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PROJECT DEVELOPMENT ASSESSMENT: PROFILIC WORM-RESISTANT MEAT SHEEP FOR MAHARASHTRA, INDIA AND AUSTRALIA[1]

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ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
ACIAR	Australian Centre for International Agricultural Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
FAO	Food and Agriculture Organization of the United Nations
IRR	Internal rate of return
NARI	Nimbkar Agricultural Research Institute
NPV	Net present value

1. INTRODUCTION

This paper describes a project development assessment of a proposal for collaborative research (ACIAR project PN9422) between Nimbkar Agricultural Research Institute, a non-government organisation in India, and four Australian institutions: The University of New England; CSIRO Division of Animal Health; CSIRO Division of Animal Health, Pastoral Research; and Australian Animal Health Laboratory (Geelong). The project development assessment uses a traded-good research evaluation model where the world is divided up into 70 countries or regions (see Appendix A).

In India, the research is focused on improving reproductive performance of sheep and enhancing resistance to infectious diseases in sheep in the Indian state of Maharashtra. The project focuses on the Deccani and Bannur sheep which are indigenous breeds in the State of Maharashtra, and on the Garole breed which is a highly prolific, probably disease-resistant breed of sheep currently found only in a small pocket of West Bengal and in danger of extinction (ACIAR 1995). The Deccani and Bannur sheep have developed from an archaic or primitive stock, through genetic isolation, natural selection and natural adaptation to the local agro-ecological conditions characterised by scanty pastures and a harsh climate (Nimbkar 1994). They are thus hardy animals with excellent disease resistance qualities, but they do not have very high production potential (Nimbkar 1994).

The focus of the research project in Australia is on increasing resistance to worms (helminths) and other diseases in sheep. In Australia, the rapid rise of resistance to anthelmintic drugs is the main incentive to develop genetic enhancement, a non-chemical means of controlling nematode parasites in sheep.

The assessment of the project takes into account the following points. On the benefits, if the project succeeds in India, then cross-breeding the Deccani and Bannur sheep with the Garole sheep will increase prolificacy of the sheep in Maharashtra. The lambing and kidding rates are likely to increase in Maharashtra. If the Garole is also disease resistant then this project is likely to reduce mortality rates of sheep in Maharashtra.

In Australia, discovery of a genetic marker for worm-resistance in sheep will make it possible to breed for worm resistance. This will have a number of benefits including:

- reduction in wool production losses;
- reduced mortality and morbidity of sheep— particularly amongst lambs less than one year old;
- reduced outlays on anthelmintics and reduced risk of worms developing resistance to chemicals;
- reduced labour costs for drenching;
- lower sheep meat production losses;

The effects of the project in both India and Australia are likely to require additional outlays for the farmers, so total costs are likely to increase initially. However, total farm-level output is likely to increase which in turn is likely to lead to a reduction in the cost of producing sheep meat and wool in India and Australia. Simulation studies by Patten and Besier (1995a) have

shown that, at least in Western Australia, cost savings from reduced drenching can outweigh the costs of breeding sheep resistant to worms by year 15.

After taking into account the cost of research, this paper concludes that the project, over a 30 year time horizon and assuming a discount rate of 8% per annum, is likely to lead to a net present value (NPV) of $A19 million and an internal rate of return (IRR) of about 24%. These estimates of NPV and IRR do not take into account the possible additional benefits from technological spillovers to the rest of India and to other regions of the world.

1.2 The project and its objectives

ACIAR (1995) gives the following five objectives of the project:

- In Maharashtra, to compare the lamb production of Deccani, Bannur and Garole sheep breeds. The aim is to improve the prolificacy of the local breeds (Deccani and Bannur) of sheep by crossing them with the more prolific Garole sheep. Prolificacy is defined as the number of lambs successfully born per ewe mated.
- In Maharashtra, to compare the Deccani, Bannur and Garole sheep breeds for resistance to infectious disease: principally the gastrointestinal nematode *Haemochus contortus* and blue tongue virus. The hypothesis is that the cross between the indigenous breeds (Deccani and Bannur) of sheep with the Garole may be more resistant to internal parasites and blue tongue virus. There is some evidence that the Garole breed is one of the local small ruminants which is resistant to some disease.
- In Australia, to improve the methods of estimating resistance to helminths and other important sheep diseases and evaluate these methods in lines of Merinos selected for worm resistance, and to develop and improve techniques for the incorporation of worm resistance into breeding programs. One possible outcome of this part of the project is the discovery of a genetic marker which will allow the more worm-resistant sheep to be easily identified.
- In India and Australia, to investigate techniques and devise strategies for the use of leguminous shrubs as browse and a cut-and-carry supplement for sheep. This minor part of the project is intended to study the anthelmintic and other effects of tannins from several tannin-containing feeds in lambs. If this minor part of the project is successful it is likely to lead to a reduction in the use of chemicals in the control of worms and to a reduction in the risk of anthelmintic resistance of worms in sheep.

1.3 The scope of the paper

The paper is organised as follows. Section 2 discusses the factors that are likely to determine the impact of research. Section 3 describes the quantification of the social welfare impacts of more sustainable production systems for small ruminants. Section 4 discusses the results from the project development assessment. Section 5 makes some concluding remarks.

2. FACTORS LIKELY TO INFLUENCE THE POTENTIAL IMPACTS OF THE RESEARCH

2.1 The size and structure of the sheep industry

The project is likely to affect the production of sheep meat and wool in Maharashtra (India) and Australia. Table 1 shows the production of sheep meat and wool in 70 countries and regions of the world. The information on production is from FAO (1994a). The evaluation assumes that the project is likely to change the levels of production of both sheep meat and wool in Maharashtra and Australia. The shifts in the supply curves for these commodities will be an important determinant of the welfare benefits of the project in Maharashtra.

Table 1. The production of sheep meat and wool in 70 regions and countries of the world

Country	Production of sheep meat 1990 (t)	Consumption of sheep meat 1990 (t)	Trade status 1990	Production of wool 1990 (t)	Consumption of wool 1990 (t)	Trade status 1990
Bangladesh	57400	57400	Non-trader	600	600	Non-trader
Bhutan	0	0	Non-trader	0	0	Non-trader
India	572000	562080	Exporter	22000	45710	Importer
Nepal*	31882	31882	Non-trader	430	7926	Importer
Pakistan	515000	514985	Non-trader	36800	35047	Exporter
Sri Lanka	1923	2066	Importer	0	1	Importer
Burma	6634	6634	Non-trader	151	151	Non-trader
Indonesia	83000	83267	Importer	0	5	Importer
Kampuchea	0	0	Non-trader	0	0	Non-trader
Laos, PDR*	495	495	Non-trader	0	0	Non-trader
Malaysia	589	10589	Importer	121	6972	Importer
Philippines	24117	24483	Importer	0	8	Importer
Thailand	1275	1381	Importer	0	4516	Importer
Vietnam	3097	3097	Non-trader	0	0	Non-trader
China	1068000	1065017	Exporter	122400	142506	Importer
Mongolia*	132000	115000	Exporter	12000	8900	Exporter
Fiji	648	4797	Importer	0	0	Non-trader
Papua New Guinea	30	27030	Importer	0	0	Non-trader
Samoa (Western)	0	2700	Importer	0	0	Non-trader
Solomon Is.*	0	0	Non-trader	0	0	Non-trader
Tonga*	30	2610	Importer	0	0	Non-trader
Vanuatu / New Hebrides	27	57	Importer	0	0	Non-trader
SPac-other	237	1747	Importer	0	0	Non-trader
Ethiopa*	148300	148300	Non-trader	6280	6280	Non-trader
Kenya	56432	56432	Non-trader	1100	802	Exporter

Table 1. (cont'd) The production of sheep meat and wool in 70 regions and countries of the world

Country	Production of sheep meat 1990 (t)	Consumption of sheep meat 1990 (t)	Trade status 1990	Production of wool 1990 (t)	Consumption of wool 1990 (t)	Trade status 1990
Malawi	4370	4370	Non-trader	0	0	Non-trader
Mozambique*	3283	3283	Non-trader	0	0	Non-trader
Tanzania	34733	34733	Non-trader	2400	2400	Non-trader
Uganda	24400	24400	Non-trader	0	0	Non-trader
Zambia	2118	2118	Non-trader	0	0	Non-trader
Zimbabwe	9227	8827	Exporter	650	650	Non-trader
Zaire	10580	10630	Importer	0	0	Non-trader
Ivory Coast	8730	9030	Importer	0	0	Non-trader
Ghana	13241	13276	Importer	0	0	Non-trader
Nigeria	144380	144380	Non-trader	0	0	Non-trader
Cameroon	26940	27000	Importer	0	0	Non-trader
Angola*	3760	4180	Importer	0	0	Non-trader
Madagascar	8682	8676	Exporter	0	0	Non-trader
Sudan*	101500	101500	Non-trader	8000	8000	Non-trader
Africa-2	243024	243176	Importer	0	0	Non-trader
Africa-3	18552	18572	Importer	0	0	Non-trader
Africa-4	6583	7105	Importer	0	0	Non-trader
Africa-5	8908	8908	Non-trader	0	0	Non-trader
Africa-6	45261	45076	Exporter	2700	840	Exporter
Africa-7	819	5675	Importer	0	1970	Importer
Turkey	370000	362888	Exporter	23650	45906	Importer
Egypt, Arab	90000	94800	Importer	1620	3940	Importer
Africa-1	260940	268673	Importer	50820	53257	Importer
Wa/na Other	688978	780863	Importer	61396	54202	Exporter
Brazil	75500	79250	Importer	17400	16704	Exporter
Colombia	14069	13762	Exporter	960	2380	Importer
Peru	31300	33974	Importer	4950	5052	Importer
Venezuela	8500	8539	Importer	0	20	Importer
Bolivia	34100	34100	Non-trader	6600	6598	Exporter
Ecuador	6081	6081	Non-trader	1000	1040	Importer
Mexico	60797	69487	Importer	2259	5786	Importer
Argentina	105600	95840	Exporter	75400	37614	Exporter
Chile	19783	12830	Exporter	10000	5329	Exporter
Paraguay	3390	3390	Non-trader	370	370	Non-trader
Uruguay	65000	40623	Exporter	59000	31796	Exporter
Latin-Amer1	13947	13957	Importer	0	0	Non-trader
Latin-Amer2	5192	16658	Importer	0	0	Non-trader

Table 1. (cont'd) The production of sheep meat and wool in 70 regions and countries of the world

Country	Production of sheep meat 1990 (t)	Consumption of sheep meat 1990 (t)	Trade status 1990	Production of wool 1990 (t)	Consumption of wool 1990 (t)	Trade status 1990
Asia-developed	160876	263943	Importer	1970	43762	Importer
Australia	636797	471371	Exporter	716300	310415	Exporter
Canada	8679	22450	Importer	825	1529	Importer
USA	164650	181509	Importer	21436	45716	Importer
USSR	1000000	1110000	Importer	282600	305801	Importer
Japan	394	64453	Importer	0	114655	Importer
Developed1-2	910368	974459	Importer	138142	221675	Importer
Developed3-4	1307280	1073848	Exporter	375963	353893	Exporter

Source: FAO (1994a).

While Table 1 shows production levels for the whole of India, the economic evaluation includes production in Maharashtra only. World Bank (1994a,b) indicates that in 1992 Maharashtra had 6% of the total population of sheep and 9% of the goat population in India. The State of Maharashtra's shares in sheep population in India are used to approximate the State's share in the production of sheep. Similarly, the State of Maharashtra's share in the sheep population in India is used to approximate Maharashtra's share in wool production in India. The rest of India is excluded because the project focuses on Maharashtra. Nevertheless there may be technological spillovers to the rest of India and to other regions in the world, after the necessary adaptive research has been done. Thus, the estimates made here should be interpreted as conservative.

In Australia, the technology proposed in the project is likely to have varying applicability depending on the rainfall level and the degree of parasite control in the area. The project focuses on the Merino breed of sheep. In this paper Australia is divided into three zones developed by ABARE (1994): namely High rainfall zone, Medium rainfall zone (wheat–sheep zone) and low rainfall (pastoral) zone. Each zone is subdivided according to parasite control level.[1] Good parasite control is a result of farmers drenching—twice on average during summer—according to sheep worm burdens, plus occasional other treatments as required to keep sheep healthy in appearance. Drenches can range from 1 to 3 per year in the high rainfall areas. Poor parasite control is the practice of not drenching sheep in summer even when they show signs of worms.The different zones, their share in the sheep population of Australia and the percentages of Merino sheep in these zones are shown in Table 2.

The losses of sheep meat and wool due to worms and other parasites are higher for farmers who follow poor parasite control practices than on farms where better worm management practices are followed.

[1]These subdivisions are based on Besier (pers. comm., November 1994).

Table 2. Australia: Sheep production zones and their share in the sheep flock.

Zone described in terms of rainfall	Average size of flock per farm	No of farms	Sheep flock at 30 June 1993[a]	Sheep population in the rainfall zones[a](%)	Merino sheep in the zones[b](%)	Proportion of farmers with poor parasite control[c]	Proportion of farmers with good parasite control[c]
High rainfall zone	1424	29546	19032768	13.81%	81%	0.25	0.75
Medium rainfall zone	1782	43053	76720446	55.66%	92%	0.30	0.70
Low rainfall (pastoral zone)	4584	4152	42073504	30.53%	100%	0.50	0.50
Total			137826718	100%			

[a]ABARE (1994).
[b]Rudwick and Turnbull (1993).
[c]Besier (pers. comm., November 1994). The numbers in these columns give the proportion of farmers in a given zone who practice the different levels of parasite control.

