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NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Composition of the National Sheep Flock and Specification of Equilibrium Prices and Quantities for the Australian Sheep and Wool Industries, 2002-03 to 2004-05

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Abstract
The data used, and the methods and assumptions fundamental to the development of an equilibrium displacement model (EDM) of the Australian sheep and wool industries specified in Mounter *et al*. (2007), are contained in this report. The national sheep flock is disaggregated into Merino and non-Merino sheep in the three agricultural zones of Australia using 2002-03 Australian agricultural and grazing industries survey data. Opening and closing sheep numbers, death rates and weaning percentages were used to derive the supply and use of sheep in each zone. Annual shorn wool production was split into four fibre-diameter categories in each zone corresponding to ABS wool export categories. Wool production percentages and relative greasy fleece weights were used to estimate the quantities of wool attributable to ewes, wethers and hoggets in each zone. Estimates were also constructed of lamb, mutton and live sheep export volumes produced from the different sheep enterprises in each agricultural zone. As the flock composition data are based on 2002-03 figures, aggregate production and export data for 2002-03 were used to validate the methods involved in deriving the disaggregated production estimates. The data in the EDM of the Australian sheep and wool industries by Mounter *et al*. (2007) are average annual values for the years 2002-03 to 2004-05. The methods and assumptions used in specifying the data are the same as those used in obtaining the disaggregated 2002-03 estimates. In some cases, where data did not exist, estimated values were calculated.

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ACRONYMS AND ABBREVIATIONS USED IN THE REPORT

AAGIS	Australian agricultural and grazing industries survey
ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AWC	Australian Wool Corporation
AWEX	Australian Wool Exchange
AWTA	Australian Wool Testing Authority
DAFF	Department of Agriculture, Fisheries and Forestry
EDM	Equilibrium displacement model
EVAO	Estimated value of agricultural operations
FOB	Free-on-board
MLA	Meat and Livestock Australia
TWC	The Woolmark Company
VIC DPI	Department of Primary Industries Victoria
WSA	Wool statistical area
cfa	cast for age
c/kg	cents per kilogram
cwt	carcass weight
kg/hd	kilograms per head
kt	kilotonnes

EXECUTIVE SUMMARY

In a companion *Economics Research Report* (Mounter *et al*. 2007), an equilibrium displacement model (EDM) of the Australian sheep and wool industries is specified, implemented and used to examine some questions relating to the returns from various possible research and development and promotion investments. In this report, the price and quantity data used to implement the model, and particularly the methods and assumptions fundamental to the development of this data set, are described and discussed.

The national sheep flock is disaggregated into Merino and non-Merino sheep in the three agricultural zones of Australia using 2002-03 Australian agricultural and grazing industries survey data. Opening and closing sheep numbers, death rates and weaning percentages were used to derive the supply and use of sheep in each zone. Annual shorn wool production was split into four fibre diameter categories in each zone corresponding to ABS wool export categories. Wool production percentages and relative greasy fleece weights were used to estimate the quantities of wool attributable to ewes, wethers and hoggets in each zone. Estimates were also constructed of lamb, mutton and live sheep export volumes produced from the different sheep enterprises in each agricultural zone.

As the flock composition data is based on 2002-03 figures, aggregate production and export data for 2002-03 were used to validate the methods involved in deriving the disaggregated production estimates. The data in the EDM of the Australian sheep and wool industries by Mounter *et al*. (2007) are average annual values for the period 2002-03 to 2004-05 inclusive. The methods and assumptions used in specifying the data are the same as those used in obtaining the disaggregated 2002-03 estimates. In some cases, where data did not exist, estimated values were calculated.

The principles described and used can be applied to update this model in the future, or to specify a similar model in another region or with a different level of disaggregation.

1 Introduction

1.1 Overview

This report documents the methods and assumptions underlying the structure and data of an equilibrium displacement model (EDM) of the Australian sheep and wool industries, as specified in Mounter *et al*. (2007). A high degree of industry disaggregation in the model meant some data were unavailable. In such instances, the necessary data were estimated. Details on the market prices and quantities in the model, their respective sources, and any calculations and assumptions used in the derivation of estimated price and quantity values are included in this report. The principles used can be applied to update this model in the future, or to specify a similar model in another region or with a different level of disaggregation.

1.2 Outline of the Report

Section 2 provides a brief description of the structure of the Australian sheep and wool industries, as represented in the EDM.

