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Newcastle disease control in Africa

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Newcastle disease control in Africa

Hayden Fisher

The Centre for International Economics

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Cover: A boy poses for this picture with his hen, which he brought to a seroprevalence testing point in Zambia, where the presence of Newcastle disease is tested for in the bird's blood. (Photo: Brigitte Bagnol)

Foreword

For the past 30 years, the Australian Centre for International Agricultural Research (ACIAR) has funded research aimed at controlling Newcastle disease in village chicken flocks in various parts of the world. This disease is a major constraint on production in many developing countries. It is of particular concern because it reduces the effectiveness of using village chickens as a means of improving food security and alleviating poverty.

ACIAR has funded research in Africa, with an initial focus on Mozambique. This was followed by a series of AusAID[1]-funded projects, which expanded disease control activities into Tanzania, Malawi and Zambia. In total, the Australian Government has contributed around $10.8 million (in nominal terms) to Newcastle disease control projects in Africa, of which ACIAR has contributed around $1.1 million.

This report details both the successes achieved and challenges encountered by research and extension workers in the countries under study. It focuses on the introduction and dissemination of the Newcastle disease I-2 vaccine, which was developed through ACIAR funding and has several advantages over previous vaccines for use in the village context.

ACIAR-funded research also developed comprehensive vaccine production, distribution and administration systems, including appropriate extension material that has been proven effective in African conditions. The knowledge developed during the ACIAR projects is embodied in several manuals, including laboratory, training and field manuals.

The report confirms that this ACIAR-funded research, together with subsequent AusAID-funded projects, has led to many poor rural households having their chickens vaccinated. The author estimates that more than 60 million chickens have been vaccinated using the I-2 vaccine in Tanzania, Mozambique and Malawi, and this is expected to increase. Evidence suggests that, at the village level, vaccination has reduced mortality rates and allowed households to expand their flocks and increase production for sale and consumption.

These projects have delivered significant economic benefits that will continue to help poor rural communities in Africa. This report estimates total net benefits to the four African partner countries of around $479 million (in 2013 Australian dollars), including more than $100 million of benefits already realised.

Around $80.6 million of those benefits can be attributed to ACIAR, which once more affirms the excellent value of investing in research for development. In this instance, the research reaped a benefit of around $60 for every dollar invested. This is a gratifying outcome, especially for the many dedicated scientists and extension workers who have worked tirelessly in difficult circumstances over many years.

Nick Austin
Chief Executive Officer, ACIAR

[1] As of November 2013, AusAID ceased to exist as a separate entity. The Department of Foreign Affairs and Trade now has responsibility for Australia's aid program.

Contents

Foreword 3

Abbreviations 7

Acknowledgments 8

Executive summary 9

1 Background and introduction 11
Village chickens in southern and eastern Africa 11
ACIAR's Newcastle disease vaccination projects in Africa 12
Subsequent projects 13
Funding 15
This report 15

2 Research outputs 17
New vaccine and related knowledge 17
Systems and methodologies for the production, distribution and administration of the vaccine 18
Enhanced capacity 20

3 Adoption of research outputs 21
Adoption 21
Factors supporting adoption 24
Barriers to adoption 24
Prospects for future adoption 25

4 Outcomes 28
Establishment of vaccine production and distribution systems 28
Village-level outcomes 29

5 Research impacts 31
Economic impacts 31
Impacts on food security and poverty alleviation 39
Impacts on women 40
Other impacts 40

6 Benefits and costs 42
Benefits 42
Costs 47
Summary 48
Risk and sensitivity analysis 49

7 Conclusions 53
Distribution and extension strategies are critical 53
Government service delivery can be effective 53
Cost-recovery improves the effectiveness and sustainability of government services 54
Well-targeted projects improve food security and alleviate poverty 54

References 56

Tables

1. Project objectives 14
2. Australian funding for Newcastle disease control projects in Africa ($) 16
3. Adoption rates in AusAID project areas 22
4. Changes in flock size and chicken off-take in AusAID project areas over time 30
5. Impact of vaccination on flock size, mortality and off-take in Tanzania 30
6. Annual incremental benefits and costs of Newcastle disease control at the farm level 33
7. Literature summary—household-level impacts 34
8. Literature summary—regional impacts 35
9. Prices of village chickens 38
10. Vaccine costs per dose 39
11. Estimated net benefits to Mozambique 43
12. Estimated net benefits to Tanzania 44
13. Estimated net benefits to Malawi 45
14. Estimated net benefits to Zambia 46
15. Nominal and real project costs 47
16. Summary measures 48
17. Distribution of benefits 48
18. Attribution of benefits 49
19. Summary measures based on benefits and costs to date 50
20. Summary measures under alternative adoption scenarios 50
21. Summary measures under alternative off-take assumptions 51
22. Summary measures under alternative price assumptions 51
23. Distribution of benefits under alternative demand elasticities 52

Figures

1. Typical vaccine cold chain in Mozambique 19
2. Vaccine production and distribution 23
3. Estimated adoption profile 27
4. Market for chickens 36

Boxes

1. Control of Newcastle disease in village chickens—impact assessment 12
2. Controlling Newcastle disease: a laboratory manual 18

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AusAID	Australian Agency for International Development
CIE	Centre of International Economics
NGO	non-government organisation
SANDCP	Southern African Newcastle Disease Control Project
SFRB	scavenging feed resource base
VIPOSIM	village poultry simulation model

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Executive summary

Raising chickens is an important economic activity for poor rural households in many developing countries, including in southern and eastern Africa. Village chickens can be a source of income, and their meat and eggs provide animal protein, which contains essential amino acids and micronutrients.

Newcastle disease is a highly virulent poultry disease that can wipe out entire flocks. It is a major constraint on production in many developing countries and reduces the utility of village chickens as a means of improving food security and alleviating poverty.

The Australian Centre for International Agricultural Research (ACIAR) has been funding research aimed at controlling Newcastle disease in village chicken flocks in various parts of the world for the past 30 years, including in Africa. This research program focused first on Mozambique and was followed by a series of projects funded by the Australian Agency for International Development (AusAID) that continued the Newcastle disease control activities in Mozambique and expanded them into Tanzania, Malawi and Zambia. (As of November 2013, AusAID ceased to exist as a separate entity. The Department of Foreign Affairs and Trade now has responsibility for Australia's aid program.)

In total, the Australian Government has contributed around $10.8 million (in nominal terms) to Newcastle disease control projects in Africa, about $1.1 million of which has been contributed by ACIAR.

Outputs delivered by ACIAR-funded research

A new vaccine for Newcastle disease—the I-2 vaccine—was developed using ACIAR funding. This vaccine has several advantages over earlier vaccines for use in the village context.

ACIAR-funded research also developed comprehensive vaccine production, distribution and administration systems, including extension material that has been shown to be effective in African conditions. The knowledge developed during the ACIAR projects is embodied in several manuals, including laboratory, training and field manuals.

Adoption and outcomes

Vaccine production and distribution systems have been established in all four countries covered by the AusAID projects. While there have been some refinements, the production and distribution systems in use are based on the systems developed in the ACIAR project.

We estimate that more than 60 million chickens have been vaccinated using the I-2 vaccine in Tanzania, Mozambique and Malawi. This is expected to increase in the future.

Evidence at the village level suggests that vaccination has reduced mortality rates and allowed households to expand their flocks and increase production for sale and consumption.

Impacts

Projects funded by the Australian Government through ACIAR and AusAID have delivered significant economic benefits to poor rural communities in Africa.

Using ACIAR's preferred discount rate of 5%, the total net benefits to the four African partner countries are estimated at around $479 million, including more than $100 million of benefits already realised (unless otherwise stated, all values are expressed in 2013 Australian dollars). Around $80.6 million of those benefits can be attributed to ACIAR.

The total project costs were around $8.0 million (using a discount rate of 5%). The net present value of the Australian aid projects is therefore estimated at around $470.9 million, representing a benefit of around $60 for every dollar invested. The internal rate of return on the investment by the Australian Government is estimated at around 96%.

Summary measures

	Value
Present value of benefits ($ million)	479.0
Present value of costs ($ million)	8.0
Net present value ($ million)	470.9
Benefit:cost ratio	59.6
Internal rate of return	96.4

Note: A discount rate of 5% is used.

Source: Centre for International Economics (CIE) estimates.

The economic benefits are estimated to flow mainly to consumers in rural communities, although consumers in urban areas may also benefit where there are linkages to wider markets. Producers who vaccinate also receive a modest benefit, while non-vaccinators may be worse off because they are likely to produce the same quantity of product but receive a lower price (although non-vaccinated chickens could gain some protection from Newcastle disease through the presence of vaccinated chickens). In the village context, many households are both consumers and producers, so the distinction between consumers and producers is less relevant.

Where the price paid by households for the vaccine does not reflect the full cost of production, distribution and administration, some costs are borne by national and provincial governments and in some cases by non-government organisations.

These projects have also contributed to improved food security and poverty alleviation and have provided significant benefits to women.

An additional benefit from controlling Newcastle disease is that the disease's absence can lead to earlier detection of highly pathogenic avian influenza.

Conclusions

The series of Newcastle disease control projects funded by the Australian Government is a good example of ACIAR-funded research developing a 'proof of concept', which is then scaled up using other Australian Government funding.

Broader lessons from this project include the following:

- These projects have reinforced the importance of effective distribution and extension strategies for new technologies. No matter how effective a new technology, it will not deliver benefits unless it is adopted by final users.
- The projects have demonstrated that government provision of new technologies can be effective.
- Effective cost-recovery mechanisms improve the effectiveness and sustainability of government services. Without them, service providers are reliant on scarce government or donor funding. Smallholders can be willing to pay for new technologies once they understand the benefits.
- The projects were well targeted as a means of improving food security and alleviating poverty because they focused on mitigating a major constraint on the production of a good that is both produced and consumed by poor rural households.

1 Background and introduction

This section describes the roles of chickens in village production systems in southern and eastern Africa, the potential benefits from controlling Newcastle disease (a significant limiter on production), and the role of the Australian Centre for International Agricultural Research (ACIAR) in improving production.

Village chickens in southern and eastern Africa

Raising village chickens is an important economic activity for many poor rural households across the developing world, including in southern and eastern Africa. Chicken meat and eggs are an important source of animal protein, which contains essential amino acids and micronutrients (see, for example, Copland and Alders 2009, pp. 11–12). For many families, sales of meat and eggs are an important source of income, and chicken faeces can be used manure in mixed production systems.

Chickens also play a broader role in village life. They provide food for special festivals, offerings and traditional ceremonies (Alders 2001, p. 80).

Raising chickens is a way of saving for basic necessities, such as medication, clothes and educational expenses for children (Bagnol 2009, p. 72). For many households, chickens can be an entry point to the production of other livestock species, such as goats and cattle (Copland and Alders 2009, p. 12).

In addition to requiring fewer inputs, poultry have further advantages over other livestock species for poor rural households. For example, they have minimal environmental impact and are resilient in natural disasters, such as floods, tsunamis and fires; unlike other types of livestock, village chickens can fly to safety in the face of such threats (Copland and Alders 2009, p. 13).

Production systems

Village chicken production is a low input – low output system. The birds are typically kept under free-range conditions and get most of their food by scavenging for worms, insects and greenery (see, for example, Mavale 2001, p. 20, and Buza and Mwamuhehe 2001, p. 38). Their diet may also be supplemented with feed such as household scraps, maize waste or maize meal (Harun and Massango 2001, p. 77).

In some cases, no housing is provided and the chickens roost in trees at night (Mavale 2001, p. 20). Where housing is provided, it is typically a simple structure built from local material and intended to prevent predation during the night. Some families house chickens in the family house, particularly during brooding.

Constraints on production

One of the consequences of a low-input system is low output. A range of constraints can prevent village chicken production reaching its full potential as a means of reducing poverty. They include high mortality rates due to various diseases and predation, and reliance on the scavenging feed resource base, which can sustain only a limited number of birds. Many of these problems could be alleviated through more intensive management, such as providing better housing and nutrition and veterinary services. However, that requires more inputs, which are often not available or affordable to poor rural households.

The single greatest constraint on village chicken production in southern and eastern Africa and many

other developing countries is Newcastle disease (Cambaza et al. 2009, p. 75). Newcastle disease is a highly virulent disease in poultry and is endemic in many developing countries. It causes high mortality, and severe outbreaks can wipe out entire flocks. Periodic outbreaks severely curtail production because birds and eggs must be retained to maintain or rebuild the flock.

In commercial flocks, it may be possible to control Newcastle disease by excluding the virus (Spradbrow 2001 p. 55). However, biosecurity approaches used in intensive production will not be effective for chickens raised in villages, where it is difficult to control the movements of people and animals.

Vaccination is therefore considered the only viable approach for controlling Newcastle disease in the village context. However, many vaccines require delivery along a cold chain, which is absent in many villages.

ACIAR's Newcastle disease vaccination projects in Africa

Background

ACIAR has been sponsoring research into thermotolerant vaccines for Newcastle disease since the early 1980s.

An initial ACIAR-funded project (AS1/1983/034, *Vaccination of Malaysian village poultry with an avirulent Australian Newcastle disease virus*) examined the potential of using a commercially available thermotolerant vaccine (HRV4), which could be readily used in the village context by coating it onto chicken feed. Field trials found that the HRV4 vaccine was effective in providing a high degree of protection to chickens under laboratory conditions and in pilot village trials in Malaysia.

A subsequent ACIAR project (AS1/1987/017, *Control of Newcastle disease in village chickens with oral V4 vaccine*) extended the trials to other countries in the region, including Indonesia, the Philippines, Sri Lanka and Thailand.

While the HRV4 vaccine was found to be effective, uptake was somewhat limited in poor rural villages for a number of reasons. One issue was the cost to local villagers with limited capacity to pay. Following the sale of the company that produced the HRV4 vaccine, the new owners decided that the vaccine would be available to villagers only on commercial terms. Another problem was that the vaccine was freeze-dried, which meant that it had to be diluted in the field, which could be complicated for vaccinators with limited formal training, particularly as the labelling and instructions were in English (R. Alders, pers. comm., 22 July 2013). There were also logistical problems in transporting and storing large quantities of vaccine-coated grain.

A third ACIAR-funded project, AS1/1993/222 (*Control of Newcastle disease in village chickens*), developed a new strain of avirulent thermostable vaccine (I-2) suitable for use in the production of vaccine for village flocks.

An impact assessment on these three ACIAR-funded projects was completed in 1998 (Box 1).

Box 1. Control of Newcastle disease in village chickens—impact assessment

A 1998 impact assessment (CIE 1998) estimated that three ACIAR-funded projects (AS1/1983/034, AS1/1987/017 and AS1/1993/222) would deliver significant benefits in Malaysia, Vietnam, the Philippines and Africa. In 1996 Australian dollar present value terms and using a 5% discount rate, the benefits were estimated at around $211 million over the 20-year period between 1993 and 2012. The costs were estimated at $3.1 million, suggesting a benefit:cost ratio of 68:1. The internal rate of return was estimated at 31%.

When the impact assessment was completed in 1998, most of the benefits had accrued in Malaysia and Vietnam. Although Africa had not yet received any benefits attributable to the ACIAR-funded research, significant benefits were expected to flow to African countries in the future. The benefits that would ultimately accrue to Africa were estimated at $131 million, or more than 60% of the total benefits attributable to these projects (CIE 1998, pp. 28–29). This was based on adoption commencing in 2003 and reaching 10% of an estimated total of 1.5 billion village chickens across Africa by 2010.

ACIAR sponsored research to develop seed cultures of the I-2 vaccine that would allow the vaccine to be produced cheaply at the local level (AS1/1995/040, *Production of a seed culture of heat resistant Newcastle disease virus suitable for producing in developing countries*). The vaccine has not been commercialised and is made available to laboratories in developing countries. Trials were initially undertaken in Vietnam and were then extended to African countries. A project extension subsequently spread the vaccine that was developed to Africa. The initial project ran from July 1993 to December 1994, and the extension from January 1995 to December 1996.