2.2 The production of sheep meat and wool in India and Australia

The implementation of the solutions that this project proposes to the prolificacy and worm resistance problems in India and Australia has to take into account biological aspects of sheep meat and wool production.

In modelling the population dynamics in a sheep sector it is useful to distinguish between the breeding stock of sheep, the wool production stock of sheep and the turn-off inventory of sheep. The breeding sheep comprise the breeding ewes mated, whose primary function is to produce and rear lambs, and the rams.

The wool production stock comprises: the wethers, which are male sheep castrated usually when a few weeks old and before the development of secondary sex characteristics; the breeding and non-breeding ewes; and the lambs and hoggets (young sheep up to 2 years old). The turn-off inventory comprises: live sheep and lamb exports; sheep and lambs slaughtered for sale; sheep and lambs for graziers; and sheep and lamb deaths.

There are 2.9 million sheep in Maharashtra (Nimbkar 1994). Less than 1% of the rural households keep sheep (Rath 1992). In 1977 in Maharashtra, about 15 per cent of the rural households keeping sheep were either landless or marginal farmers with less than 0.4 ha of land, 51.5% of the sheep-keeping households had between 0.4 and 4 ha of land, and larger farmers with more than 4 ha each formed 33.5% of all sheep keeping households (Government of Maharashtra 1979). The sheep are raised mostly by the women of about 75,000 families whose standard of living is below the poverty line (ACIAR 1995). Large farmers keep sheep mainly for the manure.

Ewes are first mated at about 7 months of age and produce lambs after 5 months of pregnancy. For every 100 ewes mated only about 70 produce lambs in a given year, giving a lambing rate of 0.7 (Rath 1992). The lambs are weaned at about 6 months of age, just before they are mated. The lambing rate is given by the following equation:

$$L_r = (L_b - L_d)/E_m \quad (1)$$

where

L_r is the lambing rate;
L_b is the number of lambs born successfully;
L_d is the number of lambs that die before they are weaned or sold; and
E_m is the number ewes joined.

The low lambing rate in Maharashtra is the result of a combination of at least two factors: the low numbers of lambs born successfully and the high mortality rates of lambs. In Maharashtra the adult sheep mortality rate is currently about 7% compared with a lamb mortality of about 15% (ACIAR 1995). Gastrointestinal nematodes (worms) contribute to the high mortality rates in lambs (ACIAR 1995).

The approach proposed by the project is to improve the economics of sheep rearing in the State of Maharashtra, India by evaluation and improvement of existing Indian genetic resources. Of the 40 recognised sheep breeds, three (the Deccani, Bannur and Garole) will be investigated, because together they have traits which are important to meeting the objectives of the industry: adaptation to grazing harsh, arid, marginal lands; high prolificacy; high levels of resistance to disease; and superior quality carcasses and skins. The Deccani is a coarse-wool meat breed and the major breed of Maharashtra and the plateaux of southern India. The Bannur is a hair breed from Karnataka State in southern India, which produces a high quality carcass. The Garole is a highly prolific, probably disease-resistant breed of meat sheep currently found only in a small pocket of West Bengal and which is in danger of extinction. Flocks of these breeds are established at Nimbkar Agricultural Research Institute.

Ninety ewes of each of these breeds in a fully pedigreed flock will be mated in a design in which all combinations of breeds, pure and crossbred, can be compared. Lamb production will be measured as the weight of lamb produced per weight of ewe mated and lambs will be compared for their resistance to gastrointestinal parasites, if necessary after experimental infection. The experiment will be replicated over two years with a pilot study in year 1. To assess the potential importance of the Garole breed as a resource for the control of other important diseases in South Asia, lambs of appropriate genotypes from this project will be challenged with footrot and liver fluke at the site of the related ACIAR footrot project in Nepal.

Performance of these Indian breeds could be enhanced by use of nutritional technology developed in related ACIAR projects on sheep in the humid tropics, particularly supplementation with urea–molasses blocks. However, the majority of sheep in semi-arid Maharashtra are migratory and genetic approaches are a more practical option. The NARI extension network provides a good opportunity for the introduction of new feeding technologies to sheep during their non-migrating season.

An integral part of the evaluation of the Garole breed is to determine the genetic basis of its prolificacy. There are documented reasons to suggest that it may be controlled by the same single major gene found in Booroola Merinos and possibly in the Indonesian Thin-Tail breed. This hypothesis will be tested by a structured mating of Garole rams with Deccani ewes and measurement among the backcross ewe progeny of ovulation rate, litter size and co-segregation with DNA markers for the Booroola gene. In addition to the historical interest in perhaps establishing the source of the Booroola gene, single genes for prolificacy, and genetic markers to identify

them, have application throughout India and other countries where increased prolificacy is desirable. Segregation analysis using microsatellite markers will be conducted in Australia using DNA isolated in Maharashtra.

The major outcome of the research in Maharashtra will be knowledge of productivity and the genetic basis of productivity of these three breeds in a commercial environment. This will allow the design of a breeding strategy to improve prolificacy, frequency of lambing and parasite resistance by developing a synthetic crossbred, by within-breed selection or introgression of a major gene for prolificacy into other breeds.

The Garole, which is associated with a lambing rate of over 3, if crossed with the Deccani and the Bannur sheep is likely to introduce the prolificacy gene in the local breeds and raise the lambing rate to a minimum of 1.2 and a maximum of 2.1. It is likely to take 5 to 7 years to get the prolificacy gene through the flock in Maharashtra. The project if successful may reduce the mortality rates by 50% for both adult sheep and for lambs in Maharashtra. Thus, crossing the Deccani and Bannur sheep breed with the Garole may introduce both the prolificacy gene and the worm and disease resistance gene in the indigenous breeds. These two effects are reflected in a higher lambing rate for the sheep in Maharashtra.

2.3 Commodity prices and elasticities of demand and supply

FAO (1994b) reports that the 12 months average price of mutton and lamb in 1990 was US$1490/t and the 12 months average price of greasy wool was $US1764/t. In this paper we use the following prices:

Country	Price of sheep meat $A/t	Price of sheep wool $A/t
Australia	$1777	$5033
Maharashtra, India	$3000	$500

The prices for sheep meat and sheep wool in Australia were obtained from ABARE (1995). In the case of Maharashtra, price data were obtained from ACIAR (1995). The elasticities of demand and supply for sheep and wool for the 70 countries and regions in Appendix A were obtained from the ACIAR Economic Evaluation Unit’s database.

3. QUANTIFICATION OF THE WELFARE IMPACTS OF MORE PROLIFIC AND WORM-RESISTANT MEAT SHEEP

This section uses a simple sheep flock dynamics model to quantify the implications of:

- the impacts of this project on prolificacy and death rates;
- the effects on the dynamics of sheep flocks in Australia and Maharashtra, India; and
- the project's impacts on the costs of production of sheep meat products and wool in the two countries.

3.1 Maharashtra: sheep flock dynamics before and after research

To describe the benefits from research for farmers in Maharashtra, a herdsman owning a flock of 50 sheep is used as a basis for the analysis. Table 3 describes the structure of the herd used in the base-case analysis in Maharashtra before research. The herd has the following five components:

Rams older than one year

It is assumed that a herd includes one ram for every 50 ewes mated. A herdsman buys one ram when establishing the flock. Table 3 shows that before research the estimated death rate amongst rams in Maharashtra is about 7% (Rath 1992). Only about one in 5 rams older than one year is sold by the farmer every year. In the case of this small flock owner the number of rams older than one year sold each year is zero.

Ewes and wethers older than one year

Ewes older than one year make up about 39% of the flock. All of these ewes are mated each year. For every 100 ewes mated, 70 produce lambs (ACIAR 1995). This low lambing rate is the focus of the project, the aim being to increase prolificacy of sheep in Maharashtra. Ewes older than one year also have a death rate of about 7% (Rath 1992) and a sale rate of about 20% every year (ACIAR 1995).

One-year-old rams and ewes

This group of sheep is estimated to form about 33% of the flock, before research. The group has a death rate of about 7%. They have a death rate of about 7% in the first year, increasing at about 1% per annum until, in year 8 of the analysis, the death rate is about 15%. The main cause of death is worms and worm-related diseases. This group of sheep is a major source of income for the farmer with a sale rate of about 40% per annum (ACIAR 1995).

Lambs less than one year old

Lambs less than one year old are about 40% of the flock. An estimate of the number of lambs less than one year old is obtained by multiplying the lambing rate for ewes mated and the number of ewes mated. Lambs less than one year old are the most sensitive to worms and worm-related diseases. They have a death rate of about 15% in the first year, increasing by about 1% per annum, until in year 8 the deathrate amongst this category of sheep is about 23%.

Table 3. Maharashtra-India: sheep flock dynamics over 8 years without the research.

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0.007843	Rams older than 1 year									
	Bought	0.39	0	0	0	0	0	0	0	0
	Begin Nos	0.39	0	0	0	0	0	0	0	0
	Death rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	Deaths	0	0	0	0	0	0	0	0	0
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	0	0	0	0	0	0	0	0	0
	End Nos	0	0	0	0	0	0	0	0	0
0.392157	Ewes older than 1 year									
	Bought	20	5	5	5	5	5	5	5	5
	Begin Nos	20	20	20	20	20	20	20	20	20
	Ewes mated	20	20	20	20	20	20	20	20	20
	Lamb rate	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
	Death rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	Deaths	1	1	1	1	1	1	1	1	1
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	4	4	4	4	4	4	4	4	4
	End Nos	15	15	15	15	15	15	15	15	15
0	Wethers older than 1 year									
	Bought	0	0	0	0	0	0	0	0	0
	Begin Nos	0	0	0	0	0	0	0	0	0
	Death rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
	Deaths	0	0	0	0	0	0	0	0	0
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	0	0	0	0	0	0	0	0	0
	End Nos	0	0	0	0	0	0	0	0	0
0.32549	Rams, and ewes 1 year old									
	Bought	16	7	7	7	7	8	8	8	8
	Begin Nos	16	16	16	16	16	16	16	16	16
	Death rate	0.07	0.08	0.09	0.1	0.11	0.12	0.13	0.14	0.15
	Deaths	1	1	1	2	2	2	2	2	2
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	6.05	5.99	5.92	5.86	5.79	5.73	5.66	5.60	5.53
	End Nos	9	9	9	9	9	9	8	8	8
0.27451	Lambs less than 1 year old									
	Lambs born	14	14	14	14	14	14	14	14	14
	Death rate	0.15	0.16	0.17	0.18	0.19	0.2	0.21	0.22	0.23

Table 3. (cont'd) Maharashtra-India: sheep flock dynamics over 8 years without the research.

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Deaths	2	2	2	2	3	3	3	3	3
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	5	5	5	5	4	4	4	4	4
	End Nos	7	7	7	7	7	7	7	6	6
50	Flock size									
1.00	At begin	50	50	50	50	50	50	50	50	50
	Deaths	5	5	5	5	6	6	6	7	7
	Sales	14	14	14	14	14	14	14	14	13
	At end	31	31	31	30	30	30	30	30	30
	Bought	36	12	12	13	13	13	13	13	13
	Shorn	50	50	50	50	50	50	50	50	50
	Adults	36	36	36	36	36	36	36	36	36
	Output by weight									
	Carcass wt per sheep (kg)	11	11	11	11	11	11	11	11	11
	Wool cut per head (kg)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Meat (t)	0.158849	0.157529	0.156209	0.154889	0.153569	0.152249	0.150929	0.149609	0.148289
	Wool (t)	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125

The impact of research on the flock

Table 4 summarises the after-research flock structure and indicates the impact of research undertaken in project PN9422 in Maharashtra. If project PN9422 succeeds then the following impacts are expected:

- The death rates are likely to decrease for all categories of sheep. The largest decrease in mortality is expected to occur in sheep up to one year old. However, there is likely to be a lag before this impact occurs.
- The lambing rate is expected to increase from 0.7 to about 1.4. However, there is again likely to be a lag before this impact occurs.

These changes have the effect of increasing flock size, reducing annual mortality and thus increasing the number of animals being sold in Maharashtra.

3.2 Australia: sheep flock dynamics before and after research

Australia is divided into three zones (ABARE 1994), namely the pastoral zone, and the medium rainfall and high rainfall zones. The pastoral zone includes the arid and semi-arid regions of Australia, where land use is characterised by extensive grazing of native pastures. The medium rainfall zone is equivalent to the wheat–sheep zone in ABARE (1994). The high rainfall zone is less suitable for broadacre cropping but suitable for grazing and thus land in this zone is used largely for livestock production.

Table 4. Maharashtra-India: sheep flock dynamics over 8 years with the research.