The composition of the Australian sheep flock is detailed in Section 3 and the supply, use and disposal of non-Merino and Merino sheep are identified. Flock composition survey data for 2002-03, and other information, are used to disaggregate the Australian sheep flock by agricultural zone, according to Merino and non-Merino sheep, wool fibre diameter category and breeding intention. Annual data for 2002-03 are used in conjunction with the 2002-03 flock composition survey data to assist in validating the methodology used. Australian Wool Exchange (AWEX) auction data and relative greasy per head fleece weights are used to quantify the annual wool production from each agricultural zone. Estimates of the lamb, mutton and live sheep exports attributable to the different enterprises in each zone are also derived in Section 3.

Section 4 presents the data used in the EDM. The data, specified as average annual values for the period 2002-03 to 2004-05, were derived using the procedures described in Section 3. The price and quantity data points that are chosen to represent the initial equilibria in these types of models are very important as the estimated benefits or costs from a displacement are closely dependent on the initial prices and quantities. Thus, the benefit from introducing a new technology in say a low-price regime will be proportionally smaller than introducing the same technology in a high-price regime. This requirement for properly representative prices and quantities is especially important in this particular EDM, where the Australian sheep and wool industries are horizontally disaggregated into different regions, products and markets, and vertically disaggregated into the various sectors of the supply chain.

Typically in EDM analysis, average values taken over a five-year period are used to represent the base equilibrium situation to dampen the impact of seasonal effects or other anomalies that occur in any particular year. In 2002, Australian woolgrowers began operating in a free market for the first time in almost thirty years after the last of the 4.7 million-bale wool stockpile was sold in 2001. Consequently, the base equilibrium values

and associated cost shares used in the model were taken as an average of prices and quantities for the three-year period 2002-03 to 2004-05 inclusive to abstract from any influence that accumulated wool stockpile sales may have had on the market prior to 2002.

Section 5 provides a discussion on the prices and quantities used in the EDM. Calculations essential to the derivation of some prices are included in this section. Some conclusions complete the report.

2 Structure of the Australian Sheep and Wool Industries

In Mounter *et al*. (2007), the Australian sheep and wool industries are horizontally disaggregated into Merino sheep and non-Merino sheep. Merino sheep are further disaggregated by production enterprise in each of the three agricultural zones; high rainfall, wheat-sheep and pastoral. Breeding intention data separate Merino ewes in the high rainfall and wheat-sheep zones into Merino and non-Merino lamb producing enterprises. Merino sheep not used for breeding purposes are classified as dry sheep and are grouped together. As such, Merino wethers and Merino hoggets within each zone are combined as a single enterprise or sector.

Australian wool production is divided into four main diameter categories corresponding to the Australian Bureau of Statistics (ABS) wool export categories of 19 micron (μm) and finer, 20-23 μm, 24-27 μm and 28 μm or broader. Vertical disaggregation of the wool industry includes the warehousing, export and Australian early-stage processing sectors. The warehouse sector is assumed to include wool handling, storage, testing and associated selling costs. The majority of Australian wool production is exported as raw greasy wool with the remainder undergoing some degree of early-stage processing before being exported as scoured wool, carbonised wool or wool tops. Limited quantities of wool tops are used as inputs in domestic later-stage processing such as spinning and weaving. Early-stage processing of wool in Australia is separated into scouring, carbonising and topmaking sectors. Post-sale costs such as transport, dumping and shipment preparation for greasy wool are included in the export sector.

Other production activities in the EDM comprise live sheep exports and lamb and mutton destined for the export and domestic markets. Vertical disaggregation of the sheepmeat supply chain beyond the farm gate consists of processing and marketing sectors. The processing sector undertakes all slaughtering and processing activities necessary to produce lamb and mutton for the export market and carcasses of lamb and mutton for sale to domestic retailers. The domestic marketing or retail sector processes the carcasses and packages the products for sale to final consumers. This sector comprises supermarkets, butchers and integrated abattoirs or independent boning rooms that undertake the same process.