A subsequent project (AS1/1996/096, *Investigations into the control of Newcastle disease in village chickens in Mozambique*) extended the small-scale trials that had been run in Vietnam, Zambia and Tanzania to Mozambique to assess the efficacy of locally prepared I-2 vaccine in the field and compare it with HRV4 vaccine. This work commenced in July 1996. The project was initially scheduled to finish in June 1998, but a series of extensions meant that it was completed in December 2001. In the interim, I-2 vaccine went into production at Mozambique's National Veterinary Research Institute.

This report is an impact assessment of the latter two projects:

- *Production of a seed culture of heat resistant Newcastle disease virus suitable for producing in developing countries* (AS1/1995/040)
- *Investigations into the control of Newcastle disease in village chickens in Mozambique* (AS1/1996/096)

In addition to these projects, ACIAR also provided funding for training and for a workshop.

Research partners

ACIAR commissioned the University of Queensland to undertake both projects. The African partner organisation was the National Veterinary Research Institute in Mozambique.

Project objectives

The stated objectives of the ACIAR-funded projects are summarised in Table 1.

Subsequent projects

Following on from the ACIAR-funded research, which focused mainly on Mozambique, the Australian Agency for International Development (AusAID) funded a series of projects relating to Newcastle disease control in Africa that built on the ACIAR work.

Southern African Newcastle Disease Control Project (Phase I)

The Southern African Newcastle Disease Control Project (SANDCP) ran from July 2002 to October 2005. The project extended the work completed under the ACIAR-funded projects and expanded it to include Tanzania and Malawi. The view at the time was that the research and development component had largely been completed, and that larger scale work to control the disease would be more appropriately funded by AusAID (J. Copland, pers. comm., May 2013). AusAID commissioned GRM International to run the SANDCP.

The overarching goal of SANDCP was to contribute to poverty reduction and increased food security in three countries of southern and eastern Africa (Alders 2009, p. 64).

Regional Newcastle Disease Control Project (Phase II)

Since 2009, AusAID had been providing funding for the Kyeema Foundation, a non-government organisation (NGO) based in Brisbane. The foundation was formed out of the SANDCP to continue to provide technical assistance to the governments of Mozambique, Tanzania and Malawi to enhance their capacity to respond to increasing demand for the production and supply of vaccines to rural communities. Phase II expanded the disease-control work into new regions in each of the three SANDCP countries, as well as into Zambia, before it concluded in mid-2013.

Phase III

A scoping study for Phase III of the Newcastle disease control work using AusAID funding is due to be completed in 2014. Phase III will focus on handing over the work to the Pan African Veterinary Vaccine Centre of the African Union (AU PANVAC). This

Table 1. Project objectives

Project	Objective
AS1/1995/040	• The original purpose of AS1/1995/040 was to produce a seed culture from an Australian strain of Newcastle disease virus, after selection for heat resistance, immunogenicity and ability to spread. If the vaccine was suitable, it would be made available to developing countries so that they could produce their own stocks.
AS1/1995/040 (extension)	• Perform further tests on the selected seed vaccine, including its behaviour in a flock of free-range chickens. • Initiate case studies on the use of similar vaccine in two African countries, probably Mozambique and Tanzania. • Organise and conduct an African workshop on the production and testing of Newcastle disease vaccines. • Allow project staff to attend a meeting of the African Network for Rural Poultry Development.
Training project	• Develop appropriate extension methodologies and material to assist in the control of Newcastle disease in the family sector. • Train a 'trainers' team' which would become responsible for the training of extension workers in each province. • Train a member of the Newcastle disease team at the National Veterinary Research Institute in Mozambique in the transfer of technology to rural farmers and participative technology development. • Hold a seminar for government departments and development agencies involved with poultry production in the family sector to present the extension material produced and personnel trained by the project.
AS1/1996/096	• Investigate distribution and administration systems for thermostable Newcastle disease vaccine in Mozambique. • Evaluate the efficacy of the thermostable V4 vaccine for the control of Newcastle disease in Mozambique under both laboratory and field conditions. • Prepare a batch of I-2 vaccine under local conditions and compare it with commercial heat-resistant V4 vaccine. • Facilitate links between Mozambican scientists and the International Village Poultry Network. • Determine a future program and strategies that will facilitate the production, distribution and testing of Newcastle disease vaccine under village conditions, and the administration of a cost-recovery system.
AS1/1996/096 (extension)	• Consolidate and complete the activities of ACIAR project AS1/1996/096 to ensure long-term benefits and impact. • Develop a sustainable production system for I-2 vaccine production and Newcastle disease control activities in Mozambique. • Continue development of quality assurance procedures and supporting documentation for locally produced vaccines. • Hold a SADC workshop to foster regional discussions and cooperation on Newcastle disease control in southern Africa to facilitate spillover benefits to other countries.

Sources: ACIAR (1996, p. 13; 1997, p. 5; 2000, p. 5).

could potentially lead to Newcastle disease control using I-2 vaccine in countries such as Cameroon, Chad, the Democratic Republic of Congo, Ethiopia, Egypt, Ghana, Kenya, Mali, Niger, Nigeria, Senegal, South Sudan, Sudan and Zimbabwe (AusAID, pers. comm., May 2013).

The Australian Government has not committed any further funding to Stage III, and various alternatives are being considered.

Funding

The Australian Government has contributed almost $11 million to Newcastle disease control in Africa (Table 2). ACIAR provided around $1.1 million (in nominal terms), while AusAID provided around $9.6 million. In-kind contributions from partner country governments and other funding sources have not been documented except in the original project documentation for AS1/1996/096. While it has not been possible to track down most of the cash and in-kind contributions from partner countries (including through national, regional and local governments), international agencies and NGOs, those costs are nevertheless taken into account in the benefit:cost analysis by estimating the implicit subsidy of the vaccine (see Section 5).

This report

This report is an impact assessment of two ACIAR-funded projects:

- Production of a seed culture of heat resistant Newcastle disease virus suitable for producing in developing countries (AS1/1995/040)
- Investigations into the control of Newcastle disease in village chickens in Mozambique (AS1/1996/096).

While the benefits of the original Newcastle disease projects in Africa were estimated in IAS 01, that report was completed before I-2 vaccine production, distribution and extension systems were established in a number of African countries. The benefits accruing to Africa estimated in that study could therefore be considered an indication of the potential.

With 15 years of hindsight, and after an additional $10 million of Australian Government funding for this work, this report provides more robust estimates of the benefits accruing to Africa.

While the focus of this report is on the impacts of the ACIAR-funded research, difficulties in disentangling the impacts of the ACIAR projects from the subsequent AusAID-funded projects mean that the report also effectively assesses the impacts of all of the Australian Government–funded projects together. Following ACIAR's guidelines for impact assessments, the remainder of the report is set out as follows:

- Chapter 2 describes the outputs delivered by the ACIAR-funded research.
- Chapter 3 discusses the adoption of the research outputs, including the factors that supported adoption and some of the barriers to adoption.
- Chapter 4 describes the outcomes.
- Chapter 5 develops a framework for analysing the impacts of the research.
- Chapter 6 estimates the benefits and costs of the projects using a standard cost–benefit analysis framework.
- Chapter 7 summarises and concludes the report.

Table 2. Australian funding for Newcastle disease control projects in Africa ($ nominal)

	ACIAR	AusAID	Partner countries	Total
AS1/1995/040				
Original project				
1993–94	23,905	0	0	23,905
1994–95	23,905	0	0	23,905
Extension				
1994–95	59,529	0	0	59,529
1995–96	59,529	0	0	59,529
Total	**166,868**	**0**	**0**	**166,868**
Training project				
1997–98	3,843	0	0	3,843
1998–99	21,157	0	0	21,157
Total	**25,000**	**0**		**25,000**
AS1/1996/096				
Original project				
1996–97	99,325	0	9,500	108,825
1997–98	50,475	0	9,000	59,475
Extension				
1998–99	49,044	0	0	49,044
1999–2000	72,963	0	0	72,963
2000–01	368,898	0	0	368,898
2001–02	247,128	0	0	247,128
Total	**887,833**	**0**	**18,500**	**906,333**
Workshop				
2001–02	40,000	50,000	0	90,000
Total	**40,000**	**50,000**	**0**	**90,000**
SANDCP (Phase I)				
2002–03	0	1,743,172	0	1,743,172
2003–04	0	1,667,933	0	1,667,933
2004–05	0	1,787,494	0	1,787,494
2005–06	0	911,748	0	911,748
Total	**0**	**6,110,347**	**0**	**6,110,347**
Phase II				
2009–10	0	579,920	0	579,920
2010–11	0	627,434	0	627,434
2011–12	0	627,434	0	627,434
2012–13	0	627,434	0	627,434
Total	**0**	**2,462,221**	**0**	**2,462,221**
Phase III				
2012–13	0	999,401	0	999,401
Total	**0**	**999,401**	**0**	**999,401**
Grand total	**1,119,701**	**9,621,968**	**18,500**	**10,760,168**

Source: ACIAR and AusAID project documents.

2 Research outputs

Outputs are the products and policies delivered by research projects. The ACIAR-funded research projects delivered:

- an important new technology—the I-2 vaccine
- methods and systems for the production, distribution and administration of the vaccine that are effective in local conditions (based on knowledge developed through scientific and socio-anthropological research)
- greater local individual and institutional capacity to implement those systems.

New vaccine and related knowledge

ACIAR project AS1/1995/040 developed seed cultures of the I-2 vaccine suitable for vaccine production in developing countries. The I-2 master seed culture is kept at the University of Queensland and is provided to developing countries free of charge.

Various research trials throughout the projects contributed to the stock of scientific knowledge about the vaccine and its properties:

- Vaccine safety
  - Trials in both minimal-disease chickens and specific pathogen-free 1-day-old chicks found that the I-2 vaccine was safe for use in village chickens.
  - The I-2 master seed culture was found to be free of a range of extraneous agents.
- Dose–response
  - There were no differences in the antibody response between birds given the normal dose and birds given between 10 times and 100 hundred times the normal dose. Only some birds receiving one-tenth of the normal dose developed protective levels of antibodies.
  - When the trial was repeated with isolated birds, the highest dose rate was found to provoke a faster and initially greater antibody response. However, there was no significant difference between the antibody titres in different dose groups after 2 weeks.
- Thermotolerance
  - Trials were conducted to determine the period that I-2 vaccine could be stored at various temperatures while retaining infectivity.
  - The infectivity of freeze-dried vaccine fell below recommended levels after 10 days when stored at 37 °C and after 2–4 weeks when stored at variable environmental temperatures (19–32 °C).
  - The infectivity of wet I-2 vaccine fell below recommended levels at 2 days when stored at 37 °C and at 2 weeks after storage at variable environmental temperatures (22–29 °C).
  - Both freeze-dried and wet vaccines retained infectivity for extended periods (more than 3 months) when stored at 4 °C and –70 °C.
- Comparison of I-2 and NDV4 strains of Newcastle disease virus (NDV4 is an Australian strain).

Systems and methodologies for the production, distribution and administration of the vaccine

ACIAR-funded project AS1/1996/096 investigated systems and methodologies for the production, distribution and administration of the I-2 vaccine in local conditions and then trialled the I-2 and NDV4 vaccines in Mozambique to find the most effective. The aim was to make them readily transferable to other countries in the region, using funding from other international development agencies, including AusAID.

This project was seen as a link between the research elements of the program and the development and extension component.

The knowledge developed through this research was embodied in several manuals.

Vaccine production system

The ACIAR-funded research developed a system for I-2 vaccine production and quality assurance that was suitable for local conditions. This was embodied in a comprehensive laboratory manual first published in 2002 and updated in 2012 (Young et al. 2002; see Box 2).

Box 2. Controlling Newcastle disease: a laboratory manual

The laboratory manual developed through ACIAR-funded research included the following topics:

- Laboratory management and maintenance:
  - Basic laboratory requirements
  - Use and maintenance of laboratory equipment
  - Cleaning and decontamination and waste disposal
  - Keeping track of stocks, reagents and consumables
  - Record keeping
- I-2 Newcastle disease vaccine production:
  - Selecting and handling eggs for vaccine production and testing
  - Inoculating eggs by the allantoic cavity
  - Harvesting allantoic fluid
  - Managing vaccine seed lots, including diluting master seed, preparing working seed and preparing vaccine from working seed
  - Storing allantoic fluid
- I-2 Newcastle disease vaccine testing:
  - Collecting blood from the wing veins of chickens
  - Preparing a washed red blood cell suspension
  - Testing for the presence of the virus
  - Estimating the concentration of the live virus
  - Testing the vaccine for the presence of contaminants
  - Laboratory challenge trials using virulent virus
  - Preparing serum
  - Testing for antibody
  - Serological surveys
- Practical aspects of I-2 Newcastle disease vaccine distribution:
  - General recommendations for freeze-drying
  - Inspecting vaccine after freeze-drying
  - Stability testing
  - Labelling
  - Storing
  - Maintaining the cold chain
  - Packaging vaccine, including freeze-dried vaccine and wet vaccine
  - Transport
  - Reconstituting and administering I-2 vaccine using an eyedropper
- Newcastle disease diagnoses:
  - Virus isolation and characterisation
  - Pathogenicity tests.

The vaccine production system outlined in the laboratory manual was supported by knowledge developed through the research. Key research findings relevant to the development of a sustainable vaccine production system included the following:

- Optimisation of yield of seed—Small inocula can be used by developing the subsidiary master seed.
- Maintenance of thermotolerance on passage through the host without heat selection—Thermotolerance is unaltered over five passages, but is greatly reduced by 10 passages. Currently, the virus is passaged only twice.

Vaccine distribution and administration systems

The research also developed vaccine distribution and administration systems that are effective in local conditions. A key requirement in the distribution system is to maintain the cold chain; while the I-2 vaccine is relatively thermotolerant, its delivery still requires a cold chain from the central vaccine store to the local vaccinator. The vaccine distribution system was outlined in the laboratory and training manuals.

A typical cold chain in Mozambique is summarised in Figure 1.

The vaccine distribution and administration systems were underpinned by knowledge gained from scientific and anthropological research. Important findings from the scientific research included the following:

- Distribution of the vaccine
  - Low-density polyethylene transfer pipettes were found to have no effect on the infectivity titre or sterility of the wet I-2 vaccine after 48 hours. The pipettes were considered suitable for short-term distribution of the vaccine.
  - The commercially available product 'DryChill' best maintained cold temperatures in polystyrene packs for vaccine transport. When these were not used, disposable water bottles filled with saturated salt solution also gave good results.
- Administration of the vaccine
  - Three routes of vaccination (eyedrop, drinking water and oral drench) were compared by measuring the antibody response and by considering farmers' comments (ACIAR 2002, p. 5).
  - Eyedrops were found to maximise the antibody response and were preferred by farmers.

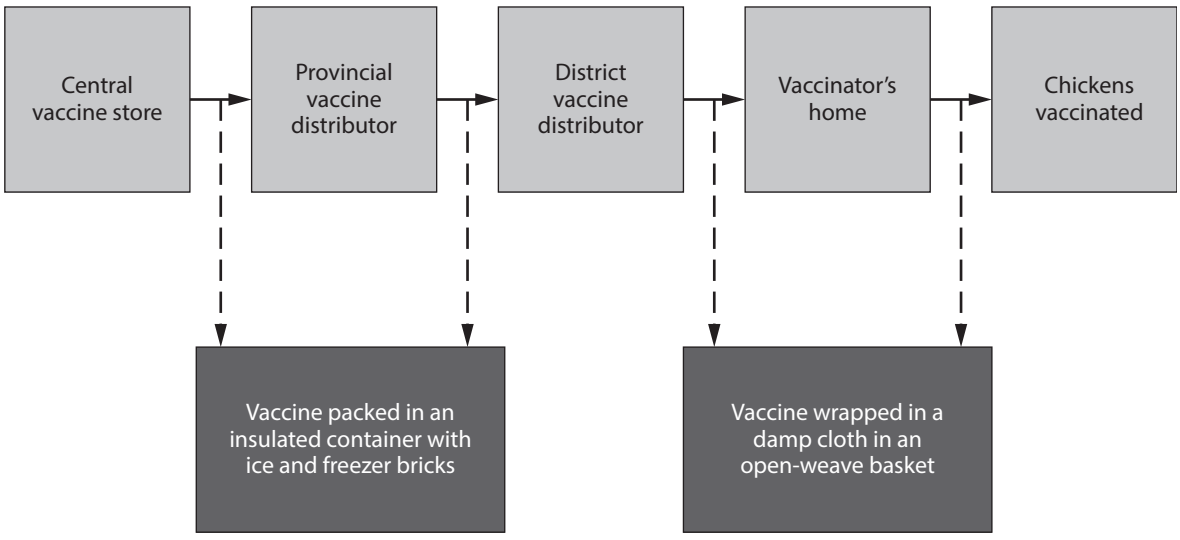

Figure 1. Typical vaccine cold chain in Mozambique. Sources: Young et al. (2002, p. 90), CIE.