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0.01	Rams older than 1 year									
	Bought	0.39	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	Begin Nos	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
	Death rate	0.07	0.07	0.07	0.07	0.07	0.065625	0.06125	0.056875	0.056875
	Deaths	0	0	0	0	0	0	0	0	0
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	0	0	0	0	0	0	0	0	0
	End Nos	0	0	0	0	0	0	0	0	0
0.39	Ewes older than 1 year	0	0.2	0.4	0.6	0.8	1	1	1	1
	Replacements	20	5	5	5	5	5	5	5	5
	Begin Nos	20	20	20	20	20	20	20	20	20
	Mated ewes	20	20	20	20	20	20	20	20	20
	Lamb rate	0.70	0.84	0.98	1.12	1.26	1.40	1.40	1.40	1.40
	Death rate	0.07	0.07	0.07	0.07	0.07	0.065625	0.06125	0.056875	0.056875
	Deaths	1	1	1	1	1	1	1	1	1
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	4	4	4	4	4	4	4	4	4
	End Nos	15	15	15	15	15	15	15	15	15
0.00	Wethers older than 1 year									
	Bought	0	0	0	0	0	0	0	0	0
	Begin Nos	0	0	0	0	0	0	0	0	0
	Death rate	0.07	0.07	0.07	0.07	0.07	0.065625	0.06125	0.056875	0.056875
	Deaths	0	0	0	0	0	0	0	0	0
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	0	0	0	0	0	0	0	0	0
	End Nos	0	0	0	0	0	0	0	0	0
0.33	Rams, and ewes 1 year old									
	Share in flock	0.33	0.27	0.22	0.16	0.11	0.05	0.05	0.05	0.05
	Bought	16	-3	-2	-4	-7	-9	-8	-8	-9
	Begin Nos	16	14	11	8	5	3	3	3	3
	Death rate	0.07	0.08	0.09	0.1	0.11	0.100625	0.09125	0.081875	0.081875
	Deaths	1.14	1.08	0.97	0.80	0.58	0.26	0.23	0.21	0.21
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	6	5	4	3	2	1	1	1	1
	End Nos	16	13	12	12	11	11	11	11	11
0.27	Lambs less than 1 year old									

Table 4. (cont'd) Maharashtra-India: sheep flock dynamics over 8 years with the research.

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Share in flock	0.27	0.33	0.38	0.44	0.49	0.55	0.55	0.55	0.55
	Lambs born	14	16	19	22	25	27	27	27	27
	Death rate	0.15	0.15	0.15	0.15	0.15	0.140625	0.13125	0.121875	0.121875
	Deaths	2.06	2.47	2.88	3.29	3.71	3.86	3.60	3.35	3.35
	Sale rate	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
	Sales	5	8	10	11	13	14	14	14	14
	End Nos	7	6	7	7	8	9	10	10	10
50	Flock size									
1.00	At begin	50	50	50	50	50	50	50	50	50
	Deaths	5	5	5	5	6	5	5	5	5
	Sales	14	17	17	18	18	19	19	19	19
	Bought	36	3	3	1	-1	-4	-3	-3	-4
	Shorn	50	50	50	50	50	50	50	50	50
	Adult	36	34	31	28	25	23	23	23	23
	Output by weight									
	Carcass wt per sheep (kg)	11	11	11	11	11	11	11	11	11
	Wool cut per head (kg)	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65
	Meat (t)	0.158849	0.188258	0.1919	0.195955	0.200252	0.206898	0.208894	0.21089	0.21089
	Wool (t)	0.120315	0.119375	0.11858	0.11793	0.117426	0.118112	0.11909	0.120067	0.120067
	Increase in wool cut	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

In Australia, the average flock size per farm in 1993 was 4584 sheep in the low rainfall pastoral zone, 1782 in the medium rain fall zone and 1424 in the high rainfall zone (ABARE 1994).

If the project is successful in revealing a genetic marker for worm-resistance in sheep it will be possible to change the breeding stock of sheep in Australia by breeding for worm resistance. This will have a number of benefits as indicated earlier.

To describe the benefits from research for farmers in Australia, three models of sheep flock dynamics are constructed for each one of the sheep producing zones in Australia.

- Table 5 shows the before-research flock dynamics for sheep in the pastoral zone of Australia, for a farmer owning a flock of about 4584 sheep;
- Table 6 shows the before research flock dynamics for sheep in the medium rainfall zone of Australia, for a farmer owning a flock of about 1782 sheep; and
- Table 7 shows the before research flock dynamics for sheep in the high rainfall zone of Australia, for a farmer owning a flock of about 1424 sheep.

Table 5. Australia-pastoral zone: sheep flock dynamics over 8 years without the research**.**

Herd structure	Sheep category		Year								
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0.01	Rams older than 1 year										
		Bought	37	8	8	8	8	8	8	8	8
		Begin Nos	37	37	37	37	37	37	37	37	37
		Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Deaths	1	1	1	1	1	1	1	1	1
		Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		Sales	7	7	7	7	7	7	7	7	7
		End Nos	29	29	29	29	29	29	29	29	29
0.40	Ewes older than 1 year										
		Bought	1,834	396	396	396	396	396	396	396	396
		Begin Nos	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834
	1	Mated ewes	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834
		Lamb rate	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
		Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Deaths	37	37	37	37	37	37	37	37	37
		Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		Sales	359	359	359	359	359	359	359	359	359
		End Nos	1,438	1,438	1,438	1,438	1,438	1,438	1,438	1,438	1,438
0.20	Wethers older than 1 year										
		Bought	917	378	378	378	378	378	378	378	378
		Begin Nos	917	917	917	917	917	917	917	917	917
		Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Deaths	18	18	18	18	18	18	18	18	18
		Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		Sales	359	359	359	359	359	359	359	359	359
		End Nos	539	539	539	539	539	539	539	539	539
0.04	Rams, ewes and wethers 1 year old										
		Bought	183	76	76	76	77	77	77	78	78
		Begin Nos	183	183	183	183	183	183	183	183	183
		Death rate	0.02	0.023	0.026	0.029	0.032	0.035	0.038	0.041	0.044
		Deaths	4	4	5	5	6	6	7	8	8
		Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		Sales	72	72	71	71	71	71	71	70	70
		End Nos	108	107	107	107	106	106	106	106	105
0.35	Lambs less than 1 year old										
		Lambs born	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614
		Death rate	0.2	0.203	0.206	0.209	0.212	0.215	0.218	0.221	0.224

Table 5. (cont'd) Australia-pastoral zone: sheep flock dynamics over 8 years without the research**.**

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Deaths	323	328	332	337	342	347	352	357	361
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	516	514	512	511	509	507	505	503	501
	End Nos	775	772	769	766	763	760	757	754	751
4584	Flock size									
1.02	At begin	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584
	Deaths	382	388	393	398	404	409	414	420	425
	Sales	1,314	1,312	1,310	1,308	1,306	1,303	1,301	1,299	1,297
	At end		2,884	2,881	2,878	2,875	2,872	2,868	2,865	2,862
	Bought	2,970	857	858	858	858	859	859	859	860
	Shorn	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584
	Adults	2,970	2,970	2,970	2,970	2,970	2,970	2,970	2,970	2,970
	Output by weight									
	Carcass wt per sheep (kg)	20	20	20	20	20	20	20	20	20
	Wool cut per head (kg)	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49
	Meat (t)	26.28	26.24	26.20	26.15	26.11	26.07	26.02	25.98	25.94
	Wool (t)	20.58	20.58	20.58	20.58	20.58	20.58	20.58	20.58	20.58

Table 6. Australia-medium rainfall zone: sheep flock dynamics over 8 years without the research.

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0.01	Rams older than 1 year									
	Bought	16	4	4	4	4	4	4	4	4
	Begin Nos	16	16	16	16	16	16	16	16	16
	Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Deaths	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	3	3	3	3	3	3	3	3	3
	End Nos	13	13	13	13	13	13	13	13	13
0.38	Ewes older than 1 year									
	Bought	677	146	146	146	146	146	146	146	146
	Begin Nos	677	677	677	677	677	677	677	677	677
	Mated ewes	677	677	677	677	677	677	677	677	677
	Lamb rate	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
	Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Deaths	14	14	14	14	14	14	14	14	14
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 6. (cont'd) Australia-medium rainfall zone: sheep flock dynamics over 8 years without the research.

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Sales	133	133	133	133	133	133	133	133	133
	End Nos	531	531	531	531	531	531	531	531	531
0.23	Wethers older than 1 year									
	Bought	410	169	169	169	169	169	169	169	169
	Begin Nos	410	410	410	410	410	410	410	410	410
	Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Deaths	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20	8.20
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	161	161	161	161	161	161	161	161	161
	End Nos	241	241	241	241	241	241	241	241	241
0.05	Rams, ewes and wethers 1 year old									
	Bought	83	34	34	35	35	35	36	36	36
	Begin Nos	83	83	83	83	83	83	83	83	83
	Death rate	0.02	0.026	0.032	0.038	0.044	0.05	0.056	0.062	0.068
	Deaths	2	2	3	3	4	4	5	5	6
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	32	32	32	32	32	31	31	31	31
	End Nos	49	48	48	48	48	47	47	47	46
0.33	Lambs less than 1 year old									
	Lambs born	596	596	596	596	596	596	596	596	596
	Death rate	0.2	0.206	0.212	0.218	0.224	0.23	0.236	0.242	0.248
	Deaths	119	123	126	130	133	137	141	144	148
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	191	189	188	186	185	184	182	181	179
	End Nos	286	284	282	280	277	275	273	271	269
1782	Flock size									
1.00	At begin	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1,782
	Deaths	143	147	151	155	159	163	167	171	175
	Sales	520	518	516	515	513	512	510	508	507
	At end	1,119	1,117	1,114	1,112	1,110	1,107	1,105	1,102	1,100
	Bought	1,186	353	353	353	354	354	354	355	355
	Shorn	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1,782
	Adults	1,186	1,186	1,186	1,186	1,186	1,186	1,186	1,186	1,186
	Output by weight									
	Carcass wt per sheep (kg)	20	20	20	20	20	20	20	20	20
	Wool cut per head (kg)	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49
	Meat (t)	10.39	10.36	10.33	10.30	10.26	10.23	10.20	10.17	10.13
	Wool (t)	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00

Table 7. Australia-high rainfall zone: sheep flock dynamics over 25 years without the research**.**

	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0.01	Rams older than 1 year									
	Bought	12	3	3	3	3	3	3	3	3
	Begin Nos	12	12	12	12	12	12	12	12	12
	Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Deaths	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	2	2	2	2	2	2	2	2	2
	End Nos	9	9	9	9	9	9	9	9	9
0.34	Ewes older than 1 year									
	Bought	484	105	105	105	105	105	105	105	105
	Begin Nos	484	484	484	484	484	484	484	484	484
	Mated ewes	484	484	484	484	484	484	484	484	484
	Lamb rate	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
	Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Deaths	10	10	10	10	10	10	10	10	10
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	95	95	95	95	95	95	95	95	95
	End Nos	380	380	380	380	380	380	380	380	380
0.31	Wethers older than 1 year									
	Bought	441	182	182	182	182	182	182	182	182
	Begin Nos	441	441	441	441	441	441	441	441	441
	Death rate	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Deaths	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83	8.83
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	173	173	173	173	173	173	173	173	173
	End Nos	260	260	260	260	260	260	260	260	260
0.04	Rams, ewes and wethers 1 year old									
	Bought	61	25	25	26	26	26	27	27	28
	Begin Nos	61	61	61	61	61	61	61	61	61
	Death rate	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1
	Deaths	1.21	1.82	2.43	3.04	3.64	4.25	4.86	5.46	6.07
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	24	24	23	23	23	23	22	22	22
	End Nos	36	35	35	35	34	34	34	33	33
0.30	Lambs less than 1 year old									
	Lambs born	426	426	426	426	426	426	426	426	426
	Death rate	0.2	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28

Table 7. (cont'd) Australia-high rainfall zone: sheep flock dynamics over 25 years without the research**.**

Sheep category		Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Deaths	85	89	94	98	102	107	111	115	119
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	136	135	133	131	130	128	126	124	123
	End Nos	205	202	199	197	194	192	189	187	184
1424	Flock size									
1.00	At begin	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424
	Deaths	105	110	115	120	125	130	134	139	144
	Sales	430	428	426	425	423	421	419	417	415
	At end	888	886	883	880	877	874	871	868	865
	Bought	998	314	314	315	315	315	316	316	317
	Shorn	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424
	Adults	998	998	998	998	998	998	998	998	998
	Output by weight									
	Carcass wt per sheep (kg)	20	20	20	20	20	20	20	20	20
	Wool cut per head (kg)	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49
	Meat (t)	8.61	8.57	8.53	8.49	8.45	8.41	8.37	8.33	8.30
	Wool (t)	6.39	6.39	6.39	6.39	6.39	6.39	6.39	6.39	6.39

The herds in the different zones have the following five components:

Rams older than one year

It is assumed that a herd includes two rams for every 100 ewes mated. A farmer buys 38 rams when establishing the flock. Tables 5–7 show that before research the death rate amongst rams is estimated at about 2% (Patten and Besier 1995b). Only about 1 in 5 rams older than one year is sold by the farmer every year (Patten and Besier 1995b).

Ewes older than one year

Ewes older than one year make up about 40% of the flock in the pastoral zone. In the medium rainfall zone, about 38% of the herd are ewes older than one year. However, in the high rainfall zone, only 34% of the sheep are ewes older than one year. Information on herd structure in Australia is obtained from Rudwick and Turnbull (1993). All of the ewes are mated each year (Patten and Besier 1995b). Ewes older than one year have a low death rate of about 2% and a sale rate of about 20% every year (Patten and Besier 1995b).

Wethers older than one year

Wethers older than one year are estimated at about 20% and 23% of the flock in pastoral and medium rainfall zones, respectively. In the high rainfall zone, wethers older than one year are estimated at about 34% of the flock (see Rudwick and Turnbull 1993). In the three zones, wethers have a death rate of about 2% and a sale rate of about 40%.

Rams, ewes and wethers one year old

This group of sheep is estimated to form 4– 5% of the flock, before research. The death rate of the group is about 2% in year one in the three zones. However, the changes in the death rates differ across the three zones. As worms develop resistance to drenches, it is assumed that the death rate in this category of the sheep flock will increase fastest in the high rainfall zone, slightly more slowly in the medium rainfall zone and slowest in the pastoral zone (Patten and Besier 1995b). These differential increases in the death rates are incorporated in the analysis in Tables 5–7. Thus, by year 8 in the analysis death rates for rams, ewes, and wethers one year old are estimated to be about 4.4%, 6.8%, and 10% in the pastoral, medium rainfall and high rainfall zones, respectively. In each one of the three zones farmers sells about 40% of sheep in this category (Patten and Besier 1995b).

