics estimates

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

Table 19. Alternative assumptions

Central case assumption	Alternative assumption
The use of superior genetics increases the average daily gain from 601 grams to 625 grams	The use of superior genetics increases the average daily gain from 597 grams to 602 grams
	The use of superior genetics increases the average daily gain from 575 grams to 650 grams
The diet recommendations decrease feeding costs by 5%	The diet recommendations decrease feeding costs by 10%
In 2007, 10% of pigs were superior quality from the Binh Thang Animal Husbandry Research and Training Centre, increasing to a maximum of 20% by 2017	The share of pigs of superior genetic quality remains at 10%
The share of pigs fed using diet recommendations was around 12% in 2007. This share is maintained over the assessment period.	The feed mills using the diet recommendations continue to produce 1.5 million tonnes of feed over the assessment period

Source: Le Pham Dai et al. (2001), Nguyen Thi Vien et al. (2001b), Nguyen van Duc and Le Thanh Hai (2001), La Van Kinh (2007) and Centre for International Economics estimates

Feeding cost reduction

La Van Kinh (2007) estimated the diet recommendations developed through the project reduces feeding costs by 5–10%. We used a 5% cost reduction as the central case in order to provide a conservative estimate. The alternative assumption used in the sensitivity analysis is a 10% cost reduction. The effect of a lower cost reduction was not tested since the lower end of the estimated range was used as the central case.

Breeding adoption profile

Researchers estimated that around 10% of pigs in Vietnam were improved quality pigs from the BTRC. This was estimated to increase to a maximum of 20% over the next 10 years. To examine the sensitivity of this assumption, we alternatively assumed the share of the pig population of superior genetic quality from the BTRC remained at 10%.

Feeding adoption profile

For the feeding component of the project, it was estimated that in 2006 around 1.5 million tonnes of feed were produced using the methods developed as part of the project. We estimated that around 12% of fattening pigs in 2006 could be fed from this amount of feed. We assumed that the share of pigs produced from this feed remained at around 12% over the assessment period. This would involve a significant increase in the quantity of feed produced using the diet recommendations developed in the project since the number of pigs in Vietnam is expected to increase considerably. A reasonable alternative assumption is that the quantity of feed produced using the methods developed during the project remains at 1.5 million tonnes since the IAS has not transferred the methods to additional feed mills.

Summary of results under alternative assumptions

The effect of varying the assumptions outlined above on the summary measures for all breeding and feeding R&D, including the ACIAR-funded project and subsequent R&D, is shown in Table 20. The results are relatively sensitive to all the assumptions examined. Using the lower average daily gain assumption reduces the net present value of the projects by nearly $0.5 billion. Conversely, using the higher average daily gain assumption increases the net present value by more than $1.3 billion. The results appear less sensitive to the feeding-cost reduction assumption, though this is largely because the feeding component was estimated to produce a smaller share of the total benefits. The alternative assumption more than doubles the estimated net benefits of the feeding component. The results are also sensitive to the adoption profiles used.

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

Table 20. Summary measures under various alternative assumptions

	Present value of benefits[a] ($m)	**Present value of costs**[a] ($m)	**Net present value**[a] ($m)	**Benefit:cost ratio**	**Internal rate of return** (%)
Central case	2,005.1	16.8	1,988.3	119.3:1	65.3
Average daily gain (low)	1,536.1	16.8	1,519.3	91.4:1	59.8
Average daily gain (high)	3,359.1	16.8	3,342.3	199.8:1	78.2
Feeding cost reduction	2,432.7	16.8	2,415.9	144.7:1	75.7
Adoption breeding	1,290.5	16.8	1,273.7	76.8:1	64.8
Adoption feeding	1,828.8	16.8	1,812.0	108.8:1	65.2

[a] Using a 5% discount rate.

Source: Centre for International Economics estimates

Conclusion

The pig breeding and feeding research begun under ACIAR Project AS2/1994/023 is estimated to have delivered significant benefits to Vietnam. When the benefits of all R&D projects that were initiated by the ACIAR project are considered, the net present value of the project is estimated to be around $2.0 billion. The internal rate of return on the investment is estimated to be around 65%.