Extension strategy

The final element of the vaccine production and distribution system developed by ACIAR was an effective extension strategy. An extension strategy is a key element of all effective research and development projects but is not necessarily considered a project output. However, the extension strategy developed for these projects was underpinned by systematic research and was designed as a 'model' strategy that could be rolled out in multiple countries. Therefore, the extension strategy can be considered to be a separate project output in this case.

Two manuals were produced (ACIAR 2002, pp. 7–8):

- a Newcastle disease training manual for trainers of community vaccinators
- a Newcastle disease field manual for senior veterinarians and veterinary field staff.

Important elements of the extension strategy included the following:

- The campaign approach
  - To maintain 80% protection within a flock, chickens need to be vaccinated every 4 months.
  - Periodic vaccination campaigns in which all owners could get their chickens vaccinated at the same time were considered to be the strategy most likely to maximise adoption.
- Incentives for vaccinators
  - The price of the vaccine should include some reward for the vaccinator to encourage them to publicise the campaign and ensure maximum uptake.
- Encouragement for women vaccinators
- A cost-recovery mechanism to ensure sustainability
- Extension material, including:
  - conventional written material
  - radio broadcasts
  - simple flip-charts for use in the field
  - a vaccine song in several local languages and Portuguese
  - a vaccine play.

Enhanced capacity

Capacity building was a crucial element of the ACIAR-funded projects. As well as building capacity through increased scientific knowledge and the development of various manuals, the projects also enhanced the capacity of partner-country institutions and individuals within them.

Institutional capacity in partner countries

Project AS1/1996/096 focused heavily on building capacity within relevant organisations in Mozambique, including government organisations such as the National Veterinary Research Institute and NGOs involved in extension activities. The manuals and protocols developed and published by the projects, which can be easily modified for use in other countries, should help to ensure that the new capacity is sustained.

The project also built the capacity of extension service providers, trainers and community vaccinators. These extension approaches included appropriate cost-recovery mechanisms.

Individual capacity in partner countries

Training was provided to farmers, community vaccinators, extension workers, chicken traders, laboratory personnel, NGO personnel, regional leaders, district leaders, council chairpersons and institutional financial officers (see, for example, Msami and Young 2009, pp. 68–69).

3 Adoption of research outputs

Adoption

There are two elements to adoption. The first element is whether the vaccine production, distribution and administration procedures and the extension strategies are being used in laboratories and by extension workers. The second element is whether the people in rural villages are having their chickens vaccinated with the I-2 vaccine.

Vaccine production and distribution systems

The vaccine production processes developed during the ACIAR-funded projects have been refined over time. Nevertheless, the basic processes have been adopted in all four of the countries included in the subsequent AusAID-funded projects.

The I-2 master seed has also been provided to a further 12 African countries (J. Meers, pers. comm., 14 June 2013):

- Angola
- Democratic Republic of Congo
- Ethiopia
- Egypt
- Ghana
- Kenya
- Madagascar
- Nigeria
- South Africa
- Sudan
- Uganda
- Zimbabwe.

Similarly, the distribution and extension strategies have been refined and adapted to different situations, but the key elements of the strategies and materials developed through the ACIAR-funded projects continue to be used.

In Mozambique, the distribution and extension strategies are also being used to distribute a commercial vaccine, ITA-NEW. Currently, the I-2 vaccine is being used in five of 11 provinces and ITA-NEW is being used in the remaining six provinces.

The various manuals and extension materials have also been used beyond the countries included in the AusAID-funded projects, including by organisations such as the Food and Agriculture Organization of the United Nations (FAO), the European Union and GALVmed (an NGO based in the United Kingdom). Manuals have been translated into French and Swahili (R. Alders, pers. comm., 27 July 2013).

Vaccination of village chickens

The pathway to adoption is broadly the same in Mozambique and Tanzania. The vaccine is distributed from the production laboratory to provincial-level veterinary officers, then to district- or local-level technicians, and then to extension officers and community vaccinators. The community vaccinator moves from household to household administering the vaccine. The pathway is similar in the other countries covered by the AusAID projects.

A number of other distribution channels have begun to emerge, including through veterinary medicine suppliers.

In some cases, these activities occurred as part of organised campaigns under the auspices of the AusAID projects. However, there has also been significant adoption outside those campaigns.

Annual surveys of households in AusAID project areas have monitored the level of adoption among households in selected villages. Adoption rates have varied across project areas, although the proportion of households participating in vaccination campaigns increased significantly in most regions (Table 3). Adoption was highest in the Singida region of Tanzania, where adoption rates were close to 100%. By contrast, in Chigubo village in Mozambique, the adoption rate initially increased but then declined as the project progressed.

In some cases, the organised campaigns also stimulated additional adoption in neighbouring villages. For example, adoption outside the targeted villages in the Singida region of Tanzania significantly outweighed adoption in the targeted villages.

In addition to adoption in project areas during the AusAID-funded projects, there is evidence of village chickens being vaccinated in other areas. Data on vaccine production and distribution are indicators of the level of adoption in the four project countries (Figure 2).

The quantity of I-2 vaccine produced has varied significantly among the four countries. Tanzania and to a lesser extent Mozambique have produced significant quantities:

- In Tanzania, vaccine production peaked at more than 37 million doses in 2010 but subsequently declined significantly. This was partly due to a government decision to raise the price of the vaccine. The shifting of vaccine production from the former Vaccine Production Unit at the Central Vaccine Laboratory to the current location at the Tanzania Vaccine Institute also disrupted vaccine production during 2012 (H. Msami, pers. comm., 6 August 2013).
- In Mozambique, vaccine production and distribution have averaged around 4 million doses per year since 2007.
- In Malawi, data on vaccine production and distribution have been readily available only since 2010. However, Malawi has been producing I-2 vaccine since 2004 and in recent years has been distributing almost 1.5 million doses per year. We have assumed that 1 million doses per year were distributed in Malawi between 2005 and 2009.

Table 3. Adoption rates (%) in AusAID project areas

Region	Baseline	Follow-up 1	Follow-up 2	Follow-up 3
SANDCP				
Cahora Bassa (Mozambique)	15.7	69.4	73.0	n.a.
Mtwara (Tanzania)	55.0		88.0	n.a.
Dodoma (Tanzania)	11.0		89.0	n.a.
Phase II				
Chigubo (Mozambique)	1.6	31.0	67.9	48.8
Massingir (Mozambique)	0.8	60.0	70.0	n.a.
Singida (Tanzania)	42.5	99.0	99.0	99.3
Malawi	52.5	68.0	76.0	86.2
Zambia	7.9	90.4	n.a.	n.a.

Sources: B. Bagnol, pers. comm., 7 June 2013; B. Muchanga, pers. comm., 6 June 2013.

- Zambia has only recently started producing the I-2 vaccine and is therefore not shown in Figure 2. Production increased to around 74,000 doses for the July 2013 vaccination campaign.

Not every dose of I-2 vaccine produced is ultimately used to vaccinate a chicken. Vaccine can be wasted for a range of reasons, including districts ordering too many vials of vaccine and community vaccinators not using all doses in each vial. Several reports have suggested that wastage rates can vary significantly, at least partly depending on how well vaccine campaigns are organised. Wastage was very low in Singida province in Tanzania, where over 90% of the doses distributed to the province were used to vaccinate chickens. However, wastage could be as high as 30–40% where campaigns were less well organised (H. Msami, pers. comm., 10 June 2013).

By contrast, the independent completion report for the SANDCP states that only 55% of the 3.3 million doses of I-2 vaccine distributed in Mozambique between March 2003 and July 2005 were used. Nevertheless, usage rates increased from around 30% to around 70% over that period as community vaccinators became better organised (AusVet Animal Health Services 2006, p. 15). Wastage rates also tended to be higher for freeze-dried vaccine, as was used in Mozambique at that time, than for the wet vaccine that is currently used (R. Alders, pers. comm., 23 July 2013). More recently, a cost-recovery study in Mozambique assumed wastage rates of around 13% (Tomo et al. 2011).

In Zambia, around one-third of the vaccine distributed to project areas in the March 2013 campaign was wasted. However, in line with experiences elsewhere, this can be expected to improve with experience.

In estimating the number of chickens vaccinated, we generally assumed wastage rates of around 20%, except where there was specific information that wastage rates had been higher (such as in Mozambique during the 2003–2005 period). Since vaccination must occur three times per year in order to achieve around 80% protection at the flock level, it was also necessary to divide the quantity of vaccine produced by three when estimating the number of chickens vaccinated in any given year.

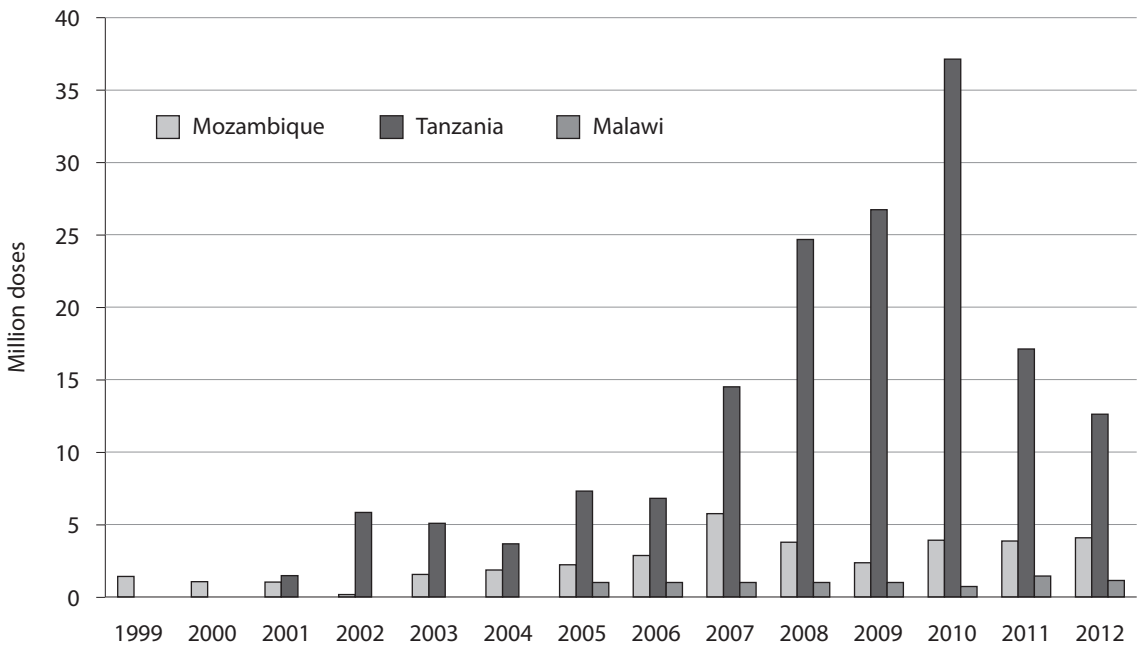

Figure 2. Vaccine production and distribution. Note: Zambia has only recently started to produce the I-2 vaccine and is therefore not shown on the chart. Data sources: H. Msami, pers. comm., 6 June 2013; J.C. Montero, pers. comm., 6 June 2013; R. Mgomezulu, pers. comm., 6 June 2013.

Factors supporting adoption

Perhaps the main factor that has supported demand for I-2 vaccine has been the severity of Newcastle disease as a constraint on village poultry production and the effectiveness of the vaccine in mitigating that problem. This has supported strong demand for the vaccine within villages once the benefits of vaccination have been understood.

However, the effectiveness of new technologies does not in itself guarantee their adoption. The comprehensive vaccine production, distribution and extension strategy developed under the ACIAR-funded project AS1/1996/096 extension has also been a key factor supporting adoption. While the main elements of the strategy (outlined in the Chapter 2) remain in place, they have been refined over time and adapted to the individual circumstances in each project area. This has included translation into relevant languages and other area-specific refinements. Researchers emphasised that attention to small details can make a significant difference to adoption rates (M. Young, pers. comm., 10 June 2013).

The production and distribution strategy developed through the ACIAR-funded projects requires government to play a significant role. Consequently, the whole strategy is not possible without strong political will.

Key lessons learned through experience include the following:

- Involve village leaders
  - in the selection and training of community vaccinators
  - in the promotion of vaccination campaigns
  - in ensuring that most households take part in the vaccination exercise (H. Msami, pers. comm., 6 August 2013).
- By allowing a margin in the vaccine price, provide an incentive for community vaccinators to spread awareness of vaccination campaigns, promote involvement and administer the vaccine.

Understanding the importance of community vaccinators was critical, as was their role in the whole system.

Nevertheless, adoption rates have varied significantly across project areas, even though similar distribution and extension strategies were used in all regions. In addition to improvements in the distribution strategy over time, a number of village characteristics can also help to support adoption. For example, one factor that supported high adoption rates in Singida was that there is a greater focus on poultry production in that region. This may be at least partly because village poultry producers in Singida have access to larger markets in Dar es Salaam.

Barriers to adoption

Some barriers to adoption have also emerged. It has taken some time to get the vaccine production system functioning effectively in all of the AusAID project countries. A recent audit has highlighted a number of problems in the system, many of which relate to maintaining the cold chain. This is partly due to the time required to develop the required capacity. In some countries, vaccine production has struggled to keep up with demand.

One factor that has constrained greater adoption in Mozambique has been a lack of resources for the laboratory producing the vaccine and for the distribution of the vaccine to communities. During the original ACIAR project and the SANDCP, the laboratory was able to retain 50% of the sale price of the vaccine, and those funds were used to support ongoing production. However, following recent restructuring in the Ministry of Agriculture, this arrangement was replaced with a less efficient system (R. Alders, pers. comm., 23 July 2013). In recent years, the laboratory has relied on support from the AusAID project to fund new equipment, equipment repairs and the purchase of key inputs, such as droppers and laboratory reagents (R. Costa, pers. comm., 23 July 2013). This raises the question of sustainability now that the AusAID project has been completed. Similarly, provincial veterinary officers reported that they had insufficient resources to introduce the vaccine into additional villages.

The lack of resources for vaccine production and distribution is partly a symptom of the lack of an effective cost-recovery system. An effective system that allows each link in the vaccine production and distribution chain to recover its costs should ensure that each agency has sufficient resources to perform its function.

Another important constraint on adoption in Mozambique in recent years has been the price that community vaccinators can charge households. The price was initially too low to give vaccinators an incentive to put in the required effort to vaccinate birds, and could be increased only with the approval of district officials. Gaining that approval took some time, which meant that the price initially set in 1998 continued to apply until 2012, when it was finally increased (R. Alders, pers. comm., 27 July 2013). This shows that cost-recovery mechanisms must be reviewed frequently.

Delays in getting the vaccine registered have also constrained greater adoption of the I-2 vaccine. Currently, it has been registered in Malawi and has received provisional registration in Tanzania, but not in the other project countries. In Mozambique, for example, the government is supporting vaccination using the I-2 vaccine in five of 11 provinces. Commercially produced ITA-NEW vaccine is used in the remaining six provinces. The government ultimately intends to use the I-2 vaccine in all provinces, but will not extend the use of the I-2 vaccine into the remaining six provinces until the vaccine has been registered and some production problems have been resolved. The vaccine is expected to be registered in Mozambique in the near future (R. Alders, pers. comm., 23 July 2013).

A number of barriers to adoption have also emerged at the village level. Some researchers reported that a lack of awareness within villages is a key barrier to adoption (H. Msami, pers. comm., 10 June 2013).

Having to pay for the vaccine also discouraged some households from using the I-2 vaccine in some areas (H. Msami, pers. comm., 10 June 2013). Some had previously received free government assistance and were therefore reluctant to pay for the vaccine. However, in many other cases, households have been happy to pay for the vaccine once they understood the benefits.