Lambs less than one year old

Lambs less than one year old make up 30–35% of the flock in the three zones. An estimate of the number of lambs less than one year old is obtained by multiplying the lambing rate for ewes mated by the number of ewes mated. Lambs less than one year old are the most sensitive to worms and worm-related diseases. They have a death rate of about 20% in the first year, increasing by different amounts depending on the sheep production zone. Thus, by year 8 in the analysis, death rates for lambs less than one year old are estimated to be about 22.4%, 24.8%, and 28% in the pastoral, medium rainfall and high rainfall zones, respectively. In each one of the three zones, farmers sell about 40% of sheep in this category (Patten and Besier 1995b).

The impact of research on the flock

Tables 8–10 summarise the after-research flock structure and indicate the impact of research undertaken in project PN9422 in three sheep-production zones in Australia. If project PN9422 succeeds then the following impacts are expected:

- reduction in wool production losses;
- reduced mortality and morbidity of sheep, particularly amongst the lambs less than one year old. However, there is likely to be a lag before this impact occurs.
- reduced outlays on anthelmintics and reduced risk of worms developing resistance to chemicals. However, there is likely to be a lag before this impact occurs.
- reduced labour costs for drenching; and
- reduce sheep-meat production losses.

Table 8. Australia-pastoral zone: sheep flock dynamics over 8 years with the research.

	Sheep category		Year							
			0	**1**	**2**	**3**	**4**	**5**	**6**	**q7**	**8**
0.01	Rams older than 1 year										
		Bought	37	8	8	8	8	8	8	8	8
		Begin Nos	37	37	37	37	37	37	37	37	37
		Death rate	0.02	0.02	0.02	0.02	0.018	0.018	0.018	0.018	0.018
		Deaths	1	1	1	1	1	1	1	1	1
		Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		Sales	7	7	7	7	7	7	7	7	7
		End Nos	29	29	29	29	29	29	29	29	29
0.40	Ewes older than 1 year										
		Bought	1,834	396	396	396	396	393	393	393	393
		Begin Nos	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834
	1	Mated ewes	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834	1,834
		Lamb rate	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
		Death rate	0.02	0.02	0.02	0.02	0.018	0.018	0.018	0.018	0.018
		Deaths	37	37	37	37	33	33	33	33	33
		Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		Sales	359	359	359	359	360	360	360	360	360
		End Nos	1438	1438	1438	1438	1440	1440	1440	1440	1440
0.20	Wethers older than 1 year										
		Bought	917	378	378	378	378	377	377	377	377
		Begin Nos	917	917	917	917	917	917	917	917	917
		Death rate	0.02	0.02	0.02	0.02	0.018	0.018	0.018	0.018	0.018
		Deaths	18	18	18	18	17	17	17	17	17
		Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		Sales	359	359	359	359	360	360	360	360	360
		End Nos	539	539	539	539	540	540	540	540	540
0.04	Rams, ewes and wethers 1 year old										
		Bought	183	76	76	76	77	76	76	76	76
		Begin Nos	183	183	183	183	183	183	183	183	183
		Death rate	0.02	0.023	0.026	0.029	0.02639	0.024015	0.021854	0.019887	0.018097
		Deaths	4	4	5	5	5	4	4	4	3
		Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		Sales	72	72	71	71	71	72	72	72	72
		End Nos	108	107	107	107	107	107	108	108	108
0.35	Lambs less than 1 year old						0.92	0.91	0.9	0.89	0.88
		Lambs born	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614	1,614
		Death rate	0.2	0.203	0.206	0.209	0.1908	0.1935	0.1962	0.1989	0.2016
		Deaths	323	328	332	337	308	312	317	321	325

Table 8. (cont'd) Australia-pastoral zone: sheep flock dynamics over 8 years with the research.

	Sheep category		Year								
			0	**1**	**2**	**3**	**4**	**5**	**6**	**q7**	**8**
		Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		Sales	516	514	512	511	522	521	519	517	515
		End Nos	775	772	769	766	783	781	778	776	773
4584	Flock size										
1.00		At begin	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584
		Deaths	382	388	393	398	363	367	371	375	379
		Sales	1,314	1,312	1,310	1,308	1,321	1,320	1,318	1,316	1,315
		Bought	2,970	857	858	858	858	854	854	853	853
		Shorn	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584	4,584
		Adult	2,970	2,970	2,970	2,970	2,970	2,970	2,970	2,970	2,970
Output by weight											
Carcass wt per sheep (kg)			20	20	20	20	20	20	20	20	20
Wool cut per head (kg)			4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49	4.49
		Meat (t)	26.28	26.24	26.20	26.15	26.42	26.39	26.36	26.33	26.30
		Wool (t)	20.58	20.58	20.58	20.58	20.58	20.58	20.58	20.58	20.58

Table 9. Australia-medium rainfall zone: sheep flock dynamics over 8 years with the research**.**

	Sheep category		Year								
			0	**1**	**2**	**3**	**4**	**5**	**6**	**q7**	**8**
0.01	Rams older than 1 year										
		Bought	16	4	4	4	4	3	3	3	3
		Begin Nos	16	16	16	16	16	16	16	16	16
		Death rate	0.02	0.02	0.02	0.02	0.016	0.016	0.016	0.016	0.016
		Deaths	0.33	0.33	0.33	0.33	0.26	0.26	0.26	0.26	0.26
		Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		Sales	3.19	3.19	3.19	3.19	3.20	3.20	3.20	3.20	3.20
		End Nos	13	13	13	13	13	13	13	13	13
0.38	Ewes older than 1 year										
		Bought	677	146	146	146	146	144	144	144	144
		Begin Nos	677	677	677	677	677	677	677	677	677
		Mated ewes	677	677	677	677	677	677	677	677	677
		Lamb rate	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
		Death rate	0.02	0.02	0.02	0.02	0.016	0.016	0.016	0.016	0.016
		Deaths	13.54	13.54	13.54	13.54	10.83	10.83	10.83	10.83	10.83
		Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		Sales	132.72	132.72	132.72	132.72	133.27	133.27	133.27	133.27	133.27
		End Nos	531	531	531	531	533	533	533	533	533

Table 9. (cont'd) Australia-medium rainfall zone: sheep flock dynamics over 8 years with the research**.**

	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**q7**	**8**
0.23	Wethers older than 1 year									
	Bought	410	169	169	169	169	168	168	168	168
	Begin Nos	410	410	410	410	410	410	410	410	410
	Death rate	0.02	0.02	0.02	0.02	0.016	0.016	0.016	0.016	0.016
	Deaths	8.20	8.20	8.20	8.20	6.56	6.56	6.56	6.56	6.56
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	161	161	161	161	161	161	161	161	161
	End Nos	241	241	241	241	242	242	242	242	242
0.05	Rams, ewes and wethers 1 year old									
	Bought	83	34	34	35	35	35	34	34	34
	Begin Nos	83	83	83	83	83	83	83	83	83
	Death rate	0.02	0.026	0.032	0.038	0.0323	0.027455	0.023337	0.019836	0.016861
	Deaths	1.66	2.15	2.65	3.15	2.68	2.27	1.93	1.64	1.40
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	32.47	32.27	32.07	31.87	32.06	32.22	32.36	32.47	32.57
	End Nos	49	48	48	48	48	48	49	49	49
0.33	Lambs less than 1 year old									
	Lambs born	596	596	596	596	596	596	596	596	596
	Death rate	0.2	0.206	0.212	0.218	0.1792	0.184	0.1888	0.1936	0.1984
	Deaths	119	123	126	130	107	110	113	115	118
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	191	189	188	186	196	195	193	192	191
	End Nos	286	284	282	280	293	292	290	288	287
1782	Flock size									
1.00	At begin	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1.782
	Deaths	143	147	151	155	127	130	132	135	137
	Sales	520	518	516	515	525	525	524	522	521
	Bought	1,186	353	353	353	354	350	350	350	350
	Shorn	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1,782	1,782
	Adult	1,186	1,186	1,186	1,186	1,186	1,186	1,186	1,186	1,186
Output by weight										
Carcass wt per sheep (kg)		20.075	20.075	20.075	20.075	20.075	20.075	20.075	20.075	20.075
Wool cut per head (kg)		4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51	4.51
	Meat (t)	10.43	10.40	10.37	10.34	10.55	10.53	10.51	10.49	10.47
	Wool (t)	8.03	8.03	8.03	8.03	8.03	8.03	8.03	8.03	8.03

Table 10. Australia-high rainfall zone: sheep flock dynamics over 8 years with the research.

Herd structure	Sheep category	Year								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0.01	Rams older than 1 year									
	Bought	12	3	2	2	2	2	2	2	2
	Begin Nos	12	12	12	12	12	12	12	12	12
	Death rate	0.019375	0.01875	0.018125	0.0175	0.016875	0.01625	0.015625	0.015	0.015
	Deaths	0.23	0.22	0.21	0.20	0.20	0.19	0.18	0.17	0.17
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	2	2	2	2	2	2	2	2	2
	End Nos	9	9	9	9	9	9	9	9	9
0.34	Ewes older than 1 year									
	Bought	484	104	104	104	104	103	103	103	103
	Begin Nos	484	484	484	484	484	484	484	484	484
	Mated ewes	484	484	484	484	484	484	484	484	484
	Lamb rate	1	1	1	1	1	1	1	1	1
	Death rate	0.019	0.019	0.018	0.018	0.017	0.016	0.016	0.015	0.015
	Deaths	9	9	9	8	8	8	8	7	7
	Sale rate	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Sales	95	95	95	95	95	95	95	95	95
	End Nos	380	380	380	381	381	381	381	382	382
0.31	Wethers older than 1 year									
	Bought	441	182	182	181	181	181	181	181	181
	Begin Nos	441	441	441	441	441	441	441	441	441
	Death rate	0.019375	0.01875	0.018125	0.0175	0.016875	0.01625	0.015625	0.015	0.015
	Deaths	9	8	8	8	7	7	7	7	7
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	173	173	173	173	174	174	174	174	174
	End Nos	260	260	260	260	260	261	261	261	261
0.04	Rams, ewes and wethers 1 year old									
	Bought	61	25	25	25	25	25	25	25	25
	Begin Nos	61	61	61	61	61	61	61	61	61
	Death rate	0.019375	0.01875	0.018125	0.0175	0.016875	0.01625	0.015625	0.015	0.015
	Deaths	1	1	1	1	1	1	1	1	1
	Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Sales	24	24	24	24	24	24	24	24	24
	End Nos	36	36	36	36	36	36	36	36	36
0.30	Lambs less than 1 year old									
	Lambs born	426	426	426	426	426	426	426	426	426

Table 10. (cont'd) Australia-high rainfall zone: sheep flock dynamics over 8 years with the research.

Herd structure	Sheep category		Year								
			0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
		Death rate	0.1875	0.175	0.1625	0.15	0.1375	0.125	0.1125	0.1	0.1
		Deaths	80	75	69	64	59	53	48	43	43
		Sale rate	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
		Sales	138	141	143	145	147	149	151	153	153
		End Nos	208	211	214	217	220	224	227	230	230
1424	Flock size										
1.00		At begin	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424
		Deaths	99	93	87	81	75	69	64	58	58
		Sales	433	435	437	440	442	444	447	449	449
		Bought	998	314	313	313	312	312	311	311	310
		Shorn	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424	1,424
		Adult	998	998	998	998	998	998	998	998	998
Output by weight											
Carcass wt per sheep (kg)			21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Wool cut per head (kg)			4.7594	4.7594	4.7594	4.7594	4.7594	4.7594	4.7594	4.7594	4.7594
		Meat (t)	9.17	9.22	9.27	9.32	9.37	9.42	9.47	9.52	9.52
		Wool (t)	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78	6.78

These changes have the effect of increasing flock size, reducing the number of animals dying in any given year and thus a larger number of animals being sold in Maharashtra.

In Australia, the project affects only the worm resistance of sheep. The analysis takes into account two physical impacts of introducing worm resistance into a flock. First, the mortality rates of sheep are likely to decline. The potential impact of research in, say, Australia's pastoral zone can be seen by comparing Table 5 with Table 6. In the pastoral zone, where the benefits to research on worm resistance are lowest, it is assumed that there is likely to be a time lag after research, before the decline in mortality rates occurs. In Table 5, the death rates for rams older than 1 year is 0.02 from year 0 to year 8. In Table 6, for years 0 to 3, the death rate for rams older than 1 year is the same as in Table 5. This is the time lag of about four years before the mortality rates change. However, from year 4 to year 8, the mortality rates fall for all the categories of sheep in the flock.

Second, the introduction of sheep which are worm resistant may lead to changes in some of the production parameters—the carcass weight and the wool cut per head. These two parameters are assumed not to change in the case of Australia's pastoral zone.

In the case of medium rainfall and high rainfall zones of Australia, both the mortality rates and the production parameters for wool and sheep meat are assumed to change from year zero. A summary of the changes relating to the high rainfall zone (Tables 9 and 10) is tabulated below. A similar tabulation could be made from Tables 7 and 8 for the medium rainfall zone.