3 Flock Composition and Annual Production

Each year the Australian Bureau of Agricultural and Resource Economics (ABARE) conducts a survey of the Australian agricultural and grazing industries. In 2002-03, data on the composition of the national sheep flock by agricultural zone were collected by ABARE as part of some supplementary questions to the standard annual Australian Agricultural and Grazing Industries Survey (AAGIS). The survey is based on farm enterprises with an estimated value of agricultural operations (EVAO) of $22,500 plus. Annual aggregate sheep numbers and production figures for shorn wool, lamb and mutton published by ABS and ABARE are based on farm enterprises with an EVAO of $5,000 or more. The 2002-03 opening and closing sheep numbers corresponding to an EVAO of $5,000 or more were disaggregated using the AAGIS survey flock composition percentages to determine the supply and use of sheep in each agricultural zone.[1]

3.1 Supply, Use and Disposal of Australian Sheep

3.1.1 Flock Composition

The 2002-03 disaggregated sheep numbers based on the AAGIS flock composition percentages are listed in Table 1. Estimates of lambs and hoggets according to sex were not included in the AAGIS flock composition percentages. Curtis and Croker's (2005) national survey data indicated the ratio of Merino wether hoggets to Merino ewe hoggets was 0.58, and, in the absence of any data and on advice from others, a 1:1 ratio for lambs was assumed. Similar assumptions were made here. Sheep deaths in 2002-03 of 3.2 million (ABARE 2006) were 3 per cent of total opening sheep numbers. The 3 per cent death rate was assumed to be constant for all categories of sheep enterprises across all agricultural zones. Calculations adapted from Martin *et al*. (2004) suggest only half of 1 per cent of non-Merino wool is produced in the pastoral zone. Hence, in the EDM, the numbers of non-Merino sheep in the pastoral zone are negligible and are assumed to be zero. As the proportion of rams in the national flock is small, around 1 per cent (Martin *et al*. 2004), the numbers of rams were included in the numbers of adult wethers.

3.1.2 Supply and Use of Non-Merino Sheep

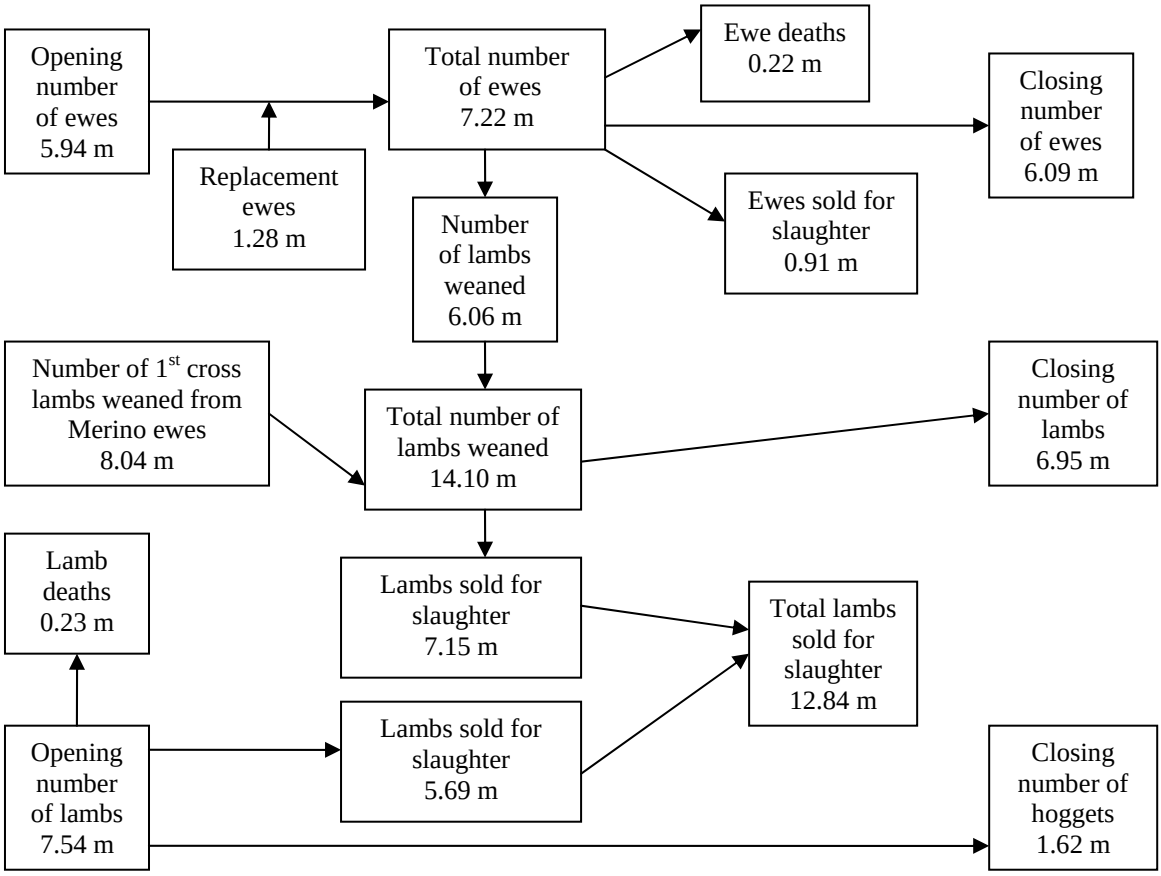
The supply and use of non-Merino sheep are depicted in Figure 1. Opening numbers of adult non-Merino ewes and non-Merino hoggets in 2002-03 were 5.94 million and 1.28 million, respectively. Non-Merino hoggets are assumed to consist entirely of ewe hoggets kept for the purpose of ewe flock replacements. Therefore, the total number of non-Merino ewes in 2002-03 was 7.22 million. The assumption of a 3 per cent death rate per year reduces the total to 7 million.