The cost-recovery mechanism (including a fee for vaccinators) is a key strategy to ensure that vaccine production and distribution are sustainable.

The reluctance of some households to pay for the I-2 vaccine is likely to reflect a lack of confidence in the treatment. In some cases, this was reinforced when vaccinated chickens subsequently died. The deaths may have occurred because chickens were already infected with Newcastle disease before vaccination or because they contracted other diseases (a common misunderstanding among households is that the vaccine protects chickens from all diseases, not just Newcastle disease). It is also possible that the vaccine was ineffective due to problems maintaining the cold chain. Once households that had used the vaccine found that it was ineffective, it was reportedly difficult to get them to participate again.

There were also external barriers to adoption, such as village characteristics and climatic conditions. One reason why adoption rates were relatively low in Chigubo in Mozambique was that households were a long way apart (B. Bagnol, pers. comm., 7 June 2013). This made it difficult for community vaccinators to administer the vaccine efficiently. Community vaccinators were provided with bicycles to help overcome this problem, but that was ineffective because of the region's sandy soil. Chigubo also suffered a drought during Phase II of the AusAID-funded project. During droughts, households are under economic stress and therefore destock to support their incomes. This helps to explain the decline in adoption in Chigubo following a reasonable level of initial uptake.

Prospects for future adoption

To estimate the benefits and costs of Newcastle disease control in Africa, it is also necessary to assess future adoption prospects, which is always difficult. Governments in participating countries have incorporated Newcastle disease control in their plans and generally have ambitious targets to produce and distribute enough vaccine to vaccinate most, if not all, village chickens.

In Tanzania, the government's target is to ultimately produce around 100 million doses of vaccine. The target is based on three doses per year for each of the country's estimated 32 million village chickens. However, it may be overambitious: an overall adoption

rate of around 60–70% is considered achievable over the next 10–20 years (H. Msami, pers. comm., 10 June 2013). Despite the decline in the production and distribution of the vaccine in Tanzania in recent years, 60–70% seems a realistic target, given the success of the Newcastle disease control program in Tanzania to date and the assistance provided by the Government of Tanzania to enhance vaccine production facilities. The recent decline in vaccine production was due largely to an increase in the price of the vaccine in 2010 to a level above that which would recover the full cost of production, and the disruption of vaccine production during 2011 and 2012 as a result of the relocation of the production facility. The government subsequently reduced the price to a level reflecting full cost-recovery, and production is expected to return to previous levels as Newcastle disease re-emerges in areas where it was previously under control.

In Mozambique, the government intends to expand its vaccination programs so that ultimately 80% of village chickens are vaccinated. It also plans to expand the use of I-2 vaccination into the six provinces that are currently using ITA-NEW vaccine. However, the barriers to adoption identified in this report will need to be surmounted and the government will need to register the I-2 vaccine to achieve that level of adoption. Other production problems are expected to be resolved in the near future. The laboratory has recently received a new freeze-dryer, which will allow it to produce both freeze-dried vaccine (which has a longer shelf life) and wet vaccine. The acquisition of virulence test has also been performed satisfactorily (R. Alders, pers. comm., 23 July 2013).

The lack of an effective cost-recovery mechanism also raises concerns about the sustainability of the current system. Sustainability concerns were noted in SANDCP project reviews in 2005. Although the elements of a cost-recovery system that were in place then have since been replaced, the sustainability of the system remains a concern.

Through FAO, Mozambique has recently received European Union support to accelerate progress towards achieving the Millennium Development Goals. This will include support to expand the capacity of the laboratory to produce I-2 vaccine and improve vaccination services (R. Costa, pers. comm., 23 July 2013). This will ensure that the system is sustained in the near to medium term. However, long-term sustainability will not be assured without the adoption of a full cost-recovery model in which each link in the supply chain fully recovers its costs through sales revenue. Given the large number of competing needs, long-term reliance on government or international development funding might not be wise.

Nevertheless, despite these resourcing issues, most stakeholders felt that it was unlikely that the vaccination program would collapse. A more likely result would be only modest increases in the number of chickens vaccinated using the I-2 vaccine. We assume that, over the next 20 years, vaccination coverage using the I-2 vaccine will increase to around 20% of the 25 million village chickens. In our view, this is a relatively conservative estimate, and it is well below government targets.

In Malawi, vaccine production and distribution have been fairly stable over recent years. As for Mozambique, we assume that over the next 20 years the proportion of village chickens vaccinated using the I-2 vaccine will increase to around 20% of the total. Kampeni (2001, p. 15) reported there were around 12 million village chickens in Malawi (although that estimate might now be out of date).

Because Zambia became involved only in Phase II of the AusAID-funded projects, its I-2 vaccine production and distribution systems are less advanced than those of other project countries. Production is still relatively small scale, and only around 17,500 doses were produced for the July 2013 vaccination campaign. Given the early stage of work in Zambia, it is more difficult to assess whether the program will be sustainable or what level of adoption is likely in the future. However, vaccine production facilities in Zambia are larger than in Malawi and veterinary services are better resourced. As for Mozambique and Malawi, we assume that, over the next 20 years, the proportion of village chickens vaccinated using the I-2 vaccine will reach 20% of the total. Songolo and Katongo (2001, p. 43) reported there were around 11 million village chickens in Zambia.

The adoption profiles used to estimate benefits and costs are shown in Figure 3.

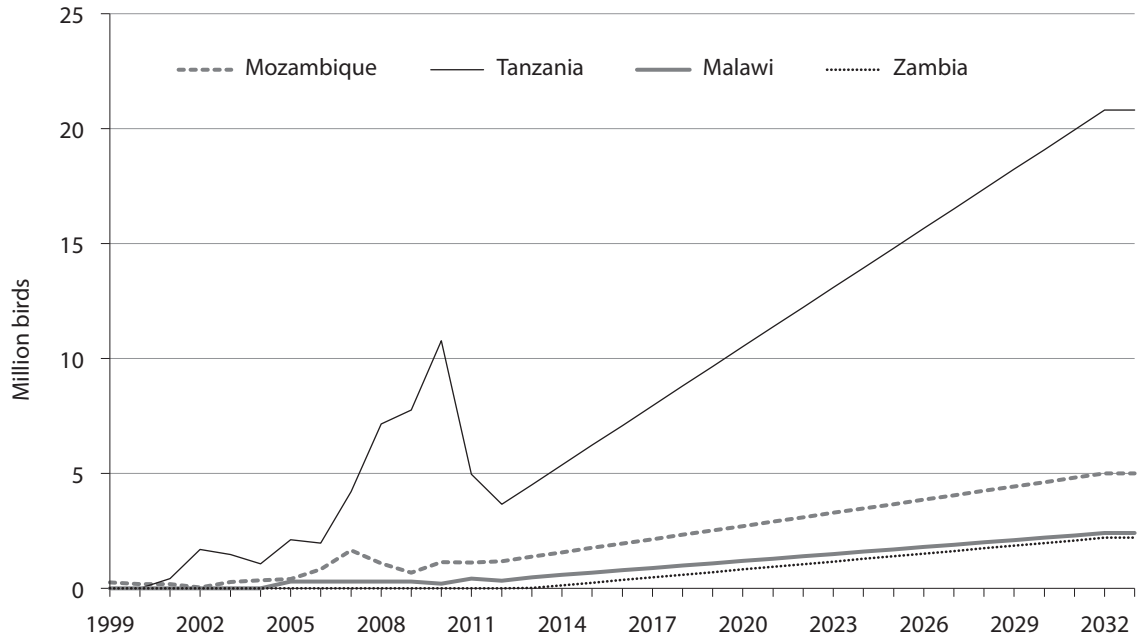

Figure 3. Estimated adoption profile. Data sources: Data provided by participating countries, CIE estimates.

4 Outcomes

Outcomes are changes in practices, products or policies as a result of the adoption of outputs delivered by ACIAR-funded projects. For these projects, they included the establishment of vaccine production and distribution systems and a number of changes at the village level.

Establishment of vaccine production and distribution systems

The I-2 vaccine is being produced in all four African countries included in the AusAID-funded projects. This has been a direct result of the outputs delivered by ACIAR-funded research, including:

- the knowledge embodied in the laboratory manual
- the institutional and individual capacity developed in the projects.

All four countries have also implemented the distribution and extension strategies developed during the projects. There is evidence that the ACIAR field, training and extension manuals continue to be used.

In impact assessment it is important to assess outcomes (and subsequently impacts) against what would have happened in the absence any intervention (in this case, the ACIAR-funded research and the subsequent AusAID-funded projects). While it is clear that the I-2 vaccine would not have been produced in the four partner countries in the absence of the ACIAR-funded research, developing a plausible counterfactual scenario is not straightforward. One alternative is for the partner governments to import a commercial vaccine for distribution to villages. This is currently happening in Mozambique, where the ITA-NEW vaccine is being distributed to villages in six of the 11 provinces.

This question has important implications for estimates of village-level impacts. If the chickens vaccinated with I-2 vaccine would not have been vaccinated at all without the ACIAR- and AusAID-funded activities, the full benefits of vaccination can be attributed to those activities.

Alternatively, if the I-2 vaccine is displacing an alternative vaccine, the impact of the ACIAR- and AusAID-funded activities is the incremental benefit of using the I-2 vaccine compared with alternative vaccines.

In assessments of various vaccines for village chickens, I-2 has generally been preferred. Its key advantage over many commercial vaccines is its thermotolerance. Vaccines without this characteristic are unlikely to be effective under village conditions.

The live I-2 vaccine has also been assessed to have several advantages over inactivated vaccines, such as ITA-NEW vaccine, in the village context. Those advantages include the following:

- I-2 vaccine has a lower cost per dose.
- I-2 is administered using eyedrops rather than injections. Eyedrop administration:
  - costs less
  - requires less skill (in some countries, injections can be given to animals only by people with veterinary training)
  - reduces the risk of injury to farmers and vaccinators
  - uses the same dose for all birds, whereas injectable vaccines are generally not administered to chicks because of the risk of traumatising the bird.

- The protection provided by live vaccines can spread to nearby unvaccinated birds, while inactivated vaccines provide protection only to vaccinated birds.

One disadvantage of live vaccines (such as I-2) is that they are required every 4 months, while inactivated vaccines (such as ITA-NEW) are required only every 6 months, reducing the burden on provincial extension officers and community vaccinators. While vaccinating every 6 months reduces costs, it also provides inferior protection, regardless of the quality of the vaccine. This is because unvaccinated hatchlings are unprotected from Newcastle disease outbreaks (P. Spradbrow, pers. comm., 5 August 2013). Given that chicks hatch throughout the year, unprotected birds could dominate the flock when vaccination occurs only every 6 months.

The benefit of the vaccine distribution and extension strategies developed through the ACIAR-funded research is the incremental increase in the uptake of vaccination using those strategies, compared with what would have been achieved using an alternative strategy.

The key question is whether the chickens that have been vaccinated using I-2 vaccine would have been vaccinated in the absence of the activities funded by ACIAR and AusAID. In most cases, that seems unlikely. While there are reports of La Sota vaccine being distributed by commercial veterinary suppliers in Malawi, researchers where highly sceptical of its effectiveness in the village environment, given that it is not thermotolerant. Therefore, it seems clear that some form of intervention was necessary for village chickens to be vaccinated.

It is possible that governments may have used alternative vaccines and alternative approaches to vaccine distribution. However, without the activities funded by ACIAR and AusAID, those activities would need to have been completed or funded by the relevant government or another donor.

The one exception is in the six provinces in Mozambique where the ITA-NEW vaccine is currently used. While the government intends to eventually replace ITA-NEW with I-2 once I-2 has been registered, the benefits of doing so would really be only the incremental benefits of I-2 vaccine over ITA-NEW, which would be difficult to estimate quantitatively. This has been taken into account in our quantitative estimates, where we assume only a modest increase in the number of chickens vaccinated using the I-2 vaccine in Mozambique.

Village-level outcomes

As a direct result of ACIAR-funded research and subsequent AusAID-funded projects, poor rural households are having their chickens vaccinated.

Where households have had their birds vaccinated, a number of studies have reported lower mortality rates and an increase in the size of flocks. Lower mortality also allows higher off-take of meat and eggs. The studies have reported survey evidence of this in project areas as well as field trials.

Data from participatory rural appraisal surveys in various AusAID project areas generally show that flock sizes and off-take rates increase as the percentage of households vaccinating chickens increases over time (Table 4). These relationships are statistically significant at the 5% level of significance.[1]

Other papers have reported differences between vaccinating and non-vaccinating households. Msami and Young (2009, p. 72) reported that in the two SANDCP pilot areas in Tanzania (Dodoma region in the central zone and Mtwara in the south) chicken mortality was reduced and bird numbers in participating households had risen (Table 5).

[1] This is based on regressions using a fixed effects model that controls for locational differences.

Table 4. Changes in flock size and chicken off-take in AusAID project areas over time

Country	Province	Baseline	Follow-up 1	Follow-up 2	Follow-up 3
Flock size (no.)					
Mozambique	Chigubo	12.4	14.3	12.2	10.1
Mozambique	Massingir	10.4	18.7	17.5	n.a.
Tanzania	Singida	16.6	16.5	21.2	20.9
Malawi	Thyolo	8.7	10.4	11.0	9.9
Mozambique	Cahora Bassa	6.0	13.0	15.0	n.a.
Chicken off-take (no.)					
Mozambique	Chigubo	16.0	20.0	17.3	13.7
Mozambique	Massingir	17.3	27.1	26.7	n.a.
Tanzania	Singida	25.4	25.3	31.2	33.9
Malawi	Thyolo	11.9	11.8	15.9	15.4
Mozambique	Cahora Bassa	1.0	2.0	3.0	n.a.
Percentage of households vaccinating (%)					
Mozambique	Chigubo	1.6	31.0	67.9	48.8
Mozambique	Massingir	0.8	60.0	70.0	n.a.
Tanzania	Singida	42.5	99.0	99.0	99.3
Malawi	Thyolo	52.5	68.0	76.0	86.2
Mozambique	Cahora Bassa	15.7	69.4	73.0	n.a.

Source: B. Bagnol, pers. comm., 7 June 2013.

Table 5. Impact of vaccination on flock size, mortality and off-take in Tanzania

	Mtwara (vaccinated)	Mtwara (non-vaccinated)	Dodoma (vaccinated)	Dodoma (non-vaccinated)
	No.	No.	No.	No.
Mean flock size	15.0	3.0	17.1	10.3
Mean chicken mortality	0.3	10.3	5.9	9.9
Mean off-take	2.9	2.2	6.7	4.3

Note: Based on a survey of around 200 households.

Source: Msami and Young (2009, p. 72).

5 Research impacts

This chapter identifies the impacts of the Newcastle disease control projects and establishes a framework for measuring them.

Economic impacts

Literature review

A number of studies, including previous work by ACIAR, have estimated the impact of Newcastle disease control at both the household and the national (or regional) levels.

Studies estimating the impact on households

Some studies have used bioeconomic models to estimate impacts on households. With varying degrees of sophistication, bioeconomic models describe the basic biological processes of a typical village chicken flock in Africa, such as eggs laid per hen, hatching rates and bird mortality due to disease and predation, combined with economic choices made by households, such as decisions to harvest meat and eggs for sale or consumption.

The impact of various interventions on the household can then be estimated by varying relevant parameters and comparing against the base case. In the case of vaccination against Newcastle disease, mortality rates are reduced.

The bioeconomic model studies vary in the methods and models used to estimate the impact of Newcastle disease control on mortality rates (that is, the shock applied to the model) and, consequently, the estimated impact on households.

Woolcock et al. (2004) developed a simple static model of village poultry production to show that even a modest decrease in bird mortality could have a significant benefit to household income. The model is intended as a generalised representation of village chicken production in Africa, in which the basic parameters are based on a survey of the literature.