Sheep category	Australia—high rainfall zone		Australia—high rainfall zone	
	Before research – Table 9 Year 0	Before research – Table 9 Year 8	Before research – Table 10 Year 8	Before research – Table 10 Year 8
Rams older than 1 year	0.02	0.02	0.019	0.015
Ewes older than 1 year	0.02	0.02	0.019	0.015
Wethers older than 1 year	0.02	0.02	0.019	0.015
Rams, ewes and wethers 1 year old	0.02	0.01	0.019	0.015
Lambs less than 1 year old	0.20	0.28	0.19	0.10
Production parameters				
Carcass weight per sheep (kg)	20	20	21.2	21.2
Wool cut per head (kg)	4.49	4.49	4.76	4.76

The increase in production in the high rainfall zone is justified by:

- the fact that in Table 2, a very high proportion (75%) of farmers in the high rainfall zone have good parasite control; and
- the evidence in the literature which suggests that live-weight and wool production in worm-suppressed sheep is about 16% higher than in untreated sheep (see, for example, Besier 1992b).

3.3 Impact on the unit cost of production of sheep meat and wool in Maharashtra

The before-research costs of producing sheep meat and wool in Maharashtra are shown in Table 11. An outline of each of the main components of cost follows.

Table 11. Maharashtra–India: the cost of producing sheep meat, and wool before research.

Cost item	Year								
	0	1	2	3	4	5	6	7	8
Purchase sheep 22.5 @ $816									
Replacement sheep	$0	$277	$279	$281	$284	$286	$288	$290	$292
Annualised initial buy	$76	$76	$76	$76	$76	$76	$76	$76	$76
Annualised replacement	$0	$26	$26	$26	$27	$27	$27	$27	$27
Own-labour	$108	$108	$108	$108	$108	$108	$108	$108	$108
Hired labour	$54	$54	$54	$54	$54	$54	$54	$54	$54
Crutching	$0	$0	$0	$0	$0	$0	$0	$0	$0
Shearing	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sheep folding costs	($30)	($30)	($30)	($30)	($30)	($30)	($30)	($30)	($30)
Fodder	$119	$119	$119	$119	$119	$119	$119	$119	$119
Land rates	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital	$4	$4	$4	$4	$4	$4	$4	$4	$4
Rent	$5	$5	$5	$5	$5	$5	$5	$5	$5

Table 11. Maharashtra–India: the cost of producing sheep meat, and wool before research.

Cost item	Year								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total cost in year t	$337	$363	$363	$363	$363	$364	$364	$364	$364
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	$312	$311	$288	$267	$247	$229	$212	$197	$182
Total PV of costs – before research	$2,245								
Sheep meat (8 years) before research	1.38 t								
Wool (8 years) before research	1.13 t								
Sheep meat costs	$A1,796								
Wool costs	$A449								
Unit costs – before research – Maharashtra, India									
Sheep meat	$A1,299/t								
Wool	$A399/t								
Price of lamb	$A3000/t								
Price of wool	$A500/t								

[a]Folding services costs are negative because a sheep and goat owner is paid by field owners for having sheep grazing on the farmer's field

Purchase of sheep

The costs of sheep purchase has two components. The first one is the annualised cost (annualised at 8% per annum over the life of a sheep) of the initial purchase of the sheep in the establishment of the flock in the first year of the enterprise. The second is an annualised cost of replacing sheep. It is assumed that a sheep costs about 450 Indian rupees (Rath 1992) which gives a price of about $A22.50 assuming an exchange rate of 20 Indian rupees to $A1.

Own labour and hired labour

Walker and Ryan (1990) estimated the cost of regular farm servants employed in India to tend livestock at no more than 120 Indian Rupees per month in 1975–76 prices. Since the technology proposed in the project is likely to lead to larger flock sizes in Maharashtra, there may be increased demand on the owner's labour time. It is therefore necessary to impute the costs of owner-labour. The estimate of the costs of own labour and of hired labour for tending sheep in India are based on World Bank (1994a,b).

Crutching and shearing costs

It is assumed that these costs are close to zero in Maharashtra.

Sheep folding costs or revenue

For part of the year, owners of sheep in Maharashtra keep their livestock on properties other than their own. The livestock graze on these properties and their droppings are used as manure by the owners of the grazed fields. In return, the livestock owners are paid for the manure value of the livestock droppings. In Table 11, these payments are equal to the sheep folding costs and

are shown in the table as negative numbers because to the sheep owner they are a source of revenue. An alternative way of modelling sheep folding services is to treat them as one of the outputs of a sheep flock owner's activities and apportion a component of the total costs to these services. However, this approach is not adopted here because sheep folding services are less than 10% of a sheep flock owner's source of income (see ACIAR 1995).

Fodder costs

Estimates of the cost of fodder are based on Rath (1992). While some farmers buy cut-and-carry fodder, many farmers in Maharashtra do not incur outlays for fodder since they get feed for their livestock from either folding arrangements or other non-cash sources. For example, they feed the small ruminants on weeds from irrigated crops, crop residues, and stubble and the animals graze on poor quality grasses and shrubs on large tracts of marginal and degraded lands that are fit for little else (Nimbkar 1994). However, if the project increases flock sizes in Maharashtra, it is possible that feed could be a limiting factor. In this analysis, it is assumed that the project is not likely to lead to an increased demand for livestock feed.

Land rates

In Maharashtra, the rural households keeping sheep are assumed not to pay land rates, before or after research.

Capital costs

The costs include a small allowance for capital to cover the cost of tools and equipment (World Bank 1994a,b). This is a very small component of total cost.

Rent

The item on rent covers the cost of renting the enclosures for the sheep (World Bank 1994a,b). In 1977 in Maharashtra, about 15 per cent of the rural households keeping sheep were either landless or marginal farmers with less than 0.4 ha of land, 51.5% of the sheep keeping households had between 0.4 and 4 ha of land, and larger farmers with more than 4 ha each formed 33.5% of all sheep keeping households (Government of Maharashtra 1979). The sheep are raised mostly by the women of about 75,000 families whose standard of living is below the poverty line (ACIAR 1995).

Table 12 shows the impact of PN9422 on unit costs of producing sheep meat and sheep wool in Maharashtra.

Table 12. Maharashtra–India: the cost of producing sheep meat, and wool after research.

Cost item	Year								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Purchase sheep 22.5 @	$816	0	0	0	0	0	0	0	0
Replacement sheep	$0	$32	$36	$9	$0	$0	$0	$0	$0
Annualised initial buy	$76	$76	$76	$76	$76	$76	$76	$76	$76
Annualised replacement	$0	$3	$3	$1	$0	$0	$0	$0	$0
Own-labour	$108	$108	$108	$108	$108	$108	$108	$108	$108
Hired labour	$54	$54	$54	$54	$54	$54	$54	$54	$54

Table 12. (cont'd) Maharashtra–India: the cost of producing sheep meat, and wool after research.

Cost item	Year								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Crutching	$0	$0	$0	$0	$0	$0	$0	$0	$0
Shearing	$0	$0	$0	$0	$0	$0	$0	$0	$0
Sheep folding costs	($30)	($30)	($30)	($30)	($30)	($30)	($30)	($30)	($30)
Fodder	$119	$119	$119	$119	$119	$119	$119	$119	$119
Land rates	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital	$4	$4	$4	$4	$4	$4	$4	$4	$4
Rent	$5	$5	$5	$5	$5	$5	$5	$5	$5
Total cost in year t	$337	$340	$340	$337	$337	$337	$337	$337	$337
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	$312	$291	$270	$248	$229	$212	$196	$182	$168
Total PV of costs before research			$2,109						
Sheep meat output (8 years) before research			1.77 t						
Wool output (8 years) before research			1.07 t						
Sheep meat costs			$A1687/t						
Wool costs			$A422/t						
Unit costs – before research – Maharashtra India									
Sheep meat			$A952/t						
Wool			$394A/t						
Change in unit cost									
Sheep meat			$348						
Wool			$A5/t						
Price of lamb			$A3000/t						
Price of wool			$A500/t						

[a]Folding services costs are negative because a sheep and goat owner is paid by field owners for having sheep grazing on the farmer's field

3.4 Impact on the unit cost of production of sheep meat and wool in Australia

The before-research costs of producing sheep meat and wool in the pastoral, medium rainfall and high rainfall zones in Australia are shown in Tables 13–15, respectively. These costs are based on estimates by ABARE (1994). The main components of cost are as follows:

Purchase of sheep

The cost of sheep purchase has two components. The first is the annualised cost (at 8% per annum over the life of a sheep) of the initial purchase of the sheep in the establishment of the flock in the first year of the enterprise. The second is an annualised cost of replacing sheep. It is assumed that a sheep costs about $A12.60. The difference in the cost of purchasing sheep in the different zones (in Tables 13–15) is a reflection of differences in flock size in the three sheep production zones in Australia.

Own labour and hired labour

Estimates of the own labour cost in Australia are based on Elders (1994). The cost of hired labour is about $A10 per hour. In this paper estimates by ABARE (1994) are translated into cost of hired labour per animal in the different zones to give the following estimates:

Zone	Estimate of hired labour per animal based on ABARE (1994)
Pastoral zone	$A1.33
Medium rainfall zone	$A0.54
High rainfall zone	$A0.58

Estimates of hired labour in the three production zones are given by the product of the flock size and the estimated cost of hired labour per animal.

Crutching and shearing costs

Based on Patten and Besier (1995b), crutching costs and shearing costs are estimated at about $A0.60 per animal and $A2.85 per animal. Again differences in these costs in the three zones (Tables 13–15) are due to differences in flock sizes.

Table 13. Australia–pastoral zone: the cost of producing sheep meat and wool before research.

Cost item	Year								
	0	1	2	3	4	5	6	7	8
Purchase sheep 12.60555 @ $37,444									
Replacement sheep	$0	$10,806	$10,810	$10,814	$10,819	$10,823	$10,827	$10,831	$10,835
Annualised initial buy	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508
Annualised replacement	$0	$1,012	$1,013	$1,013	$1,013	$1,014	$1,014	$1,015	$1,015
Own-labour	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099
Hired labour	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118
Crutching	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750
Shearing	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064
Fertiliser	$0	$0	$0	$0	$0	$0	$0	$0	$0
Fodder	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006
Crop chemicals	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drenches adult animals	$505	$505	$505	$505	$505	$505	$505	$505	$505
Drenches lambs	$323	$323	$323	$323	$323	$323	$323	$323	$323
Land rates	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714
Capital	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858
Rent	$840	$840	$840	$840	$840	$840	$840	$840	$840
Fuel, oil, grease	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802

Table 13. (cont'd) Australia–pastoral zone: the cost of producing sheep meat and wool before research.

Cost item	Year								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Repairs	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324
Other materials	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095
Contracts	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484
Other services	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464
Other cash costs	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402
Total cost in year (t)	$182,355	$183,367	$183,368	$183,368	$183,369	$183,369	$183,369	$183,370	$183,370
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	$168,847	$157,208	$145,563	$134,781	$124,798	$115,554	$106,994	$99,069	$91,731
Total PV of costs before research		$1,144,544							
Sheep meat output – year total before research		235.00 t							
Wool output (eight year total) before research		185.24 t							
Sheep meat costs		$A343,363							
Wool costs		$A801,181							
Unit cost before research medium rainfall zone									
Sheep meat		$A1,461/t							
Wool		$A4,325/t							
Price of lamb		$A1777/t							
Price of wool		$A5033/t							

Table 14. Australia – medium rainfall zone: the cost of producing sheep meat and wool before research.

Cost item	Year								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Purchase sheep									
12.60555@	$14,951								
Replacement sheep	$0	$4,447	$4,451	$4,454	$4,458	$4,462	$4,466	$4,469	$4,473
Annualised initial buy	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401
Annualised replacement	$0	$417	$417	$417	$418	$418	$418	$419	$419
Own-labour	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310
Hired labour	$964	$964	$964	$964	$964	$964	$964	$964	$964
Crutching	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069
Shearing	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079

Table 14. (cont'd) Australia – medium rainfall zone: the cost of producing sheep meat and wool before research.

Cost item	Year								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Fertiliser	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204
Fodder	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400
Crop chemicals	$475	$475	$475	$475	$475	$475	$475	$475	$475
Drenches adults animals	$202	$202	$202	$202	$202	$202	$202	$202	$202
Drenches lambs	$119	$119	$119	$119	$119	$119	$119	$119	$119
Land rates	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040
Capital	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850
Rent	$266	$266	$266	$266	$266	$266	$266	$266	$266
Fuel, oil, grease	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575
Repairs	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902
Other materials	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641
Contracts	$894	$894	$894	$894	$894	$894	$894	$894	$894
Other services	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437
Other cash costs	$196	$196	$196	$196	$196	$196	$196	$196	$196
Total cost in year (t)	$76,024	$76,441	$76,441	$76,442	$76,442	$76,442	$76,443	$76,443	$76,443
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	$70,393	$65,536	$60,682	$56,187	$52,025	$48,172	$44,604	$41,300	$38,241
	$135,571								
Total PV of costs before research	$477,138								
Sheep meat output – year total before research	92.38 t								
Wool output (eight year total) before research	72.01 t								
Sheep meat costs	$A143,141								
Wool costs	$A333,996								
Unit cost before research medium rainfall zone									
Sheep meat	$A1,550/t								
Wool	$A4,638/t								
Price of lamb	$A1777/t								
Price of wool	$A5033/t								

Fertilizers

In the pastoral zone, farmers do not use fertilizers on sheep pastures. Thus, in Table 13 fertilizer costs are zero. In the medium rainfall zone, farmers can put on about 100 kg/ha of superphosphate at a cost of about $A200/t or $A20/ha. Assuming 8 dry sheep equivalent per hectare implies an average farm size of about 223 ha (= 1782 sheep/8). Total fertilizer costs are

estimated at $4460 per year. However, some of these fertilizers are for other crops. In the medium rainfall zone it is assumed that about half of the fertilzers are attributable to sheep meet and wool production, thus the estimate of $2204 for fertilizers in Table 15.