Approximately 84 per cent of all non-Merino ewes were joined to produce 2003-04 lambs (Martin *et al*. 2004). Therefore, of the 7.00 million non-Merino ewes, 5.88 million were breeding ewes and 1.12 million were maiden (unjoined) ewes. The closing number of

[1] Total opening and closing sheep numbers associated with an EVAO of $5,000 or more were 106.2 million and 99.3 million, respectively. Total opening and closing sheep numbers associated with an EVAO of $22,500 or more were 103.2 and 96.1 million, respectively.

adult non-Merino ewes, from Table 1, is 6.09 million. The total number of adult non-Merino ewes either sold as culls or cast for age (cfa) and slaughtered for mutton was 0.91 million, calculated as the difference between the total number of adult ewes, including replacements minus deaths, and the closing number of adult ewes.

Figure 1: Supply and use of non-Merino sheep (Australia) (millions)



Opening non-Merino lamb numbers in 2002-03 were 7.54 million. Closing hogget numbers indicate that 1.62 million non-Merino lambs were kept for the purpose of flock replacements. After accounting for deaths, a total of 5.69 million opening number non-Merino lambs were sold for slaughter.

Average weaning rates for non-Merino ewes and Merino ewes joined to non-Merino rams were estimated to be 103 per cent and 91 per cent, respectively (Curtis and Croker 2005). A weaning rate of 103 per cent equates to 6.06 million lambs weaned from 5.88 million non-Merino breeding ewes. The total number of first-cross lambs weaned from Merino ewes was estimated to be 8.04 million (see Section 3.1.3) for a combined total of 14.10 million non-Merino lambs weaned from non-Merino and Merino ewes in 2002-03. A closing figure of 6.95 million non-Merino lambs implies that 7.15 million of the 14.10 million lambs weaned were sold for slaughter. Together with the 5.69 million opening number of non-Merino lambs sold for slaughter, the total number of non-Merino lambs sold for slaughter during 2002-03 was 12.84 million.

Table 1: 2002-03 Australian sheep flock composition (millions)

	Opening Numbers (m)	%	Closing Numbers (m)	%
Total Sheep	106.20	100	99.30	100
Merino Sheep	90.91	85.6	84.00	84.6
Non-Merino sheep	15.29	14.4	15.30	15.4
Merino Flock Profile				
Pastoral Zone				
Ewes	5.96	48.8	5.99	59.0
Wethers	2.07	16.9	1.97	19.4
Lambs	2.12	17.4	1.13	11.1
Hoggets	2.07	16.9	1.07	10.5
Total	**12.22**	100	**10.16**	100
(Ewe Lambs)	1.06		0.57	
(Wether Lambs)	1.06		0.56	
(Ewe Hoggets)	1.31		0.68	
(Wether Hoggets)	0.76		0.39	
Wheat-Sheep Zone				
Ewes	24.90	50.6	24.62	52.1
Wethers	7.03	14.2	6.62	14.0
Lambs	10.67	21.7	9.40	19.9
Hoggets	6.63	13.5	6.62	14.0
Total	**49.23**	100	**47.26**	100
(Ewe Lambs)	5.34		4.70	
(Wether Lambs)	5.33		4.70	
(Ewe Hoggets)	4.20		4.19	
(Wether Hoggets)	2.43		2.43	
High Rainfall Zone				
Ewes	11.07	37.5	10.90	41.0
Wethers	7.14	24.2	6.33	23.8
Lambs	6.17	20.9	5.02	18.9
Hoggets	5.14	17.4	4.33	16.3
Total	**29.52**	100	**26.58**	100
(Ewe Lambs)	3.09		2.51	
(Wether Lambs)	3.08		2.51	
(Ewe Hoggets)	3.25		2.74	
(Wether Hoggets)	1.89		1.59	
Merino Adult Age Distribution				
Ewes under 4 years		51.8		52.7
Ewes 4 years and over		48.2		47.3