Village chicken production is assumed to be constrained by a fixed scavenging feed resource base (SFRB), so the model limits the flock size to the feed resource available, either by removing surplus eggs for sale or by reducing hen numbers. Due to a lack of data, the SFRB is not estimated directly but is defined based on the number of adult bird equivalents: birds are assigned a bird unit based on their average weight (a cock is assigned a bird unit of 1, a hen 0.8, a grower 0.4 and a chick 0.07). For illustrative purposes, the model assumes that the SFRB available is the number of adult bird equivalents before Newcastle disease control plus 17% unused capacity due to the disease (Woolcock et al. 2004, pp. 4–5). This is based on the following assumptions:

- Before Newcastle disease control, the SFRB is fully utilised, except during periods when the flock is wiped out by Newcastle disease, when the SFRB is underutilised until a new flock is built.
- The flock is wiped out once every 18 months.
- It takes 6 months to build a new flock.
- The SFRB is, on average, 50% utilised during rebuilding.

Asgedom (2007) developed a dynamic stochastic village poultry simulation model (VIPOSIM) to explore management options for village poultry systems. It is significantly more complex than the simple model developed by Woolcock et al. VIPOSIM takes into

account seasonal variation in mortality rates from disease and predation, and consumption and sales patterns. It includes the dynamic aspects of village chicken production, such as flock rebuilding after a Newcastle disease outbreak, that the simple static model ignores. VIPOSIM estimates the direct benefits of chicken and egg consumption and sales, as well as indirect benefits from chickens as a source of manure and as a stock of wealth (VIPOSIM assumes a benefit equivalent of 15% of the market value of the bird).

The model was validated using field data collected in Tigray in Ethiopia, although some input values were based on the literature. The model was subsequently used to estimate the potential impacts of vaccination against Newcastle disease.

Tomo (2009) and Tomo et al. (2012) adapted VIPOSIM to estimate the economic impact of vaccination using the I-2 vaccine in Mozambique at the farm level, as well as at the district and national levels. Unlike Asgedom (2007), these studies focused on the direct benefits of meat and egg sales and consumption and ignore the indirect benefits from manure production and from using the birds as a store of wealth. They used field data obtained from Chibuto village in Mozambique to validate the model but retained some of the original input parameters.

Typically, the impact of vaccination on household income is estimated by reducing mortality rates from Newcastle disease based on estimates from the literature. In these bioeconomic models, lower mortality rates allow households to increase the off-take of birds and/or eggs for sale and consumption.

The reductions in mortality rates from Newcastle disease used in each of the above studies are as follows:

- Woolcock et al. (2004) assumed that vaccination against Newcastle disease would:
  - reduce the mortality rate of adult chickens from 20% to 15%
  - reduce the mortality rate of chicks from 62% to 45%
  - reduce the mortality rate of pullets and cockerels from 45% to 30%.
- Asgedom (2007) assumed that vaccination reduces Newcastle disease mortality rates by 50%.
- Tomo (2009) and Tomo et al. (2012) treated Newcastle disease mortality rates as a random variable in the stochastic model and estimated that the mortality rate from Newcastle disease was around 63% in the deterministic model. Vaccination was estimated to reduce mortality rates from Newcastle disease by around 80%, based on field observations in the literature.

Based on the models and assumptions outlined above, the impact on households from vaccination was estimated as follows:

- Woolcock et al. (2004) estimated that vaccination using the I-2 vaccine could increase household income from village chickens by more than US$20 per year, regardless of whether the benefits of lower mortality were realised through an increased off-take of meat or eggs. They also showed that some modest changes to current practices that are possible once Newcastle disease is under control could increase household incomes even further.
- Asgedom (2007) estimated that vaccination against Newcastle disease could increase net returns to farmers by around 1,000 birr over the 12-season (3-year) simulation period. This is equivalent to around A$20 per year.
- Tomo (2009) estimated that there was a 90% chance that the annual net benefits from vaccination at the farm level would be between 248 meticals and 543 meticals, with a most likely estimate of around 483 meticals per year (Table 6), which is around A$19 using 2012 exchange rates. This was similar to the estimate using a deterministic approach. Tomo also showed that the benefits of vaccination varied depending on flock size (Table 6).

An alternative approach used by Henning et al. (2013) estimated the economic impact of vaccinating village chickens in Burma using the I-2 vaccine, based on field trials. The study compared sales, consumption and hatchings for vaccinated flocks (using the I-2 vaccine) against an unvaccinated control group. The study found

that vaccination increased bird off-take (for sales and consumption combined) by around 11%. The estimated impact of Newcastle disease vaccination on off-take in the study was therefore significantly less than generally predicted by the bioeconomic models.

Table 6. Annual incremental benefits and costs of Newcastle disease control at the farm level

	Annual net benefits (meticals)	Annual costs of vaccination (meticals)
0–5 chickens	269	40
6–10 chickens	494	42
11–15 chickens	607	50
16–20 chickens	756	62
21–25 chickens	789	64
26 or more chickens	1179	93
Overall benefit	**481**	**47**

Source: Tomo (2009, p. 60).

Nevertheless, the benefit:cost ratio for vaccinating households was estimated at 28.8:1 (over 10 years using a discount rate of 10%). This high benefit:cost ratio was partly a result of the low price of the vaccine in Burma due to government subsidies. When the full cost of vaccination production and distribution is borne by the farmer, the benefit:cost ratio is estimated at 3.8:1. However, the stochastic model suggested that Newcastle disease vaccination was not profitable for farmers in around 25% of cases.

This study suggests that the bioeconomic models approach may be overstating the benefits of vaccinating against Newcastle disease for the following reasons:

- The models effectively assume that households receive no benefits from birds that become infected with Newcastle disease. In practice, households may slaughter and eat birds showing signs of the disease, thereby receiving a benefit from those birds, although this practice could potentially expose them to highly pathogenic avian influenza (HPAI), which is clinically indistinguishable from Newcastle disease (R. Alders, pers. comm., 23 July 2013). Some households also adapt to expectations of losses from Newcastle disease during the periods when the disease is most prevalent by destocking in advance. Anecdotal evidence suggests that prices fall significantly during these periods because the market is flooded. This means that those households receive some benefit from the birds, albeit a smaller one than they would gain in the absence of Newcastle disease.
- Anecdotal evidence also suggests that fowlpox emerged in some areas in both Tanzania and Mozambique as more of a problem that it had previously been once Newcastle disease was controlled. This issue has not been taken into account in the studies using bioeconomic models.

On the other hand, the Burma study may understate the benefits of Newcastle disease control in Africa for the following reasons:

- The benefits of vaccination depend on Newcastle disease mortality rates in the absence of the vaccine. The severity of Newcastle disease outbreaks can vary from year to year and between areas. The severity of any outbreak in unvaccinated flocks during the field trials in Burma might not be representative of a typical year in African conditions.
- The Burma study controlled for flock size, which does not allow for households to increase the numbers of their birds. The survey results suggest that most households increase production by increasing flock size when Newcastle disease is controlled.

Key differences among the studies are summarised in Table 7.

Table 7. Literature summary—household-level impacts

Study	Methods/models	Shock	Estimated impact on households
Woolcock et al. (2004)	• Simple static village chicken production model • Considers both chicken and egg consumption in different models • Allows for some increase in flock size on the basis that the SFRB is underutilised due to Newcastle disease deaths • Overall, village chicken production is constrained by feed resources	Newcastle disease control estimated to reduce mortality: • from 20% to 15% in adult birds • from 62% to 45% in chicks • from 45% to 30% in cockerels and pullets	• Off-take increases by more than 90% • Net annual household income from village chicken production increases by around US$20, or 45%
Asgedom (2007)	• Dynamic stochastic village chicken production model validated using field data from Ethiopia • Considers both chicken and egg consumption • No price impact • Flock size varies over time, but is constrained by model inputs • Includes indirect benefits from manure production and wealth storage	• Vaccination estimated to reduce mortality from Newcastle disease by 50%	• Increases household income by around 1,000 birr or US$20 per year.
Tomo (2009) and Tomo et al. (2012)	• Dynamic stochastic poultry production model validated using data from Chigubo village in Mozambique • Considers both chicken and egg consumption • No price impact • Explicitly deals with different flock sizes	• Vaccination estimated to reduce mortality from Newcastle disease by 80% based on published estimates	• An average increase in household income of around 481 meticals (about US$19) per year
Henning et al. (2013)	• Considers both chicken and egg consumption • Estimates based on field trials • No price impact	• Off-take increases by 11%	• Net benefit to household estimated at 30,791 kyat (around US$31)

Sources: Woolcock et al. (2004), Asgedom (2007), Tomo (2009), Tomo et al.(2012), Henning et al. (2013).

Regional-level impacts

A number of studies, including previous ACIAR studies, have estimated the regional or national impacts of vaccinating against Newcastle disease (Table 8).

Johnston and Cumming (1991) found that the HRV4 vaccine could be expected to increase the off-take of chickens from a given flock by between 38% and 47%. Those estimates were based on field trials in the Philippines, where the effects of vaccination with HRV4 were compared using control groups of chickens that had never been vaccinated (CIE 1998, pp. 20–21).

The ACIAR impact assessment of the three earliest Newcastle disease control projects (projects AS1/1983/034, AS1/1987/017 and AS1/1993/222) used a partial equilibrium economic surplus framework

to estimate the benefits of Newcastle disease control (CIE 1998). The analysis assumed:

- a perfectly inelastic supply curve, on the basis that the low-input production system used for village chickens limits flock numbers (however, some supplementary feeding required as a result of Newcastle disease control was included in the analysis)
- an elasticity of demand of 1.5
- an increase in production of 40%, based on the findings of Johnston and Cumming (1991).

Tomo (2009) also scaled up the household-level analysis to estimate the net benefits of regional and national vaccination campaigns. Unlike the ACIAR studies, Tomo assumed no impact on the price of village chickens. The regional net benefit of the vaccination campaign in Chibuto was estimated at around 34.6 million meticals, or US$1.4 million.

Table 8. Literature summary—regional impacts

Study	Approach to estimation	Shock	Estimated benefits
Johnston and Cumming (1991)	• Focuses on meat rather than egg consumption • Partial equilibrium economic surplus framework • Considers price impact through a downward sloping demand curve (elasticity of demand assumed to be −1.5) • Perfectly inelastic supply curve, based on feed constraint (upward sloping supply as maximum is approached) • Does not allow for increase in flock size	• Newcastle disease control estimated to increase off-take by 38–47% for a given flock size, based on field trials in the Philippines	• Benefit:cost ratio estimated at 44.7:1 • Internal rate of return estimated at 50.7%
ACIAR (1998)	• Focuses on meat rather than egg consumption. • Partial equilibrium economic surplus framework • Considers price impact through a downward sloping demand curve (elasticity of demand assumed to be −1.5) • Perfectly inelastic supply curve • Does not allow for increase in flock size • Includes additional feed costs	• Newcastle disease control assumed to increase production by 40%, based on the findings of Johnston and Cumming (1991) • Adoption rate in Africa estimated at 10% of all village chickens	• Benefits to Africa estimated at $130.6 million
Tomo (2009)	• Aggregates household-level impacts estimated using dynamic stochastic simulation model • Considers both meat and egg consumption • Assumes no price impact	• Vaccination estimated to reduce mortality from Newcastle disease by 80% based on published estimates • Adoption rate estimated at 50%	• Net benefits of vaccination campaign in Chibuto estimated at US$1.4 million • Internal rate of return on investment in extension and distribution at the district level estimated at around 37%

Sources: Johnston and Cumming (1991), CIE (1998), Tomo (2009).

Approach to estimation

In estimating the benefits of Newcastle disease vaccination, we focused on the market for village chickens used for meat. This is consistent with previous ACIAR work. The consumption of eggs varies significantly among communities. While some communities do not consume eggs at all, others consume significant numbers. Woolcock et al. (2004) showed that benefits to households from Newcastle disease control were broadly similar regardless of whether they were realised through greater chicken or egg consumption.

An interpretation of the impact of Newcastle disease vaccination on a local market for village chickens in Africa is shown in Figure 4.

We assumed the supply curve for village chickens to be perfectly inelastic because the marginal cost of production is negligible, but production is constrained by both Newcastle disease and the SFRB. Village chicken production is also likely to be insensitive to price; when market prices are very low, households may consume their chickens rather than sell them. This assumption was consistent with previous ACIAR studies, although Johnston and Cumming (1991) assumed that the supply curve is upward sloping as it approaches this maximum production level.

We also assumed a downward sloping demand curve. This assumption was also consistent with previous ACIAR studies, but was in contrast to the household-level studies on the impact of vaccination against Newcastle disease. The household-level studies generally assumed no impact on price. Because the actions of a single household will have a negligible impact on price (that is, the household is a price taker), that is a reasonable assumption for household-level studies. However, when looking at regional or national impacts, widespread adoption of the I-2 vaccine could potentially increase the supply of village chickens significantly, which would undoubtedly mean that prices are lower than they would otherwise be.

As discussed above, vaccination against Newcastle disease allows households to increase their off-take of meat and eggs. This is represented as a rightward shift in the supply curve (S_0 to S_1). However, this additional production does not occur at zero marginal cost, because the household must pay for the vaccine. The cost of vaccination may be partly subsidised by the government or possibly by NGOs.

The increase in production is likely to reduce the sale price of village chickens (P_0 to P_1). This provides a benefit to consumers. The benefit to consumers (consumer surplus) is represented by areas A and B in Figure 4.

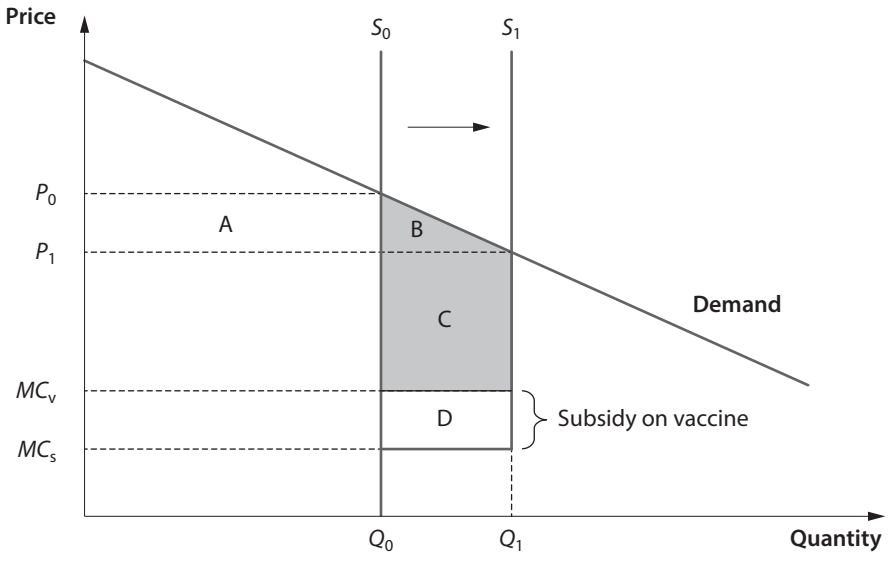

Figure 4. Market for chickens. Data source: CIE.

Producers gain from the additional production (areas C and D), but this is at least partly offset by the lower price received for the chickens produced (area A). Where the vaccine is partly subsidised, there is also a cost to the government or the NGO (area D).

The overall benefit to the community from vaccination is therefore represented by the shaded areas B and C. While this framework distinguishes between the benefits to consumers and those to producers, in the context of village chicken production the same people are consumers and producers.

Estimating the impacts

The net benefits of Newcastle disease vaccination are represented as the shaded area in Figure 4. This is effectively the change in consumer and producer surplus less the subsidy on the vaccine.

The change in consumer surplus (areas A and B in Figure 4) in each period is given by:

$$\Delta CS = \Delta P \times Q_0 + \frac{1}{2} \times \Delta P \times \Delta Q \quad (1)$$

where ΔCS is the change in consumer surplus; ΔP is the change in price (in absolute terms); Q_0 is the quantity of chicken produced in the relevant market in the absence of vaccination; and ΔQ is the change in supply as a result of vaccination.

The change in producer surplus (C + D – A in Figure 4) is given by:

$$\Delta PS = (P_1 - MC_s) \times \Delta Q - \Delta P \times \Delta Q_0 \quad (2)$$

where ΔPS is the change in producer surplus; P_1 is the observed price per chicken (in 2013 terms); and MC_s is the marginal subsidised cost of the vaccine per additional chicken produced.

The cost of the subsidy on the vaccine (area D in Figure 4) is given by:

$$C_s = (MC_v - MC_s) \times \Delta Q \quad (3)$$

where MC_S is the marginal cost of vaccination per additional chicken produced with the subsidy.