In the high rainfall zone (Tables 17 and 18) it is estimated that fertilizer costs attributable to sheep meat and wool are about $4300 per annum.

Fodder costs

The fodder costs are low in the pastoral zone, where farmers may occasionally buy feed. Feed cost in the medium and high rainfall zones is almost double that in the pastoral zone (Patten and Besier 1995b). Supplementary feed comprising of 20% lupin and 80% hay is often required in the medium and high rainfall zones for about 120 days. Total cost is estimated at about $A5400 per year.

Table 15. Australia – high rainfall zone: the cost of producing sheep meat and wool before research.

Cost item	**Year**								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Purchase sheep									
12.60555@	$12,580								
Replacement sheep	$0	$3,958	$3,962	$3,967	$3,972	$3,976	$3,981	$3,985	$3,990
Annualised initial buy	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178
Annualised replacement	$0	$371	$371	$372	$372	$372	$373	$373	$374
Own-labour	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891
Hired labour	$831	$831	$831	$831	$831	$831	$831	$831	$831
Crutching	$854	$854	$854	$854	$854	$854	$854	$854	$854
Shearing	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058
Fertiliser	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300
Fodder	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400
Crop chemicals	$287	$287	$287	$287	$287	$287	$287	$287	$287
Drenches adult animals	$722	$722	$722	$722	$722	$722	$722	$722	$722
Drenches lambs	$138	$138	$138	$138	$138	$138	$138	$138	$138
Land rates	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119
Capital	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061
Rent	$351	$351	$351	$351	$351	$351	$351	$351	$351
Fuel, oil, grease	$1,133	$1,133	$1,133	$1,133	$1,133	$1,133	$1,133	$1,133	$1,133
Repairs	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616
Other materials	$1,392	$1,392	$1,392	$1,392	$1,392	$1,392	$1,392	$1,392	$1,392
Contracts	$420	$420	$420	$420	$420	$420	$420	$420	$420
Other services	$3,835	$3,835	$3,835	$3,835	$3,835	$3,835	$3,835	$3,835	$3,835
Other cash costs	$413	$413	$413	$413	$413	$413	$413	$413	$413

Table 15. (cont'd) Australia – high rainfall zone: the cost of producing sheep meat and wool before research.

Cost item	Year								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total cost in year (t)	$65,000	$65,371	$65,371	$65,372	$65,372	$65,372	$65,373	$65,373	$65,374
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	$60,185	$56,045	$51,894	$48,050	$44,491	$41,196	$38,144	$35,319	$32,703
Total PV of costs before research		$408,027							
Sheep meat output –year total before research		76.06 t							
Wool output (eight year total) before research		57.54 t							
Sheep meat costs		$A122,408							
Wool costs		$A285,619							
Unit cost before research high rainfall zone									
Sheep meat		$A1,609/t							
Wool		$A4,964/t							
Price of lamb		$A1777/t							
Price of wool		$A5033/t							

Crop chemicals

Sheep farmers in the pastoral zones rarely use crop chemicals. In the medium rainfall zone (Table 14), it is assumed that farmers would probably use Glyphosate herbicide costing $12.60/ L and applied at about 350 L/ha. This is equivalent to a crop chemicals cost of about $A4.42/ ha. Assuming that about half of this is attributable to sheep meat and wool production implies that crop chemicals in the sheep enterprise are about $A2.21 per hectare or a total annual cost of about $A475. Crop chemical costs in the high rainfall zone (Table 15) are about half the cost estimate for the medium rainfall zone.

Drenches

It is rare for sheep farmers in the pastoral zone to use drenches, so it is estimated that drench costs are zero there. In the medium rainfall zone, it is assumed that sheep farmers drench their sheep once a year and use the following drenches: 'Ivermectin', 'Combination', and 'White' in some rotation each year. The price per head for the three drenches is as follows:

Drench	Price per head
Ivermectin	22 cents
Combination	5 cents
White	7 cents

Source: Estimates by Karen Patten based on experience in Western Australia

The average cost per head is about 11 cents per head of drench costs and about 6 cents per head in labour costs. The estimates in Table 14 are based on an estimate drenching costs of 17 cents per adult sheep. Some farmers in the medium rainfall zone use Ivermectin with Cydectin which is a more expensive combination of drenches and use them more frequently (up to three times a year).

In the high rainfall zone, (Table 15) sheep worms are a major constraint in sheep meat and wool production and thus costs of drenching sheep are higher than in the medium rainfall zone.

Farm system costs

The costs discussed so far relate more directly to the production of sheep meat and sheep wool. However, the sheep enterprise is often part of a larger set of farming activities which have to cover the joint costs of the farm system. The remaining estimates of cost in Tables 13–15 refer to the joint farm costs. Estimates of the contribution that the sheep enterprise makes to the joint costs are based on ABARE (1994). These estimates by ABARE are converted to costs per animal to give the following costs used in this paper:

Cost item	Cost per animal Pastoral zone	Cost per animal Medium rainfall zone	Cost per animal High rainfall zone
Land rates	$0.37	$0.58	$0.79
Capital costs	$1.71	$1.60	$2.15
Rent	$0.18	$0.15	$0.25
Fuel, oil, grease	$1.05	$1.45	$0.80
Repairs	$1.38	$1.63	$1.13
Other material	$0.89	$0.92	$0.98
Contracts	$0.32	$0.50	$0.29
Other services	$3.37	$4.17	$2.69
Other cash costs	$0.31	$0.11	$0.29

Source: Based on ABARE (1994)

ABARE (1994) provides estimates of farm costs for each sheep production zone. These farm system joint costs are distributed to the different farm activities in a zone in proportion to the contributions of the different activities to farm revenue. Each cost item attributed to the sheep enterprise is then divided by flock size in a zone to get an estimate of cost per animal.

Tables 16–18 show the impacts of PN9422 on unit costs of producing sheep meat and wool in Australia, in the pastoral zone, the medium rainfall zone and the high rainfall zone, respectively. The main change is that drench costs drop to zero as a result of more-widespread use of the worm-resistant sheep in the production of sheep meat and wool. All the other costs remain unchanged. However, the changes in the unit costs are also affected by changes in the flock dynamics and in yields summarised in Tables 3–10.

Comparing the before–research (Tables 11–14) and the after-research (Tables 15–18) unit costs leads to the following estimates of changes in units of producing livestock products:

Livestock product	Before-research costs	After-research costs	Change in unit cost
	$A/t	$A/t	$A/t
Wool costs			
Maharashtra	$399	$394	$5
Pastoral zone	$4325	$4306	$20
Medium rainfall zone	$4638	$4601	$36
High rainfall zone	$4694	$4918	$45
Sheep meat costs			
Maharashtra	$1299	$952	$348
Pastoral zone	$1461	$1444	$17
Medium rainfall zone	$1550	$1515	$35
High rainfall zone	$1609	$1526	$84

3.5 The biological lag effect of the research

It is likely to take a long time for the full effect of introducing a worm-resistant gene to have an impact in the total Australian flock.[2] Even when the research is successful, there is likely to be a biological lag effect. It is likely to take some time for the effect of the project to spread through the flock, even if the only constraint on the process is the biological aspects of the production system. It is assumed that the prolificacy effects are likely to spread faster in the flock than the worm resistance effects. That is why the entries for Australia with an emphasis on worm resistance differ from those of India where the research project is focused on prolificacy. The biological lag effects are estimated to be as follows:

Year	Maharashtra, India	Australia—fast rate of spread	Australia—slow rate of spread
1–9	0	0	0
10	0.2	0	0.05
11	0.3	0	0.07
13	0.5	0.1	0.09
14	0.6	0.2	0.11
15	0.7	0.3	0.13
16	0.8	0.4	0.15
17	0.9	0.5	0.17
18	0.9	0.52	0.19
19	0.9	0.54	0.21

[2]This statement is based on Dash (1986) who notes the following: ‘The heritability of resistance to infection with worm parasites is of the order od 0.3–0.4 (Windon and Dinnen 1984), so selective breeding for enhanced resistance is possible. However, the gains will not be rapid. One problem in initiating breeding programs is finding a genetic marker which will allow the more resistant animals to be easily identified’.

Year	Maharashtra, India	Australia—fast rate of spread	Australia—slow rate of spread
20	0.9	0.56	0.23
21	0.9	0.58	0.25
22	0.9	0.60	0.27
23	0.9	0.62	0.29
24	0.9	0.64	0.31
25	0.9	0.66	0.33
26	0.9	0.68	0.35
27	0.9	0.70	0.35
28	0.9	0.70	0.35
29	0.9	0.70	0.35
30	0.9	0.70	0.35

Thus, by the year 30, the prolific gene of the Garole breed of sheep is likely to have been introduced in 90% of the flock in Maharashtra.

Table 16. Australia–pastoral zone: the cost of producing sheep meat and wool after research

Cost item	Year								
	0	**1**	**2**	**3**	**43**	**5**	**6**	**7**	**8**
12.60555 @	$37,444								
Replacement sheep	$0	$10,806	$10,810	$10,814	$10,819	$10,763	$10,760	$10,757	$10,754
Annualised initial buy	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508	$3,508
Annualised replacement	$0	$1,012	$1,013	$1,013	$1,013	$1,008	$1,008	$1,008	$1,007
Own-labour	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099	$109,099
Hired labour	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118	$6,118
Crutching	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750	$2,750
Shearing	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064	$13,064
Fertiliser	$0	$0	$0	$0	$0	$0	$0	$0	$0
Fodder	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006	$3,006
Crop chemicals	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drenches adults	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drenches lambs	$0	$0	$0	$0	$0	$0	$0	$0	$0
Land rates	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714	$1,714
Capital	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858	$7,858
Rent	$840	$840	$840	$840	$840	$840	$840	$840	$840
Fuel, oil, grease	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802	$4,802
Repairs	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324	$6,324
Other materials	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095	$4,095
Contracts	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484	$1,484
Other services	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464	$15,464

Table 16. (cont'd) Australia–pastoral zone: the cost of producing sheep meat and wool after research

Cost item	Year								
	0	**1**	**2**	**3**	**43**	**5**	**6**	**7**	**8**
Other cash costs	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402	$1,402
Total cost in year t	$181,527	$182,540	$182,540	$182,540	$182,541	$182,536	$182,535	$182,535	$182,535
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	$168,081	$156,498	$144,906	$134,173	$124,234	$115,028	$106,508	$98,618	91312.86
Total PV of costs	$1,139,359								
Sheep meat output (over 8 years)	237 t								
Wool output (over 8 years)	185 t								
Sheep meat costs	$A341,808								
Wool costs	$A797,552								
Unit cost after research medium rainfall zone									
Sheep meat	$A1,444/t								
Wool	$A4,306/t								
Change in unit cost ($A/t)									
Sheep meat	$17								
Wool	$20								
Price of sheep meat	$1777								
Price of sheep wool	$5033								

Table 17. Australia–medium rainfall zone: the cost of producing sheep meat, and wool after research.

Cost item	Year								
	0	**1**	**2**	**3**	**43**	**5**	**6**	**7**	**8**
Purchase sheep									
12.60555 @	$14,951	0	0	0	0	0	0	0	0
Replacement sheep	$0	$4,447	$4,451	$4,454	$4,458	$4,414	$4,411	$4,409	$4,406
Annualised initial buy	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401	$1,401
Annualised replacement	$0	$417	$417	$417	$418	$414	$413	$413	$413
Own-labour	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310	$39,310
Hired labour	$964	$964	$964	$964	$964	$964	$964	$964	$964
Crutching	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069	$1,069
Shearing	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079	$5,079
Fertiliser	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204	$2,204
Fodder	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400
Crop chemicals	$475	$475	$475	$475	$475	$475	$475	$475	$475

Table 17. (cont'd) Australia–medium rainfall zone: the cost of producing sheep meat, and wool after research.