Although it is difficult to precisely measure the benefits of the capacity building, it is clear that it was a key factor in the success of the project. An important aspect of capacity utilisation was the ability of the Institute of Agricultural Science to attract additional funding from the Ministry of Agriculture and Rural Development and the governments of the Netherlands and Belgium. The researchers involved in the project felt that the capacity built during the ACIAR-funded project was critical to receiving this funding.

The net benefits of the capacity-building activities undertaken as part of the ACIAR-funded project are estimated at around $423 million. This is around 21% of the total benefits.

It is clear that capacity building was extremely important to the success of the project, which suggests that a significant capacity-building component should continue to be included in future ACIAR projects. Comparison with the lesser benefits of a simple investment in good genetics without the research and capacity-building components reinforces this conviction and demonstrates the value of the ACIAR approach to the development of partner countries.

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

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Appendix — Survey results

The survey respondents indicated how strongly they agreed or disagreed with a series of statements relating to their project participation. The scoring system for responses is shown in Table A1.

Table A1. Scoring of responses

	Strongly agreed	Agreed	Neutral	Disagreed	Strongly disagreed
Points	5	4	3	2	1

The average response to each question is shown in Table A2.

Table A2. Survey results

Statement	GIPPET course Average score	AI technician training Average score
Relevance		
The topics of the activities were directly related to my field of work at the time	4.6	4.5
Quality of training/education provided		
The trainers/mentors were knowledgeable and provided information of a good quality	4.3	4.0
I found participating in the activities difficult due to my level of English	3.5	3.8
I found the activities well structured and content well focused	4.3	4.5
Capacity built		
I increased my capacity to conduct high-quality research	4.5	4.7
I acquired new or improved laboratory or other technical skills	4.1	5.0
I acquired new skills for managing research projects efficiently and effectively	4.0	3.8
I better understand the issues and principles in my field, and the resources I can access to assist in my research	4.4	4.0
I acquired new ways to approach work problems	4.4	4.5
I learned new or improved ways of communicating with networks within my field	4.1	4.0

Table A2. (continued)

Statement	GIPPET course Average score	AI technician training Average score
Capacity utilised		
I was able to apply the knowledge/skills gained to my work	4.5	4.3
I continue to use the knowledge/skills gained	4.3	4.8
I increased my professional collaboration with organisations both nationally and internationally	3.9	4.0
I have trained others in the skills I learned	3.9	4.2
I was able to secure additional resources to expand or enhance my research	4.2	3.7
The networks made during the project have enabled me to produce better research outputs	4.4	4.8
The technologies/knowledge/skills gained from the project enabled me to perform better at work	4.5	4.5
Outcomes—personal		
I was offered a promotion	3.9	4.3
I have pursued work opportunities in the field of the workshop	4.1	4.4
As a result of what I learned and have applied I gain greater satisfaction from my work	4.2	4.8
Outcomes—organisational		
The organisation I work for has increased its R&D outputs	4.2	4.8
The project added to the quality of research our organisation produces	4.2	4.5
As a result of the project I was able to carry out more productive experiments	4.4	3.6
The training increased the speed at which I was able to make advances	4.3	4.2
I have been able to apply the knowledge gained in this project to research in other fields	4.3	4.2
This project enabled me to begin conducting experiments in pig genetics and nutrition	4.3	4.4
I have been able to use the database and models compiled in the project to further my experimentation	4.0	4.0

From: Fisher H. and Gordon J. 2008. *Breeding and feeding pigs in Vietnam: assessment of capacity building and an update on impacts*. ACIAR Impact Assessment Series Report No. 52, 56 pp.

IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A. (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Waterhouse, D., Dillon, B. and Vincent, D. (1999)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh, P. (1999)	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod, R. (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell, C. and Wilson, C. (2001)	Breeding and feeding pigs in Australia and Vietnam AS2/1994/023	
18	Vincent, D. and Quirke, D. (2002)	Controlling *Phalaris minor* in the Indian rice–wheat belt	CS1/1996/013
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