The price and quantity variables relate specifically to the markets in which the vaccinated chickens are sold. Where village chickens are sold within the village and producers are not linked to larger markets, the increase in supply due to vaccination will affect the price of chickens only in that village. However, where village chicken producers sell into larger regional markets, better control of Newcastle disease in a particular village will have less impact on price because the increase in supply will be smaller, relative to the size of the market.

The size of the market that households using the vaccine sell into varies by village. In Mozambique, village-level markets tend to be mostly closed (R. Costa, pers. comm., 13 June 2013). However, chicken distribution mechanisms tend to be more advanced in Tanzania, and in many cases the households adopting the vaccine sell into larger regional markets. For example, village chicken producers in Singida region supply the market in Dar es Salaam (H. Msami, pers. comm., 10 June 2013).

In our quantitative analysis, we assumed that village-level markets are closed. This implies that increases in the number of chickens vaccinated are achieved through introducing the vaccine to new villages, rather than increasing adoption rates in villages that are already vaccinating. While this assumption may not reflect reality in some cases, particularly in Tanzania, it is unlikely to have much impact on the overall estimates. However, it may affect the distribution of benefits between consumers and producers.

Quantity variables

Given the above assumption, the increase in village chicken production in each period can be estimated as follows:

$$\Delta Q = V \times O \times X \quad (4)$$

where V is the number of chickens vaccinated (see Chapter 4); O is the ratio of annual chicken off-take to flock size in unvaccinated flocks (according to the FAO data, the off-take to flock size ratio is around 1.4:1 in the relevant countries[1]); and X is the percentage increase in off-take from vaccinated chicken flocks compared with unvaccinated flocks.

As discussed above, estimates of the increase in village chicken production in vaccinated flocks vary significantly between about 11% and more than 40%.

[1] While this is slightly higher in Tanzania, that is likely to reflect a higher proportion of commercial chickens in that country.

We assumed that the increase in village chicken production was around the middle of this range at about 25%. The studies tracing the impacts from reduced mortality from Newcastle disease through to off-take rates using bioeconomic models are likely to overstate the benefits because they do not take into account the strategies used in the presence of Newcastle disease or the emergence of other diseases, such as fowlpox. The Henning et al. (2013) study was undertaken in Burma, so it might not be representative of African conditions, and it does not take into account increases in flock size due to Newcastle disease control. That study may therefore understate the benefits of Newcastle disease vaccination.

To estimate the quantity of village chickens produced in the relevant markets without the vaccine (Q_0), we assumed that the proportion of chickens vaccinated in each individual village-level market (r) is around 70%, based on observed adoption rates in the villages monitored under the AusAID-funded projects. We estimated the quantity of village chickens produced in the relevant markets without vaccination as follows:

$$Q_0 = \frac{V}{r} \times O \tag{5}$$

Price and cost variables

The observable prices of village chickens (P_1) were obtained from in-country consultations in Mozambique and Tanzania. While the price may vary between villages (since in many cases there are no linkages between village-level markets) and over time, the prices used in the analysis are shown in Table 9. The prices for Malawi and Zambia were based on the average for Mozambique and Tanzania, converted to local currency.

Table 9. Prices of village chickens

Country	Price of village chickens
Mozambique (meticals)	100[a]
Tanzania (shillings)	10,000[b]
Malawi (kwachas)	1,234[c]
Zambia (kwachas)	25,249[c]

a C.L.J. Banze, pers. comm., 14 June 2013.
b H. Msami, pers. comm., 10 June 2013.
c Based on the average price in Mozambique and Malawi, converted to local currency using International Monetary Fund data.

The change in price (in absolute terms) was estimated as follows:

$$\Delta P = \left|P_0 - P_1\right| = \left|\frac{P_1}{(1+\%\Delta P)} - P_1\right| \tag{6}$$

where P_0 is the unobservable price without Newcastle disease control and $\%\Delta P$ is the percentage change in price in the relevant markets as a result of Newcastle disease control. This can be estimated as follows:

$$\%\Delta P = \frac{\%\Delta Q}{\varepsilon} = \frac{rX}{\varepsilon} \tag{7}$$

where ε is the elasticity of demand.

Johnston and Cumming (1991) postulated that an elasticity of demand of –1.5 is appropriate for the Philippines, indicating relatively elastic demand. The same elasticity was also used by in the previous ACIAR impact assessment (CIE 1998). On the other hand, Henning et al. (in press) suggest that demand for village poultry in Burma may be relatively inelastic. In the absence of any better information, we used an elasticity of demand of –1.

In the estimation framework outlined above, the vaccine cost variables (MC_v and MC_s) are based on the marginal cost of vaccination per additional chicken produced. The marginal cost of vaccination is given by:

$$MC_v = \frac{V \times d \times c_v}{\Delta Q} \tag{8a}$$

where d is the number of doses given per year (three doses of the I-2 vaccine are given per year) and c_v is the unsubsidised cost per dose.

Similarly, the subsidised marginal cost of vaccination is given by:

$$MC_s = \frac{V \times d \times c_s}{\Delta Q} \tag{8b}$$

where c_s is the subsidised cost per dose.

The estimated cost of vaccine production, distribution and administration is based on the cost-recovery studies completed under Phase II of the AusAID-funded projects (Table 10). In the absence of information on the cost of vaccine production, distribution and administration in Zambia, we assumed the average of the costs in the other three countries.

Table 10. Vaccine costs per dose

	Mozambique[a] (meticals)	Tanzania[b] (shillings)	Malawi[c] (kwachas)	Zambia[d] (kwachas)
Production	0.61	10		
Distribution	0.15	5		
Administration	0.77	35		
Total	**1.53**	**50**	**15**	**249**

a Tomo et al. (2011).

b H. Msami, pers. comm., 10 June 2013.

c R. Mgomezulu, pers. comm., 7 June 2013.

d Based on the average in the other three countries.

The price charged to chicken owners for the vaccine is as follows:

- In Mozambique, the price of the vaccine was 0.5 meticals per dose prior to 2012, but was raised to 1 metical per dose from 2012. This implies a subsidy of 1.03 meticals per dose before 2012 and a subsidy of 0.53 meticals in subsequent periods.
- The price of the vaccine in Tanzania was set at 45 shillings per dose until 2010, when it was raised to 55 shillings. It was subsequently reduced to 50 shillings per dose (H. Msami, pers. comm., 10 June 2013). This implies a subsidy of 5 shillings per dose until 2010, a profit for the government (a negative subsidy) of 5 shillings per dose in 2011 and 2012, and full cost-recovery (no subsidy) in subsequent periods.
- The price of the vaccine in Malawi was 10 kwachas per dose, but was raised to 15 kwachas per dose from 2012 (R. Mgomezulu, pers. comm., 6 June 2013). We assumed that the 15 kwacha price is based on full cost-recovery. This implies a subsidy of 5 kwachas per dose before 2012.
- We assumed that the price charged in Zambia reflects full cost-recovery, implying that there is no subsidy.

Impacts on food security and poverty alleviation

The 1996 World Food Summit developed a widely accepted definition of food security:

> Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

FAO identifies the following dimensions of food security (FAO 2006, p. 1):

- *Food availability*—the availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports
- *Food access*—access by individuals to adequate resources (entitlements) for acquiring appropriate food for a nutritious diet
- *Utilisation*—utilisation of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional wellbeing in which all physiological needs are met
- *Stability*—to be food secure, a population, household or individual must have access to adequate food at all times; they should not risk losing access to food as a consequence of sudden shocks (such as an economic or climatic crisis) or cyclical events (seasonal food insecurity).

Vaccination against Newcastle disease improves the food security of poor rural households in at least three of the four dimensions.

Newcastle disease vaccination increases the *availability* of food in rural communities. This is particularly the case where the additional chickens produced due to lower Newcastle disease mortality are consumed within the village.

Vaccinating against Newcastle disease also improves *access* to food in a number of ways. The framework developed for analysing the impact of vaccination (see Figure 4) shows that increasing the supply of village chickens reduces the price within the village. This improves affordability and therefore access to food for all households, including those that do not raise chickens.

Vaccination also potentially raises the incomes of households that raise chickens. However, the framework suggests that the impact on producers' welfare is ambiguous, as the additional income from the increase in the quantity produced is at least partly offset by lower prices, as well as the cost of the vaccine.

Non-vaccinating households may receive some benefit when vaccination coverage is high in the village because the number of Newcastle disease outbreaks is reduced. Otherwise, households that do not vaccinate will be worse off because they receive a lower price without any compensating increase in production (although, within villages, producers and consumers are often the same people). Nevertheless, where vaccination improves a household's income, it improves that household's capacity to buy food, as well as other necessary items such as medicine and school fees (B. Bagnol, pers. comm., 7 June 2013).

The occurrence of fewer Newcastle disease outbreaks also improves the stability of food supply. Households are able to maintain more stable chicken flocks, without significant reductions during the Newcastle disease season caused either by mortality from the disease or by pre-emptive off-take.

The evidence also suggests that lower mortality from Newcastle disease has allowed households to increase the size of their flocks. Chickens act as a store of wealth, which can be run down during periods of economic stress, such as droughts.

While vaccination against Newcastle disease contributes to improved food security, as well as alleviating poverty, the overall impact on most households is likely to be quite modest. For example, Tomo (2009, p. 61) estimated that vaccination increases household incomes by around 7%. While that is significant, it is not clear whether it is sufficient to have a large impact on various poverty indicators or other measures of human development, such as health outcomes.

We understand that ACIAR has committed funding to examine the impact of Newcastle disease on child nutrition. That study should provide greater insight into this issue.

Impacts on women

The Newcastle disease control projects have generally benefited women, who tend to own the village chickens in many communities. Vaccination against Newcastle disease therefore raises women's incomes. However, some evidence has also begun to emerge that in some cases where Newcastle disease is controlled through vaccination and the income from chickens increases, men sometimes take over control of the chickens (B. Bagnol, pers. comm., 7 June 2013).

Women have also been targeted to take on the community vaccinator role (B. Bagnol, pers. comm., 3 May 2013). A key finding from the SANDCP was that female community vaccinators are more likely to remain working in their home areas than their male counterparts (Alders 2009b, p. 66). The community vaccinator role has been found to raise the status of some women within the community and has also provided an additional source of income.

Other impacts

An additional benefit from controlling Newcastle disease is that it can lead to earlier detection of HPAI, which is potentially a risk to human health. HPAI is clinically indistinguishable from Newcastle disease.

Where Newcastle disease has been controlled through vaccination, HPAI is easier to detect.

As part of a new HPAI initiative, Newcastle disease vaccination is now being recommended by FAO in Africa. FAO is using the I-2 Newcastle disease vaccine in Ethiopia as a pilot for its new approach (R. Alders, pers. comm., 23 July 2013).

6 Benefits and costs

Benefits

The benefits of the ACIAR- and AusAID-funded Newcastle disease control projects to each of the four countries covered by the AusAID projects are estimated in this chapter using the framework and assumptions outlined in Chapter 5. The total benefits to each country are the consumer surplus plus the producer surplus less the subsidy on the vaccine. The benefits are estimated in local currencies at real 2013 prices and converted to Australian dollars using International Monetary Fund exchange-rate data. Following ACIAR guidelines, all future benefits once the maximum adoption rate has been reached are included by dividing by the discount rate (5%).

The estimated benefits to Mozambique are shown in Table 11. Interestingly, most of the benefits flow to consumers rather than producers. This is because the increase in the production of village chickens reduces prices. Lower prices benefit consumers, but offset some of the benefits of higher production for producers. This is explained further below.

The net benefits to Tanzania are estimated in Table 12. The benefits are estimated in Tanzanian shillings and converted to Australian dollars using IMF exchange-rate data.

The estimated net benefits to Malawi are shown in Table 13. Unlike in the other countries, the producer surplus becomes negative from 2012 onwards. This reflects the increase in the cost of the vaccine. Negative producer surplus indicates that, in aggregate, producers are actually worse off as a result of increased levels of vaccination.

As discussed above, the increase in production is likely to result in lower prices, which are a benefit to consumers but a cost to producers. Producers who vaccinate are better off from vaccination because the quantity of chickens they produce increases. The decrease in the price only partly offsets the benefits from increased production. However, producers who do not vaccinate are worse off because they receive a lower price for the chickens they produce but do not benefit from increased production (although, in practice, they may receive some spillover benefits from neighbours vaccinating their chickens).

Unlike in the other countries, in Malawi the losses to non-vaccinating producers are estimated to outweigh the benefits to producers who vaccinate. This is mainly because the price of the I-2 vaccine is higher in Malawi and does not appear to be subsidised.

Nevertheless, there was less information on prices and vaccine costs available for Malawi, so these estimates should be considered indicative only. Furthermore, consumers and producers are in many cases the same people. The distribution of benefits is discussed further below. The key point from Table 13 is that vaccination against Newcastle disease using the I-2 vaccine results in a net benefit to the community.

Estimated net benefits to Zambia are shown in Table 14. The subsidy is estimated to be zero because we have assumed that the price of the vaccine reflects full cost-recovery. This assumption does not change the total benefits, but changes the distribution of benefits and costs between producers and the government.

Table 11. Estimated net benefits to Mozambique

	Consumer surplus (million meticals)	Producer surplus (million meticals)	Subsidy (million meticals)	Total (million meticals)	Exchange rate (meticals per $A)	Total benefits (A$ million)
1994	0.0	0.0	0.0	0.0	4.4	0.0
1995	0.0	0.0	0.0	0.0	6.7	0.0
1996	0.0	0.0	0.0	0.0	8.8	0.0
1997	0.0	0.0	0.0	0.0	8.6	0.0
1998	0.0	0.0	0.0	0.0	7.5	0.0
1999	9.8	0.4	0.8	9.5	8.2	1.2
2000	7.2	0.3	0.6	7.0	9.1	0.8
2001	7.2	0.3	0.6	6.9	10.7	0.6
2002	1.2	0.1	0.1	1.1	12.9	0.1
2003	10.7	0.5	0.9	10.3	15.5	0.7
2004	13.0	0.6	1.1	12.5	16.6	0.8
2005	15.4	0.7	1.3	14.8	17.6	0.8
2006	31.6	1.4	2.6	30.4	18.8	1.6
2007	63.3	2.7	5.1	60.9	21.4	2.8
2008	41.6	1.8	3.4	40.0	20.6	1.9
2009	25.9	1.1	2.1	25.0	21.1	1.2
2010	43.1	1.9	3.5	41.5	30.3	1.4
2011	42.4	1.8	3.4	40.8	30.0	1.4
2012	45.1	0.2	1.9	43.4	29.4	1.5
2013	52.4	0.2	2.2	50.4	29.4	1.7
2014	59.6	0.2	2.5	57.4	29.4	2.0
2015	66.9	0.3	2.8	64.3	29.4	2.2
2016	74.1	0.3	3.1	71.3	29.4	2.4
2017	81.4	0.3	3.4	78.3	29.4	2.7
2018	88.7	0.3	3.7	85.3	29.4	2.9
2019	95.9	0.4	4.0	92.3	29.4	3.1
2020	103.2	0.4	4.3	99.3	29.4	3.4
2021	110.4	0.4	4.6	106.3	29.4	3.6
2022	117.7	0.5	4.9	113.2	29.4	3.9
2023	125.0	0.5	5.2	120.2	29.4	4.1
2024	132.2	0.5	5.5	127.2	29.4	4.3
2025	139.5	0.5	5.8	134.2	29.4	4.6
2026	146.7	0.6	6.1	141.2	29.4	4.8
2027	154.0	0.6	6.4	148.2	29.4	5.0
2028	161.3	0.6	6.7	155.2	29.4	5.3
2029	168.5	0.7	7.0	162.2	29.4	5.5
2030	175.8	0.7	7.3	169.1	29.4	5.8
2031	183.1	0.7	7.6	176.1	29.4	6.0
2032	190.3	0.7	8.0	183.1	29.4	6.2
2033–	3,806.3	15.0	159.0	3,662.3	29.4	124.6

Source: CIE estimates.