Cost item	Year								
	0	**1**	**2**	**3**	**43**	**5**	**6**	**7**	**8**
Drenches adults	$0	$0	$0	$0	$0	$0	$0	$0	$0
Drenches lambs	$0	$0	$0	$0	$0	$0	$0	$0	$0
Land rates	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040	$1,040
Capital	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850	$2,850
Rent	$266	$266	$266	$266	$266	$266	$266	$266	$266
Fuel, oil, grease	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575	$2,575
Repairs	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902	$2,902
Other materials	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641	$1,641
Contracts	$894	$894	$894	$894	$894	$894	$894	$894	$894
Other services	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437	$7,437
Other cash costs	$196	$196	$196	$196	$196	$196	$196	$196	$196
Total cost in year t	$75,703	$76,120	$76,120	$76,121	$76,121	$76,117	$76,117	$76,116	$76,116
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	$70,096	$65,261	$60,427	$55,951	$51,807	$47,967	$44,413	$41,123	$38,077
Total PV of costs	$475,121								
Sheep meat output		94 t							
Wool output		72 t							
Sheep meat costs		$A142,536							
Wool costs		$A332,585							
Unit costs-after res-medium rain zone									
Sheepmeat		$A1,515 /t							
Wool		$A4,601 /t							
Change in unit cost									
Sheep meat		$34.49							
Wool		$36.85							

Table 18. Australia–high rainfall zone: the cost of producing sheep meat, and wool after research

Cost item	Year								
	0	**1**	**2**	**3**	**43**	**5**	**6**	**7**	**8**
Purchase sheep									
12.60555 @	$12,580								
Replacement sheep	$0	$3,952	$3,947	$3,941	$3,936	$3,930	$3,925	$3,919	$3,914
Annualised initial buy	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178	$1,178

Table 18. (cont'd) Australia–high rainfall zone: the cost of producing sheep meat, and wool after research

Cost item	Year								
	0	**1**	**2**	**3**	**43**	**5**	**6**	**7**	**8**
Annualised replacement	$0	$370	$370	$369	$369	$368	$368	$367	$367
Own-labour	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891	$33,891
Hired labour	$1,293	$1,293	$1,293	$1,293	$1,293	$1,293	$1,293	$1,293	$1,293
Crutching	$854	$854	$854	$854	$854	$854	$854	$854	$854
Shearing	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058	$4,058
Fertiliser	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300	$4,300
Fodder	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400	$5,400
Crop chemicals	$446	$446	$446	$446	$446	$446	$446	$446	$446
Drenches adults	$578	$505	$433	$361	$289	$217	$144	$72	$0
Drenches lambs	$110	$97	$83	$69	$55	$41	$28	$14	$0
Land rates	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119	$1,119
Capital	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061	$3,061
Rent	$351	$351	$351	$351	$351	$351	$351	$351	$351
Fuel, oil, grease	$1,762	$1,762	$1,762	$1,762	$1,762	$1,762	$1,762	$1,762	$1,762
Repairs	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616	$1,616
Other materials	$1,311	$1,311	$1,311	$1,311	$1,311	$1,311	$1,311	$1,311	$1,311
Contracts	$653	$653	$653	$653	$653	$653	$653	$653	$653
Other services	$5,965	$5,965	$5,965	$5,965	$5,965	$5,965	$5,965	$5,965	$5,965
Other cash costs	$643	$643	$643	$643	$643	$643	$643	$643	$643
Total cost in year t	$68,591	$68,876	$68,789	$68,703	$68,616	$68,530	$68,443	$68,357	$68,270
Discount rate	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Time	1	2	3	4	5	6	7	8	9
Discount factor	1.08	1.1664	1.259712	1.360489	1.469328	1.586874	1.713824	1.85093	1.999005
Present value	63,511	59,050	54,607	50,499	46,699	43,185	39,936	36,931	34,152
Total PV of costs	428,569								
Sheep meat output over 8 years		84 t							
Wool output over 8 years		61 t							
Sheep meat costs		$A128,571							
Wool costs		$A299,999							
Unit costs-after res-high rain zone									
Sheep meat		$A1,526/t							
Wool		$A4,918/t							
Change in unit cost									
Sheepmeat		$84							
Wool		$45							
Price of sheep meat		1777							
Price of sheep wool		5033							

3.6 The adoption of the results from the project

In this project development assessment the ceiling adoption levels are obtained from ACIAR's database. However, the adoption levels for Australia are adjusted to allow for information about the proportion of farmers in the different zones who currently apply good parasite control practices. This leads to the following matrix of assumed adoption rates:

Adoption rates assumed in the analysis

Year No.	Year	Maharashtra (India)	Australia		
			Pastoral zone	Medium rainfall zone	High rainfall zone
1	1996	0	0	0	0
2	1997	0	0	0	0
3	1998	0	0	0	0
4	1999	0	0	0	0
5	2000	0	0	0	0
6	2001	0	0	0	0
7	2002	0	0	0	0
8	2003	0	0	0	0
9	2004	0	0	0	0
10	2005	0	0	0	0
11	2006	0	0	0	0
12	2007	0	0	0	0
13	2008	0	0	0	0
14	2009	0.2	0.1	0.14	0.15
15	2010	0.3	0.15	0.21	0.225
16	2011	0.4	0.2	0.28	0.3
17	2012	0.52	0.25	0.35	0.375
18	2013	0.52	0.25	0.35	0.45
19	2014	0.52	0.25	0.35	0.49
20	2015	0.52	0.25	0.35	0.53
21	2016	0.52	0.25	0.35	0.57
22	2017	0.52	0.25	0.35	0.61
23	2018	0.52	0.25	0.35	0.65
24	2019	0.52	0.25	0.35	0.69
25	2020	0.52	0.25	0.35	0.73
26	2021	0.52	0.25	0.35	0.73
27	2022	0.52	0.25	0.35	0.73
28	2023	0.52	0.25	0.35	0.73
29	2024	0.52	0.25	0.35	0.73
30	2025	0.52	0.25	0.35	0.73

Source:Estimates by project scientists.

3.7 Estimation of welfare benefits

Use is made of standard research evaluation equations in the estimation of welfare benefits. These equations have been discussed extensively elsewhere (see, for example, Alston et al. 1995; Davis et al. 1987). They are thus not discussed here. The equations used are for a situation where a technology changes the farm level unit cost of production for a commodity which is internationally traded, since sheep meat and wool are internationally traded commodities.

4. RESULTS

This section discusses the results of the project development assessment. In sub-section 4.1, the base–case results are discussed. The base case is based on the assumptions and data in Tables 1–18. Subsection 4.2 discusses sensitivity analyses where some of the assumptions made in the base case are varied to assess how sensitive the results in the paper are to the base-case assumptions.

4.1 Summary of results for the base case

A summary of the benefits from the project is given in three tables:

- Table 19 shows a summary of benefits attributable to sheep meat;
- Table 20 shows a summary of benefits attributable to sheep wool; and
- Table 21 shows the sum of benefits attributable to both sheep meat and sheep meat.

The project is estimated to generate a net present value of about $A19 million over a period of 30 years at a discount rate of 8% per annum. The internal rate of return to funds spent on the project is estimated to be 24 per cent.

The total potential benefits are distributed as follows:

Region or country benefiting from research	Benefits to producers of sheep meat	Benefits to producers of sheep wool	Total
Maharashtra, India	$A3.67m	$A0.01m	$A3.68m
Pastoral zone, Australia	$A 0.49m	$A0.58m	$A1.07m
Medium rainfall zone, Australia	$A3.29m	$A3.59m	$A6.88m
High rainfall zone, Australia	$A4.84m	$A2.57m	$A7.40m
Rest of the world	$A0.01m	$A0.00m	$A0.01m
Total	$A12.30m	$A6.74m	$A19.04m

The major beneficiaries are the sheep farmers in Australia in the high rainfall zone, followed by those in the medium rainfall zone and sheep producers in Maharashtra, India.

The rest of the world gains very little from the project. However, this is partly a result of the assumptions made in the base-case scenario. For example, it is assumed that the project is likely to affect production in Maharashtra State only, and will not have spillover effects to the rest of India and the rest of the world. This then means that because Maharashtra State is a minor

producer of global sheep products, the project does not have a major impact on the world price. This assumption is partially removed in the next section where one of the sensitivity analyses examines the implications of assuming that the technology from the project is equally applicable to the whole of India.

Table 19. A summary of the flow of aggregated benefits from impacts on sheep meat, from an ACIAR project entitled 'Prolific worm-resitant meat sheep for Maharashtra in India and Australia' (PN9422) $Amillion, 1995.

	Year	Maharashtra	Australia Pastoral zone	Australia Medium rainfall zone	Australia High rainfall zone	Rest of the world	Total benefits
1	1996	$0	$0	$0	$0	$0	$0
2	1997	$0	$0	$0	$0	$0	$0
3	1998	$0	$0	$0	$0	$0	$0
4	1999	$0	$0	$0	$0	$0	$0
5	2000	$0	$0	$0	$0	$0	$0
6	2001	$0	$0	$0	$0	$0	$0
7	2002	$0	$0	$0	$0	$0	$0
8	2003	$0	$0	$0	$0	$0	$0
9	2004	$0	$0	$0	$0	$0	$0
10	2005	$0	$0	$0	$0	$0	$0
11	2006	$0	$0	$0	$0	$0	$0
12	2007	$0	$0	$0	$0	$0	$0
13	2008	$0	$0	$0	$0	$0	$0
14	2009	$199	$0	$0	$0	$0	$199
15	2010	$447	$45	$307	$189	$1	$989
16	2011	$795	$91	$614	$379	$1	$1,880
17	2012	$1,344	$152	$1,024	$633	$2	$3,153
18	2013	$1,344	$190	$1,283	$950	$2	$3,768
19	2014	$1,344	$190	$1,283	$1,245	$2	$4,063
20	2015	$1,344	$190	$1,283	$1,467	$2	$4,285
21	2016	$1,344	$190	$1,283	$1,706	$2	$4,525
22	2017	$1,344	$190	$1,283	$1,964	$2	$4,783
23	2018	$1,344	$190	$1,283	$2,240	$2	$5,059
24	2019	$1,344	$190	$1,283	$2,535	$2	$5,353
25	2020	$1,344	$190	$1,283	$2,847	$2	$5,666
26	2021	$1,344	$190	$1,283	$3,017	$2	$5,836
27	2022	$1,344	$190	$1,283	$3,017	$2	$5,836
28	2023	$1,344	$190	$1,283	$3,017	$2	$5,836
29	2024	$1,344	$190	$1,283	$3,017	$2	$5,836
30	2025	$1,344	$190	$1,283	$3,017	$2	$5,836
PV in $Am		$3.67	$0.49	$3.29	$4.84	$0.01	$12.30

[a]PV stands for present values of benefits discounted at 8% over 30 years.

Table 20. A summary of the flow of aggregated benefits from impacts on sheep wool, from an ACIAR project entitled 'Prolific worm-resitant meat sheep for Maharashtra in India and Australia' (PN9422) $A, millions, 1995.

	Year	Maharashtra	Australia Pastoral zone	Australia Medium rainfall zone	Australia High rainfall zone	Rest of the world	Total benefits
1	1996	$0	$0	$0	$0	$0	$0
2	1997	$0	$0	$0	$0	$0	$0
3	1998	$0	$0	$0	$0	$0	$0
4	1999	$0	$0	$0	$0	$0	$0
5	2000	$0	$0	$0	$0	$0	$0
6	2001	$0	$0	$0	$0	$0	$0
7	2002	$0	$0	$0	$0	$0	$0
8	2003	$0	$0	$0	$0	$0	$0
9	2004	$0	$0	$0	$0	$0	$0
10	2005	$0	$0	$0	$0	$0	$0
11	2006	$0	$0	$0	$0	$0	$0
12	2007	$0	$0	$0	$0	$0	$0
13	2008	$0	$0	$0	$0	$0	$0
14	2009	$2	$0	$0	$0	$0	$2
15	2010	$2	$38	$233	$72	$0	$345
16	2011	$3	$85	$524	$161	$0	$773
17	2012	$3	$150	$931	$287	$0	$1,371
18	2013	$3	$235	$1,455	$448	$0	$2,141
19	2014	$3	$235	$1,455	$645	$1	$2,338
20	2015	$3	$235	$1,455	$765	$1	$2,458
21	2016	$3	$235	$1,455	$895	$1	$2,588
22	2017	$3	$235	$1,455	$1,035	$1	$2,728
23	2018	$3	$235	$1,455	$1,185	$1	$2,878
24	2019	$3	$235	$1,455	$1,346	$1	$3,039
25	2020	$3	$235	$1,455	$1,516	$1	$3,210
26	2021	$3	$235	$1,455	$1,697	$1	$3,391
27	2022	$3	$235	$1,455	$1,697	$1	$3,391
28	2023	$3	$235	$1,455	$1,697	$1	$3,391
29	2024	$3	$235	$1,455	$1,697	$1	$3,391
30	2025	$3	$235	$1,455	$1,697	$1	$3,391
PV in $Am		$0.01	$0.58	$3.59	$2.57	$0.00	$6.74

aPV stands for present values of benefits discounted at 8% over 30 years.

Table 21. A summary of research costs and the flow of aggregated benefits from impacts on sheep meat and sheep wool, from an ACIAR project entitled Prolific worm-resitant meat sheep for Maharashtra in India and Australia (PN9422) $Amillion, 1995.

	Year	Maharashtra	Australia Pastoral zone	Australia Medium rainfall zone	Australia High rainfall zone	Rest of the world	Total benefits	Research costs	Net benefits
1	1996	$0	$0.00	$0	$0.00	$0	$0	521.594	($522)
2	1997	$0	$0.00	$0	$0.00	$0	$0	448.063	($448)
3	1998	$0	$0.00	$0	$0.00	$0	$0	454.46	($454)
4	1999	$0	$0.00	$0	$0.00	$0	$0	0	$0
5	2000	$0	$0.00	$0	$0.00	$0	$0	0	$0
6	2001	$0	$0.00	$0	$0.00	$0	$0	0	$0
7	2002	$0	$0.00	$0	$0.00	$0	$0	0	$0
8	2003	$0	$0.00	$0	$0.00	$0	$0	0	$0
9	2004	$0	$0.00	$0	$0.00	$0	$0	0	$0
10	2005	$0	$0.00	$0	$0.00	$0	$0	0	$0
11	2006	$0	$0.00	$0	$0.00	$0	$0	0	$0
12	2007	$0	$0.00	$0	$0.00	$0	$0	0	$0
13	2008	$0	$0.00	$0	$0.00	$0	$0	0	$0
14	2009	$201	$0.02	$0	$0.01	$0	$201	0	$201
15	2010	$450	$83.09	$539	$260.60	$1	$1,333	0	$1,333
16	2011	$798	$175.63	$1,138	$540.15	$1	$2,652	0	$2,652
17	2012	$1,347	$302.16	$1,955	$919.17	$2	$4,525	0	$4,525
18	2013	$1,347	$424.93	$2,738	$1,397.85	$2	$5,909	0	$5,909
19	2014	$1,347	$424.94	$2,738	$1,889.77	$2	$6,401	0	$6,401
20	2015	$1,347	$424.94	$2,738	$2,231.22	$3	$6,743	0	$6,743
21	2016	$1,347	$424.94	$2,738	$2,600.99	$3	$7,113	0	$7,113
22	2017	$1,347	$424.94	$2,738	$2,999.08	$3	$7,511	0	$7,511
23	2018	$1,347	$424.94	$2,738	$3,425.49	$3	$7,937	0	$7,937
24	2019	$1,346	$424.94	$2,737	$3,880.22	$3	$8,392	0	$8,392
25	2020	$1,346	$424.94	$2,737	$4,363.28	$3	$8,875	0	$8,875
26	2021	$1,346	$424.95	$2,737	$4,714.58	$3	$9,227	0	$9,227
27	2022	$1,346	$424.95	$2,737	$4,714.58	$3	$9,227	0	$9,227
28	2023	$1,346	$424.95	$2,737	$4,714.58	$3	$9,227	0	$9,227
29	2024	$1,346	$424.95	$2,737	$4,714.58	$3	$9,227	0	$9,227
30	2025	$1,346	$424.95	$2,737	$4,714.58	$3	$9,227	0	$9,227
NPV in $A,m 1991		$3.68	$1.07	$6.88	$7.40	$0.01	$19.04	$1.23	$17.81
Internal rate of return		na	na	na	na	na	na	na	24%

[a]NPV stands for present values of net benefits discounted at 8% over 30 years.

4.2 Sensitivity analyses

This section discusses the following sensitivity analyses:

- what would happen if the unit cost reduction is only a tenth of that assumed in the base case because in India, for example, the lambing rate is increased by lower amounts than those assumed in the base case?
- what would happen if the unit cost reduction is only a tenth of that assumed in the base case because in Australia, for example, the impact on mortality rates assumed in the base case is not realised?
- what would happen if the technology is applicable to the whole of India?
- the probability of success.

As expected, the present value of benefits is sensitive to changes in the lambing rate and the internal rate of return does not change much with changes in these two parameters. However, when the impact of the project is assumed to be applicable in India beyond the State of Maharashtra, both the present value of benefits and the internal rate of return associated with the project increase significantly.

Similarly, reducing the unit cost saving in Australia reduces the net benefits and the internal rate of return of the project.

A key parameter in the estimation of potential impacts of research is the probability of success of the project. The chances of the research being successful can depend on a range of factors, for example: the international level of knowledge of the issue being researched relevant to the particular production environment; the capacity of the research group to address the research issues; and the facilities and resources available to the group. Quantification of the chance of research success can be complex. It can be measured as a simple 0–1 index or as a probability distribution. In this study it is assumed that the project has a probability of success of one. However, if the probability of success is lower then the expected benefits are correspondingly lower. In particular, if the project fails, implying a probability of success of zero, the expected net benefits from the project will be negative and the rate of return will be negative.

5. CONCLUDING REMARKS

This paper has discussed a project development assessment of a proposal to develop sustainable production systems for small ruminants in India and Australia. The assessment takes into account the following. If the project succeeds in India, then cross-breeding the Deccani and Bannur sheep with the Garole sheep will increase prolificacy of the sheep in Maharashtra. The lambing rate and kidding rates are likely to increase in the Maharashtra. If the Garole is also disease-resistant then this project is likely to reduce mortality rates of sheep in Maharashtra.

In Australia, discovery of a genetic marker for worm-resistance in sheep will make it possible to breed for worm resistance. This will have a number of benefits, including reduced mortality and morbidity of sheep—particularly amongst the lambs less than one year old, reduced outlays on anthelmintics and reduced risk of worms developing resistance to chemicals.

The effects of the project in both India and Australia are likely to require additional outlays for the farmers, so total costs are likely to increase. However, total farm level output is likely to increase which in turn is likely to lead to a reduction in the cost of producing sheep meat and wool in India and Australia.

After taking into account the cost of research, this paper concludes that the project, over a 30-year time horizon and assuming a discount rate of 8% per annum, is likely to lead to net present value (NPV) of $A19 million and an internal rate of return (IRR) of about 24%. These estimates of NPV and IRR do not take into account the possible additional benefits from technological spillovers to the rest of India and to other regions of the world.

A much higher internal rate of return is possible if it is assumed that the project results are applicable to the whole of India. However, this extension to the whole of India needs to be made with caution since the costs on which this analysis is based are for Maharashtra as opposed to whole of India.

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APPENDIX A COUNTRIES USED IN THE RESEARCH EVALUATION MODEL

	Country or region name	Geographical region	Region or country code	Region name to which a country is aggregated
1	Bangladesh	1	102	
2	Bhutan	1	103	
3	India	1	104	
4	Nepal*	1	105	
5	Pakistan	1	106	
6	Sri Lanka	1	107	
7	Burma	2	201	
8	Indonesia	2	202	
9	Timor/east Timor	2	202	
10	Kampuchea (Cambodia)	2	203	
11	Laos, Pdr*	2	204	
12	Malaysia	2	205	
13	Philippines	2	206	
14	Thailand	2	207	
15	Vietnam	2	208	
16	China	3	301	
17	Mongolia*	3	302	
18	Fiji	4	401	
19	Papua New Guinea	4	403	
20	Samoa (Western)	4	404	
21	Solomon Is.*	4	405	
22	Tonga*	4	406	
23	Vanuatu / New Hebrides)	4	408	
24	Christmas Is.	4	420	Spac-other
25	Cocos Is.	4	420	Spac-other
26	Cook Is.	4	420	Spac-other
27	Guam	4	420	Spac-other
28	Kiribati, Rep.	4	420	Spac-other
29	Nauru	4	420	Spac-other
30	New Caledonia	4	420	Spac-other
31	Niue	4	420	Spac-other
32	Polynesia,french	4	420	Spac-other
33	Samoa,American	4	420	Spac-other
34	Tokelau	4	420	Spac-other
35	Tr Terr Pacific	4	420	Spac-other
36	Tuvalu	4	420	Spac-other

Countries used in the research evaluation model

	Country or region name	Geographical region	Region or country code	Region name to which a country is aggregated
37	Wallis & Futura	4	420	Spac-other
38	Ethiopa*	5	501	
39	Kenya	5	502	
40	Malawi	5	503	
41	Mozambique*	5	504	
42	Tanzania	5	505	
43	Uganda	5	506	
44	Zambia	5	507	
45	Zimbabwe	5	508	
46	Zaire	5	509	
47	Ivory Coast	5	510	
48	Ghana	5	511	
49	Nigeria	5	512	
50	Cameroon	5	513	
51	Angola*	5	514	
52	Madagascar	5	515	
53	Sudan*	5	516	
54	Cape Verde*	5	522	Africa-2
55	Chad*	5	522	Africa-2
56	Djibouti	5	522	Africa-2
57	Gambia	5	522	Africa-2
58	Mali	5	522	Africa-2
59	Mauritania	5	522	Africa-2
60	Niger	5	522	Africa-2
61	Senegal	5	522	Africa-2
62	Somalia	5	522	Africa-2
63	St Helena	5	522	Africa-2
64	Upp.volta	5	522	Africa-2
65	Benin	5	523	Africa-3
66	Guinea*	5	523	Africa-3
67	Guinea-bissa	5	523	Africa-3
68	Liberia	5	523	Africa-3
69	Sierra Leone	5	523	Africa-3
70	Togo	5	523	Africa-3
71	Central Africa	5	524	Africa-4
72	Congo Pr	5	524	Africa-4
73	Equatorial Guinea	5	524	Africa-4
74	Gabon*	5	524	Africa-4

Countries used in the research evaluation model

	Country or region name	Geographical region	Region or country code	Region name to which a country is aggregated
75	Sao Tome	5	524	Africa-4
76	Burundi	5	525	Africa-5
77	Rwanda	5	525	Africa-5
78	Botswana*	5	526	Africa-6
79	Lesotho*	5	526	Africa-6
80	Namibia*	5	526	Africa-6
81	Swaziland*	5	526	Africa-6
82	Comoros*	5	527	Africa-7
83	Maldives	5	527	Africa-7
84	Mauritius	5	527	Africa-7
85	Reunion	5	527	Africa-7
86	Seychelles*	5	527	Africa-7
87	Turkey	6	600	
88	Egypt, Arab Republic	6	601	
89	Algeria	6	610	Africa-1
90	Libyan Arab Republic	6	610	Africa-1
91	Morocco	6	610	Africa-1
92	Tunisia	6	610	Africa-1
93	Western Sahara	6	610	Africa-1
94	Afghanistan*	6	620	Wa/na Other
95	Iran*	6	620	Wa/na Other
96	Iraq*	6	620	Wa/na Other
97	Jordan*	6	620	Wa/na Other
98	Lebanon*	6	620	Wa/na Other
99	Syria	6	620	Wa/na Other
100	Yemen Arab Republic	6	620	Wa/na Other
101	Yemen PDR	6	620	Wa/na Other
102	Brazil	7	701	
103	Colombia	7	702	
104	Peru	7	703	
105	Venezuela	7	704	
106	Bolivia	7	705	
107	Ecuador	7	706	
108	Mexico	7	707	
109	Argentina	7	708	
110	Chile	7	709	
111	Paraguay	7	710	
112	Uruguay	7	711	

Countries used in the research evaluation model

	Country or region name	Geographical region	Region or country code	Region name to which a country is aggregated
113	Costa Rica	7	712	Latin-amer1
114	Cuba	7	712	Latin-amer1
115	Dominican Rep.	7	712	Latin-amer1
116	El Salvador*	7	712	Latin-amer1
117	Guatemala	7	712	Latin-amer1
118	Haiti	7	712	Latin-amer1
119	Honduras	7	712	Latin-amer1
120	Nicaragua*	7	712	Latin-amer1
121	Panama	7	712	Latin-amer1
122	Suriname	7	712	Latin-amer1
123	Antigua	7	713	Latin-amer2
124	Bahamas	7	713	Latin-amer2
125	Barbados	7	713	Latin-amer2
126	Belize*	7	713	Latin-amer2
127	Bermuda	7	713	Latin-amer2
128	Br.virgin Is	7	713	Latin-amer2
129	Cayman Is	7	713	Latin-amer2
130	Dominica	7	713	Latin-amer2
131	Grenada*	7	713	Latin-amer2
132	Guadeloupe	7	713	Latin-amer2
133	Guiana,french	7	713	Latin-amer2
134	Guyana	7	713	Latin-amer2
135	Jamaica	7	713	Latin-amer2
136	Martinique	7	713	Latin-amer2
137	Montserrat	7	713	Latin-amer2
138	Neth Antilles	7	713	Latin-amer2
139	St Kitts-	7	713	Latin-amer2
140	St Lucia*	7	713	Latin-amer2
141	St Pierre	7	713	Latin-amer2
142	St Vincent	7	713	Latin-amer2
143	Trinidad & Tobago	7	713	Latin-amer2
144	Turks & Caic	7	713	Latin-amer2
145	Bahrain	8	820	Asia-developed
146	Brunei	8	820	Asia-developed
147	Gaza Strip	8	820	Asia-developed
148	Hong Kong	8	820	Asia-developed
149	Israel	8	820	Asia-developed
150	Korea, DPR*	8	820	Asia-developed

Countries used in the research evaluation model

	Country or region name	Geographical region	Region or country code	Region name to which a country is aggregated
151	Korea, Rep.	8	820	Asia-developed
152	Kuwait*	8	820	Asia-developed
153	Macao*	8	820	Asia-developed
154	Oman	8	820	Asia-developed
155	Qatar	8	820	Asia-developed
156	Saudi Arabia	8	820	Asia-developed
157	Singapore*	8	820	Asia-developed
158	Taiwan	8	820	Asia-developed
159	United Arab Rep.	8	820	Asia-developed
160	Australia	9	901	
161	Canada	9	902	
162	USA	9	905	
163	USSR	9	906	
164	Japan	9	907	
165	Albania*	9	921	Developed1-2
166	Cyprus*	9	921	Developed1-2
167	Greece	9	921	Developed1-2
168	Italy	9	921	Developed1-2
169	Portugal	9	921	Developed1-2
170	South Africa	9	921	Developed1-2
171	Spain	9	921	Developed1-2
172	Yugoslavia	9	921	Developed1-2
173	Austria	9	922	Developed1-2
174	Bulgaria	9	922	Developed1-2
175	Czechoslovakia	9	922	Developed1-2
176	Hungary	9	922	Developed1-2
177	Romania*	9	922	Developed1-2
178	Switzerland	9	922	Developed1-2
179	Belgium-luxe	9	923	Developed3-4
180	Denmark	9	923	Developed3-4
181	France	9	923	Developed3-4
182	German,Dem R	9	923	Developed3-4
183	Germany Fr	9	923	Developed3-4
184	Netherlands	9	923	Developed3-4
185	New Zealand	9	923	Developed3-4
186	Poland	9	923	Developed3-4
187	United Kingdom	9	923	Developed3-4
188	Faeroe Is	9	924	Developed3-4

Countries used in the research evaluation model

	Country or region name	Geographical region	Region or country code	Region name to which a country is aggregated
189	Falkland Is	9	924	Developed3-4
190	Finland	9	924	Developed3-4
191	Greenland	9	924	Developed3-4
192	Iceland	9	924	Developed3-4
193	Ireland, Republic	9	924	Developed3-4
194	Malta	9	924	Developed3-4
195	Norfolk Is.	9	924	Developed3-4
196	Norway	9	924	Developed3-4
197	Puerto Rico	9	924	Developed3-4
198	Sweden	9	924	Developed3-4

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