Table 12. Estimated net benefits to Tanzania

	Consumer surplus (million shillings)	Producer surplus (million shillings)	Subsidy (million shillings)	Total benefits (million shillings)	Exchange rate (shillings per A$)	Total benefits (A$ million)
1994	0.0	0.0	0.0	0.0	372.9	0.0
1995	0.0	0.0	0.0	0.0	397.7	0.0
1996	0.0	0.0	0.0	0.0	456.4	0.0
1997	0.0	0.0	0.0	0.0	460.1	0.0
1998	0.0	0.0	0.0	0.0	419.2	0.0
1999	0.0	0.0	0.0	0.0	480.8	0.0
2000	0.0	0.0	0.0	0.0	466.1	0.0
2001	1,620.3	76.6	6.4	1,690.5	453.1	3.7
2002	6,424.5	303.8	25.3	6,703.0	525.7	12.8
2003	5,595.4	264.6	22.1	5,838.0	677.0	8.6
2004	4,048.5	191.5	16.0	4,224.0	802.3	5.3
2005	8,057.8	381.1	31.8	8,407.1	860.6	9.8
2006	7,500.6	354.7	29.6	7,825.8	943.2	8.3
2007	16,010.6	757.2	63.1	16,704.6	1,044.1	16.0
2008	27,242.3	1,288.3	107.4	28,423.3	1,020.4	27.9
2009	29,499.3	1,395.0	116.3	30,778.1	1,045.3	29.4
2010	40,996.6	1,615.6	−161.6	42,773.8	1,296.9	33.0
2011	18,904.2	745.0	−74.5	19,723.7	1,623.7	12.1
2012	13,908.0	602.9	0.0	14,510.9	1,640.0	8.8
2013	17,171.1	744.4	0.0	17,915.5	1,640.0	10.9
2014	20,434.2	885.8	0.0	21,320.1	1,640.0	13.0
2015	23,697.3	1,027.3	0.0	24,724.6	1,640.0	15.1
2016	26,960.4	1,168.7	0.0	28,129.2	1,640.0	17.2
2017	30,223.5	1,310.2	0.0	31,533.7	1,640.0	19.2
2018	33,486.6	1,451.6	0.0	34,938.3	1,640.0	21.3
2019	36,749.7	1,593.1	0.0	38,342.8	1,640.0	23.4
2020	40,012.8	1,734.5	0.0	41,747.4	1,640.0	25.5
2021	43,275.9	1,876.0	0.0	45,151.9	1,640.0	27.5
2022	46,539.0	2,017.5	0.0	48,556.5	1,640.0	29.6
2023	49,802.1	2,158.9	0.0	51,961.0	1,640.0	31.7
2024	53,065.2	2,300.4	0.0	55,365.6	1,640.0	33.8
2025	56,328.3	2,441.8	0.0	58,770.1	1,640.0	35.8
2026	59,591.4	2,583.3	0.0	62,174.7	1,640.0	37.9
2027	62,854.5	2,724.7	0.0	65,579.2	1,640.0	40.0
2028	66,117.6	2,866.2	0.0	68,983.8	1,640.0	42.1
2029	69,380.7	3,007.6	0.0	72,388.3	1,640.0	44.1
2030	72,643.8	3,149.1	0.0	75,792.9	1,640.0	46.2
2031	75,906.9	3,290.5	0.0	79,197.4	1,640.0	48.3
2032	79,170.0	3,432.0	0.0	82,602.0	1,640.0	50.4
2033–	1,583,400.0	68,640.0	0.0	1,652,040.0	1,640.0	1,007.3

Source: CIE estimates.

Table 13. Estimated net benefits to Malawi

	Consumer surplus (million kwachas)	Producer surplus (million kwachas)	Subsidy (million kwachas)	Total benefits (million kwachas)	Exchange rate (kwachas per A$)	Total benefits (A$ million)
1994	0.0	0.0	0.0	0.0	6.4	0.0
1995	0.0	0.0	0.0	0.0	11.3	0.0
1996	0.0	0.0	0.0	0.0	12.0	0.0
1997	0.0	0.0	0.0	0.0	12.2	0.0
1998	0.0	0.0	0.0	0.0	19.6	0.0
1999	0.0	0.0	0.0	0.0	28.5	0.0
2000	0.0	0.0	0.0	0.0	34.7	0.0
2001	0.0	0.0	0.0	0.0	37.3	0.0
2002	0.0	0.0	0.0	0.0	42.0	0.0
2003	0.0	0.0	0.0	0.0	64.2	0.0
2004	0.0	0.0	0.0	0.0	80.2	0.0
2005	136.2	2.6	4.4	134.4	90.3	1.5
2006	136.2	2.6	4.4	134.4	102.5	1.3
2007	136.2	2.6	4.4	134.4	117.4	1.1
2008	136.2	2.6	4.4	134.4	119.8	1.1
2009	136.2	2.6	4.4	134.4	111.7	1.2
2010	95.3	1.8	3.0	94.1	138.4	0.7
2011	196.1	3.7	6.3	193.6	161.9	1.2
2012	155.3	−2.0	0.0	153.2	259.8	0.6
2013	226.1	−3.0	0.0	223.1	259.8	0.9
2014	273.5	−3.6	0.0	269.9	259.8	1.0
2015	320.9	−4.2	0.0	316.8	259.8	1.2
2016	368.4	−4.8	0.0	363.6	259.8	1.4
2017	415.8	−5.4	0.0	410.4	259.8	1.6
2018	463.2	−6.0	0.0	457.2	259.8	1.8
2019	510.6	−6.7	0.0	504.0	259.8	1.9
2020	558.1	−7.3	0.0	550.8	259.8	2.1
2021	605.5	−7.9	0.0	597.6	259.8	2.3
2022	652.9	−8.5	0.0	644.4	259.8	2.5
2023	700.3	−9.1	0.0	691.2	259.8	2.7
2024	747.8	−9.8	0.0	738.0	259.8	2.8
2025	795.2	−10.4	0.0	784.8	259.8	3.0
2026	842.6	−11.0	0.0	831.6	259.8	3.2
2027	890.0	−11.6	0.0	878.4	259.8	3.4
2028	937.5	−12.2	0.0	925.2	259.8	3.6
2029	984.9	−12.9	0.0	972.0	259.8	3.7
2030	1,032.3	−13.5	0.0	1,018.8	259.8	3.9
2031	1,079.7	−14.1	0.0	1,065.6	259.8	4.1
2032	1,127.2	−14.7	0.0	1,112.5	259.8	4.3
2033–	22,543.4	−294.3	0.0	22,249.0	259.8	85.6

Source: CIE estimates.

Table 14. Estimated net benefits to Zambia

	Consumer surplus (million kwachas)	Producer surplus (million kwachas)	Subsidy (million kwachas)	Total benefits (million kwachas)	Exchange rate (kwachas per $A)	Total benefits (A$ million)
1994	0.0	0.0	0.0	0.0	489.8	0.0
1995	0.0	0.0	0.0	0.0	642.1	0.0
1996	0.0	0.0	0.0	0.0	945.5	0.0
1997	0.0	0.0	0.0	0.0	978.1	0.0
1998	0.0	0.0	0.0	0.0	1,171.7	0.0
1999	0.0	0.0	0.0	0.0	1,540.9	0.0
2000	0.0	0.0	0.0	0.0	1,811.3	0.0
2001	0.0	0.0	0.0	0.0	1,866.7	0.0
2002	0.0	0.0	0.0	0.0	2,392.5	0.0
2003	0.0	0.0	0.0	0.0	3,085.5	0.0
2004	0.0	0.0	0.0	0.0	3,520.1	0.0
2005	0.0	0.0	0.0	0.0	3,402.5	0.0
2006	0.0	0.0	0.0	0.0	2,714.6	0.0
2007	0.0	0.0	0.0	0.0	3,356.7	0.0
2008	0.0	0.0	0.0	0.0	3,192.6	0.0
2009	0.0	0.0	0.0	0.0	3,995.0	0.0
2010	0.0	0.0	0.0	0.0	4,412.1	0.0
2011	0.0	0.0	0.0	0.0	5,015.3	0.0
2012	0.0	0.0	0.0	0.0	5,316.2	0.0
2013	168.2	0.9	0.0	169.0	5,316.2	0.0
2014	1,272.1	6.6	0.0	1,278.7	5,316.2	0.2
2015	2,376.0	12.3	0.0	2,388.3	5,316.2	0.4
2016	3,479.9	18.0	0.0	3,497.9	5,316.2	0.7
2017	4,583.9	23.7	0.0	4,607.6	5,316.2	0.9
2018	5,687.8	29.4	0.0	5,717.2	5,316.2	1.1
2019	6,791.7	35.1	0.0	6,826.8	5,316.2	1.3
2020	7,895.6	40.8	0.0	7,936.4	5,316.2	1.5
2021	8,999.5	46.5	0.0	9,046.1	5,316.2	1.7
2022	10,103.5	52.2	0.0	10,155.7	5,316.2	1.9
2023	11,207.4	57.9	0.0	11,265.3	5,316.2	2.1
2024	12,311.3	63.6	0.0	12,374.9	5,316.2	2.3
2025	13,415.2	69.3	0.0	13,484.6	5,316.2	2.5
2026	14,519.1	75.0	0.0	14,594.2	5,316.2	2.7
2027	15,623.1	80.8	0.0	15,703.8	5,316.2	3.0
2028	16,727.0	86.5	0.0	16,813.4	5,316.2	3.2
2029	17,830.9	92.2	0.0	17,923.1	5,316.2	3.4
2030	18,934.8	97.9	0.0	19,032.7	5,316.2	3.6
2031	20,038.7	103.6	0.0	20,142.3	5,316.2	3.8
2032	21,142.7	109.3	0.0	21,251.9	5,316.2	4.0
2033–	422,853.4	2,185.6	0.0	425,039.0	5,316.2	80.0

Source: CIE estimates.

Costs

The nominal costs shown in Table 15 are converted to real 2013 dollars using the Australian gross domestic product deflator published by the Australian Bureau of Statistics. In real 2013 dollars, the Australian Government has contributed around $14 million to Newcastle disease control in Africa (around $1.8 million through ACIAR and $12.3 million through AusAID.

As discussed in Chapter 1, in most cases the cash and in-kind contributions from partner-country governments (including central and provincial governments), and in some cases NGOs and international agencies involved in vaccine production and distribution, have not been documented. It has not been possible to track those costs, but most of them have been taken into account in the estimated vaccine subsidy.

Table 15. Nominal and real project costs

	Nominal (A$'000)				Deflator 2013 = 100	Real (2013 A$'000)			
	ACIAR	AusAID	Partner	Total		ACIAR	AusAID	Partner	Total
1994	23.9	0.0	0.0	23.9	56.5	42.3	0.0	0.0	42.3
1995	83.4	0.0	0.0	83.4	57.8	144.4	0.0	0.0	144.4
1996	59.5	0.0	0.0	59.5	59.2	100.5	0.0	0.0	100.5
1997	99.3	0.0	9.5	108.8	60.0	165.6	0.0	15.8	181.4
1998	54.3	0.0	9.0	63.3	60.8	89.4	0.0	14.8	104.2
1999	70.2	0.0	0.0	70.2	61.0	115.0	0.0	0.0	115.0
2000	73.0	0.0	0.0	73.0	62.6	116.6	0.0	0.0	116.6
2001	368.9	0.0	0.0	368.9	65.5	562.8	0.0	0.0	562.8
2002	287.1	50.0	0.0	337.1	67.4	426.2	74.2	0.0	500.4
2003	0.0	1,743.2	0.0	1,743.2	69.3	0.0	2,516.0	0.0	2,516.0
2004	0.0	1,667.9	0.0	1,667.9	71.4	0.0	2,336.3	0.0	2,336.3
2005	0.0	1,787.5	0.0	1,787.5	74.2	0.0	2,410.0	0.0	2,410.0
2006	0.0	911.7	0.0	911.7	77.7	0.0	1,173.2	0.0	1,173.2
2007	0.0	0.0	0.0	0.0	81.5	0.0	0.0	0.0	0.0
2008	0.0	0.0	0.0	0.0	85.3	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0	89.5	0.0	0.0	0.0	0.0
2010	0.0	579.9	0.0	579.9	90.4	0.0	641.7	0.0	641.7
2011	0.0	627.4	0.0	627.4	95.8	0.0	654.7	0.0	654.7
2012	0.0	627.4	0.0	627.4	97.3	0.0	645.1	0.0	645.1
2013	0.0	1,626.8	0.0	1,626.8	100.0	0.0	1,626.8	0.0	1,626.8
Total	**1,119.6**	**9,621.8**	**18.5**	**10,759.9**		**1,762.8**	**12,078.0**	**30.6**	**13,871.4**

Note: Differences in totals are due to rounding.

Sources: ACIAR and AusAID project documents, Australian Bureau of Statistics, CIE.

Summary

The total benefits and costs in present value terms using various discount rates are estimated in Table 16. Using ACIAR's preferred discount rate of 5%, the total net benefits to the four African partner countries are estimated at around $479 million (in 2013 Australian dollars). The total project costs were around $8.0 million (also expressed in 2013 dollar present value terms, using a discount rate of 5%). The net present value of the Australian aid projects is therefore estimated at around $471 million. This represents a benefit of around $60 for every dollar invested. The internal rate of return on the investment by the Australian Government is estimated at around 96%.

Table 16. Summary measures

	Discount rate		
	1%	5%	10%
Present value of benefits ($ million)	5,154.6	479.0	120.9
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	5,142.2	470.9	116.0
Benefit:cost ratio	416.7	59.6	24.4
Internal rate of return (%)	96.4	96.4	96.4

Source: CIE estimates.

Distribution of benefits

Table 17 shows the distribution of benefits across countries and major stakeholder groups. By country, around 80% of the benefits flow to Tanzania, due to both higher adoption in the past and assumed adoption in the future.

In village situations, the distinction between consumers and producers is less meaningful than in commercial situations because, in many cases, producers and consumers are the same people. Nevertheless, most of the benefits from vaccination are estimated to flow to consumers. Producers who vaccinate their chickens also benefit, although producers who do not vaccinate may be worse off (although, in practice, they may receive some spillover benefits from other producers vaccinating their chickens). In Mozambique, Tanzania and Zambia, the benefits to adopters are estimated to exceed the losses to non-adopters. However, in Malawi, the losses to non-adopters outweigh the benefits to adopters due to a higher vaccine price in that country.

Where the full cost of vaccine production, distribution and administration is not reflected in the price paid by farmers, the providers of those services incur a cost. Providers are largely governments at the national and provincial levels, but could include NGOs.

This finding that producers receive only minimal—and in some cases negative—benefits from Newcastle disease vaccination may seem counterintuitive as well as inconsistent with the household-level studies that show significant benefits to households that vaccinate their chickens. As discussed above, this is due to the impact of increased production on prices, which is generally not taken into account in those studies.

Table 17. Distribution of benefits (A$ million)

	Mozambique	Tanzania	Malawi	Zambia	Total
Consumers	48.2	367.1	29.4	20.5	465.2
Producers:					
Adopters	9.8	87.0	5.4	4.1	106.3
Non-adopters	−9.3	−70.9	−5.7	−4.0	−89.8
All producers	0.5	16.1	−0.2	0.1	16.5
Government	−2.4	−0.2	−0.1	0.0	−2.7
Total	46.3	383.0	29.0	20.6	479.0

Note: A discount rate of 5% is used.

Source: CIE estimates.

The distribution of benefits between consumers and producers depends on the elasticity of demand. We assumed an elasticity of demand of –1, which implies that producers' total revenue would not be significantly changed through an increase in production, as the decrease in price is offset by the increase in the quantity produced (if all producers vaccinate). An elastic demand curve would reduce the revenue received by producers and shift the benefits to consumers, while an inelastic demand curve would shift the benefits from consumers to producers.

In addition, we assumed small, closed, village-level markets. This means that the estimated impact on price from any increase in the quantity of chickens produced arising from vaccination against Newcastle disease will be greater than if the village is connected to larger markets. It also means that, to a large extent, producers and consumers are the same people—poor rural households.

In places where village chicken producers are linked to larger markets, such as in parts of Tanzania, vaccination uptake will have a much smaller impact on price because the total increase in the quantity supplied to that market will be diluted. This would shift some of the benefits from consumers to producers. It would also mean that some of the benefits would go to urban consumers, rather than poor rural households.

Attribution of benefits

Attribution of benefits between the research component funded by ACIAR and the implementation component funded by AusAID is difficult. Clearly, the benefits estimated above would not have been delivered without ACIAR-funded research that developed the I-2 vaccine and the associated production, distribution and extension strategies. However, it is also unlikely that the benefits to Mozambique, Tanzania, Malawi and Zambia would have been realised had those strategies not been implemented under the AusAID-funded projects.

One approach is to simply attribute benefits on a cost-share basis. In present value terms (using a discount rate of 5%), ACIAR contributed around 17% of the total costs, and AusAID contributed around 83%. Consequently, benefits of around $80.6 million can be attributed to the ACIAR-funded projects, and benefits of around $396.8 million to AusAID (Table 18).

Table 18. Attribution of benefits

	Total contributions (A$)	Share of total (%)	Benefits attributed (A$ million)
ACIAR	1,353,113	16.8	80.6
AusAID	6,660,147	82.8	396.8
Other	25,867	0.3	1.5
Total	8,039,127	100.0	478.9

Source: CIE estimates.

Risk and sensitivity analysis

Although we can be more certain than in the previous impact assessment (CIE 1998) that the ACIAR-funded research has delivered benefits to Africa, significant uncertainties in the estimates remain. Key areas of uncertainty include:

- future adoption rates
- the increase in off-take from vaccinated flocks
- the price of chickens
- the elasticity of demand.

This section examines the sensitivity of the estimates to alternative assumptions for each of these variables and the robustness of the results.

Future adoption

Future adoption is always an important source of uncertainty in impact assessment. The summary measures based on the estimated benefits received and costs incurred to date are shown in Table 19. Based on ACIAR's preferred 5% discount rate, more than three-quarters of the total benefits are estimated to accrue in the future, confirming that future adoption is a key risk that our estimates will overstate (or potentially understate) the actual benefits.

Nevertheless, the Newcastle disease control projects funded by the Australian Government are estimated to have already delivered benefits of more than $100 million to African partner countries. Even if there are no further benefits, the return on the Australian Government's investment is estimated at around 36%.

Table 19. Summary measures based on benefits and costs to date

	Discount rate		
	1%	**5%**	**10%**
Present value of benefits ($ million)	175.8	104.8	57.5
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	163.4	96.8	52.5
Benefit:cost ratio	14.2	13.1	11.5
Internal rate of return (%)	36.1	36.1	36.1

Source: CIE estimates.

We also tested the sensitivity of our estimates to alternative future adoption assumptions, using two scenarios (Table 20):

- a low future adoption scenario—in this scenario, the number of chickens vaccinated using the I-2 vaccine remains at the current level into the future
- a high future adoption scenario—in this scenario, adoption rates in all four countries are estimated to reach 65% (the central case scenario for Tanzania).

While the estimates are relatively sensitive to future adoption rates, the Australian Government's Newcastle disease control projects are estimated to deliver significant future net benefits to African partner countries, even if the number of birds vaccinated remains at current levels.

Table 20. Summary measures under alternative adoption scenarios

	Discount rate		
	1%	**5%**	**10%**
Low adoption scenario[a]			
Present value of benefits ($ million)	1,105.7	196.3	77.4
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	1,093.4	188.3	72.4
Benefit:cost ratio	89.2	24.5	15.5
Internal rate of return (%)	96.4	96.4	96.4
High adoption scenario[b]			
Present value of benefits ($ million)	7,612.0	648.8	146.7
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	7,599.7	640.7	141.7
Benefit:cost ratio	613.9	81.1	29.3
Internal rate of return (%)	96.4	96.4	96.4

a Assumes that the number of chickens vaccinated remains at current levels into the future.

b Assumes that adoption rates in all four countries reach 65% after 20 years.

Source: CIE estimates.

Increase in off-take from vaccinated flocks

As no formal experimental field trials have been run in the African partner countries to measure the impact of vaccination on off-take, the increase in off-take from vaccinated flocks is also a key area of uncertainty. We assumed that off-take from vaccinated flocks increased by 25%. This was based on estimates in various countries ranging between about 10% and 40%.

We examined the sensitivity of the benefit estimates to the off-take assumption by using the lower and upper end of that range as alternative assumptions (Table 21). The results are relatively sensitive to this assumption, but even under the conservative 10% increase assumption, the Newcastle disease control projects are estimated to deliver benefits well above the costs.

Table 21. Summary measures under alternative off-take assumptions

	Discount rate		
	1%	**5%**	**10%**
Low off-take assumption[a]			
Present value of benefits ($ million)	1,803.2	167.8	42.4
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	1,790.8	159.8	37.5
Benefit:cost ratio	145.4	21.0	8.5
Internal rate of return (%)	60.9	60.9	60.9
High off-take assumption[b]			
Present value of benefits ($ million)	8,796.3	817.1	206.2
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	8,783.9	809.0	201.2
Benefit:cost ratio	709.4	102.1	41.2
Internal rate of return (%)	116.3	116.3	116.3

a Assumes that chicken off-take increases by 10% in vaccinated flocks.

b Assumes that off-take increases by 40% in vaccinated flocks.

Source: CIE estimates.

Chicken prices

Our estimates are based on the reported price of village chickens in Mozambique and Tanzania. However, the price of chickens can vary significantly over time and by location. Chicken prices are therefore another area of uncertainty in the estimates. To test the sensitivity of our estimates to the chicken price assumption, we varied the price by 50% either way (Table 22). While the results are relatively sensitive to the chicken price assumption, the project delivers large benefits relative to the cost, even using the low price assumption.

Table 22. Summary measures under alternative price assumptions

	Discount rate		
	1%	**5%**	**10%**
Low price assumption[a]			
Present value of benefits ($ million)	2,442.4	227.1	57.4
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	2,430.0	219.1	52.4
Benefit:cost ratio	197.0	28.4	11.5
Internal rate of return (%)	70.9	70.9	70.9
High price assumption[b]			
Present value of benefits ($ million)	7,866.9	730.8	184.4
Present value of costs ($ million)	12.4	8.0	5.0
Net present value ($ million)	7,854.5	722.8	179.5
Benefit:cost ratio	634.4	91.4	36.7
Internal rate of return (%)	112.0	112.0	112.0

a Assumes that chicken prices are 50% lower than in the central case scenario.

b Assumes that chicken prices are 50% higher than in the central case scenario.

Elasticity of demand

There is no reliable information on the elasticity of demand for village chickens in the African partner countries. In the absence of better information, an elasticity of demand of –1 is typically a reasonable assumption. Under that assumption, most of the benefits were estimated to flow to consumers. This contrasted with previous ACIAR work, which used an elasticity of demand of –1.5, implying relatively elastic demand.

We tested the sensitivity of the results to the elasticity of demand assumption, using the following alternative assumptions:

- elasticity of demand of –0.5 (relatively inelastic demand)—this implies that prices would be relatively insensitive to the increase in production resulting from increased levels of vaccination against Newcastle disease.
- elasticity of demand of –1.5 (relatively elastic demand)—this implies that prices would be relatively sensitive to the increase in production.

The distribution of benefits among stakeholder groups and countries under these alternative assumptions is shown in Table 23. The total benefits are less sensitive to the elasticity of demand assumption than to the future adoption and increase in off-take assumptions. However, the total benefits are slightly lower when demand is relatively inelastic, but producers receive a greater share of the benefits. Alternatively, if demand is relatively elastic, the total benefits are slightly higher due to larger benefits to consumers. However, under the elastic demand assumption, producers would be worse off from increased levels of vaccination, regardless of whether or not they vaccinate. Under those circumstances, it is doubtful whether producers would vaccinate without a subsidy.

Table 23 Distribution of benefits (A$ million) under alternative demand elasticities

	Mozambique	Tanzania	Malawi	Zambia	Total
Inelastic demand[a]					
Consumers	24.1	183.5	14.7	10.3	232.6
Producers:	20.7	169.7	12.1	8.7	211.1
Adopters	25.3	205.1	14.9	10.7	256.0
Non-adopters	–4.6	–35.4	–2.8	–2.0	–44.9
Government	–2.4	–0.2	–0.1	0.0	–2.7
Total	42.4	353.0	26.6	19.0	441.0
Elastic demand[b]					
Consumers	72.2	550.6	44.1	30.8	697.7
Producers:	–19.6	–137.5	–12.6	–8.5	–178.1
Adopters	–5.7	–31.2	–4.0	–2.5	–43.4
Non-adopters	–13.9	–106.3	–8.5	–5.9	–134.7
Government	–2.4	–0.2	–0.1	0.0	–2.7
Total	50.3	412.9	31.4	22.3	516.9

a Estimates assume an elasticity of demand of –0.5.

b Estimates assume an elasticity of demand of –1.5.

Note: A discount rate of 5% is used. Differences in totals are due to rounding.

Source: CIE estimates.

7 Conclusions

The analysis in this report suggests that the ACIAR- and AusAID-funded projects aimed at controlling Newcastle disease in Africa have delivered significant benefits to the African partner countries, particularly Tanzania.

The net benefits to the four African partner countries are estimated at around $479 million (in 2013 Australian dollars using a discount rate of 5%), and around $80.6 million of those benefits are attributable to ACIAR. The partner countries are estimated to have already received net benefits of more than $100 million. Expressed in comparable terms, the cost of the projects was around $8.0 million, which means that a benefit of around $60 accrued for every dollar invested. The internal rate of return on the projects is estimated at around 96%. While there remains significant uncertainty about the estimates, the broad conclusions are robust, given that the projects are estimated to deliver significant benefits to partner countries under all alternative assumptions considered.

This project has been a good example of ACIAR-funded research developing a 'proof of concept', which was then scaled up with further Australian Government funding (J. Copland, pers. comm., 12 August 2013).

Many lessons about Newcastle disease control in Africa have been learned during these projects. This section draws some broad conclusions that may be useful in guiding future investments.

Distribution and extension strategies are critical

Although the benefits to each household are likely to be modest, the projects have effectively delivered large benefits to partner countries by reaching a large number of households.

Perhaps the key factor that has enabled the projects to achieve such widespread adoption was the nature of the intervention: vaccination against Newcastle disease is an effective, low-cost solution to a significant problem and requires minimal change in farmers' practices.

Despite that, achieving widespread adoption has required significant effort and coordination among a range of stakeholders, including laboratories, provincial extension service providers, vaccinators and trainers. This re-emphasises the importance of an effective distribution and extension strategy. No matter how effective a new technology is in overcoming production constraints, it will not deliver benefits unless sound distribution and extension strategies are in place. The relative funding contributions of ACIAR and AusAID show that, in some cases, the research component can be a relatively small component of the overall effort in agricultural projects in developing countries. The effort required in developing capacity and in extension work can be significant.

Government service delivery can be effective

An interesting question to emerge from this project is whether new technologies are more effectively delivered to poor rural households by the government or by commercial providers.

The strategy developed in the ACIAR projects and implemented in the AusAID projects focused on government production of the vaccine. This was a relatively ambitious strategy, requiring the building of

vaccine production capacity in government laboratories in each partner country, as well as the development of vaccine distribution systems. While some vaccine production problems remain in all of the project countries, the projects have generally been successful in achieving those aims. However, that has required significant political will from partner countries and a long-term funding commitment through multiple projects from the Australian Government.

This raises the question of whether some of the benefits could have been achieved faster and more cheaply if the vaccine had been commercialised. It is possible that commercial laboratories may have been able to use existing expertise to establish vaccine production systems more quickly with less external funding. On the other hand, the Kyeema Foundation remains concerned that commercialising the vaccine may increase the price to a level beyond what is affordable to smallholders. This concern is perhaps understandable, given the circumstances that led to the development of the I-2 vaccine.

There is no clear answer to this question. However, these projects have demonstrated that, while government service delivery can be effective, it may require an ongoing funding commitment.

Cost-recovery improves the effectiveness and sustainability of government services

Another interesting feature of the projects is the recommendation that government agencies involved in vaccine production and distribution recover their costs, ultimately from the households using the technology. Cost-recovery has been implemented to varying extents in the project countries. In some cases, charging households to vaccinate their chickens has been a barrier to adoption. However, where implemented effectively, it has also improved the effectiveness of the system and increased the prospects for long-term sustainability.

It is interesting to compare the arrangements that apply in Tanzania with those in Mozambique. In Tanzania, an effective cost-recovery system in which every link along the vaccine production and distribution chain recovers its costs has been implemented. This appears to be one of the major factors contributing to the larger scale of adoption achieved in Tanzania compared with the other countries, because it means that every stakeholder is sufficiently resourced and has an incentive to produce and distribute greater quantities of vaccine. In Mozambique, by contrast, only community vaccinators receive some income for the services they provide. The government laboratory and providers of extension services in the provinces are reliant on government and donor funding. This has inevitably led to resourcing problems: the laboratory producing the vaccine often has difficulty obtaining sufficient funding to purchase inputs, and extension officers have insufficient resources to organise vaccination campaigns. These resourcing issues appear to be a major barrier to expanding adoption.

Experiences in these projects have demonstrated that smallholders can be willing to pay for new technologies once they understand the benefits. Where they are willing to pay, cost-recovery can improve the effectiveness and sustainability of government services.

Well-targeted projects improve food security and alleviate poverty

All of the estimated benefits are considered to flow to poor rural communities (although some benefits may also flow to urban consumers in cases where village chicken producers are linked into larger markets). The projects could therefore be expected to improve food security and help to alleviate poverty in those communities.

Because most poor rural households produce chickens, consume them, or both, improving village chicken production is a well-targeted strategy for improving food security and alleviating poverty.

Nevertheless, the overall impact on most households is likely to be modest. For most, the increase in chicken production could be expected to be several chickens per year. It is not clear whether this would be sufficient to significantly improve child nutrition and other development indicators. A new ACIAR project may provide some insight into this question.

A significant unmeasured benefit may be that more effective Newcastle disease control makes it viable for some households to make greater investments in chicken and/or egg production. Case studies prepared by the Kyeema Foundation have highlighted a number of such cases.

Our analysis also showed that consumers are the main beneficiaries. This demonstrates that the benefits of reducing a production constraint can be spread more broadly across the community than just to the individuals who adopt the technology. Indeed, it is possible that producers are collectively worse off as a result of vaccination campaigns, particularly those who choose not to vaccinate.

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2	George P.S. 1998.	Increased efficiency of straw utilisation by cattle and buffalo	AS1/1982/003, AS2/1986/001 and AS2/1988/017
3	Centre for International Economics 1998.	Establishment of a protected area in Vanuatu	ANRE/1990/020
4	Watson A.S. 1998.	Raw wool production and marketing in China	ADP/1988/011
5	Collins D.J. and Collins B.A. 1998.	Fruit fly in Malaysia and Thailand 1985–1993	CS2/1983/043 and CS2/1989/019
6	Ryan J.G. 1998.	Pigeonpea improvement	CS1/1982/001 and CS1/1985/067
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8	McKenney D.W. 1998.	Australian tree species selection in China	FST/1984/057 and FST/1988/048
9	ACIL Consulting 1998.	Sulfur test KCL–40 and growth of the Australian canola industry	PN/1983/028 and PN/1988/004
10	AACM International 1998.	Conservation tillage and controlled traffic	LWR2/1992/009
11	Chudleigh P. 1998.	Postharvest R&D concerning tropical fruits	PHT/1983/056 and PHT/1988/044
12	Waterhouse D., Dillon B. and Vincent D. 1999.	Biological control of the banana skipper in Papua New Guinea	CS2/1988/002-C
13	Chudleigh P. 1999.	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
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33	Vere D. 2005.	Research into conservation tillage for dryland cropping in Australia and China	LWR2/1992/009 and LWR2/1996/143
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80	Fisher H., Sar L. and Winzenried C. 2012	Oil palm pathways: an analysis of ACIAR's oil palm projects in Papua New Guinea	ASEM/1999/084, ASEM/2002/014, ASEM/2006/127, CP/1996/091, CP/2007/098, PC/2004/064, PC/2006/063
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84	Mayne J. and Stern E. 2013	Impact evaluation of natural resource management research programs: a broader view	
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86	Lindner B., McLeod P. and Mullen J. 2013	Returns to ACIAR's investment in bilateral agricultural research	
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