Table 1 (cont.): 2002-03 Australian sheep flock composition (millions)

	Opening Numbers (m)	%	Closing Numbers (m)	%
Wethers under 4 years		67.6	10.32	70.2
Wethers 4 years and over		32.4		29.8
Non-Merino Flock Profile				
Wheat-Sheep Zone				
Ewes	3.79	39.0	3.88	39.8
Wethers	0.30	3.1	0.41	4.2
Lambs	4.82	49.5	4.43	45.4
Hoggets	0.82	8.4	1.03	10.6
Total	**9.73**	100	**9.75**	
(Ewe Lambs)	2.41		2.22	
(Wether Lambs)	2.41		2.21	
High Rainfall Zone				
Ewes	2.15	39.0	2.21	39.8
Wethers	0.17	3.1	0.23	4.2
Lambs	2.72	49.5	2.52	45.4
Hoggets	0.46	8.4	0.59	10.6
Total	**5.50**	100	**5.55**	
(Ewe Lambs)	1.36		1.26	
(Wether Lambs)	1.36		1.26	
Non-Merino Age Distribution				
Ewes under 4 years		49.3		49.9
Ewes 4 years and over		50.7		50.1

3.1.3 Supply and Use of Merino Sheep

Figure 2 traces the supply and use of Merino sheep in the pastoral zone. The opening number of adult Merino ewes in the pastoral zone for 2002-03 was 5.96 million (Table 1). Merino ewe flock replacements, taken from the opening ewe hogget numbers, were 1.31 million. The total numbers of Merino ewes in the pastoral zone, less a 3 per cent death rate, was calculated as 7.05 million. An estimated 85.6 per cent of Merino ewes were joined to produce 2003-04 lambs (Martin *et al*. 2004). The number of Merino breeding ewes in the pastoral zone was estimated as 6.03 million and the number of non-breeding ewes as 1.02 million.

A weighted average 2002-03 lambing rate of 31 per cent for the pastoral zone was calculated from Martin *et al*. (2004) estimates. The number of lambs weaned was 1.82 million, estimated as the number of lambs born less the assumed 3 per cent death rate. Closing lamb numbers of 1.13 million indicate that 0.69 million 2002-03 pastoral zone Merino lambs were sold for slaughter. Opening lamb numbers for the pastoral zone were

2.12 million. Taking into account the 3 per cent death rate, closing hogget numbers of 1.07 million suggest that 0.99 million of the opening numbers of lambs were sold for slaughter or live export.

Opening wether numbers for the pastoral zone were 2.07 million and opening wether hogget numbers were 0.76 million, making a combined total of 2.83 million wethers. Closing wether numbers were 1.97 million. After the assumed death rate, 0.78 million wethers were sold for slaughter or live export.

The supply and use of Merino sheep in the wheat-sheep and high rainfall zones, shown in Figures 3 and 4, respectively, were similarly estimated. Of the adult Merino ewes joined to produce 2003-04 lambs, 75.5 per cent were joined to Merino rams and 24.5 per cent to non-Merino rams (Martin *et al*. 2004). The numbers of ewes sold for slaughter from each type of breeding enterprise were based on these percentages. Using the assumed weaning rate of 91 per cent, the total number of non-Merino lambs weaned from Merino ewes in the high rainfall and wheat-sheep zones were 2.65 million and 5.39 million, respectively. The number of Merino lambs slaughtered was 4.26 million, calculated as the total number of 17.1 million lambs slaughtered (ABARE 2006) minus the 12.84 million non-Merino lambs slaughtered.[2]

Closing Merino lamb numbers of 15.55 million were added to the 4.26 million Merino lambs slaughtered to obtain a total of 19.81 million Merino lambs weaned. The numbers of Merino lambs weaned in the wheat-sheep and high rainfall zones were 17.99 million, derived as the difference between the total number of Merino lambs weaned and the 1.82 million lambs weaned in the pastoral zone.

Merino lamb weaning percentages for the wheat-sheep and high rainfall zones could not be estimated in a similar manner to the pastoral zone, as numbers of non-Merino lambs were inclusive in the totals. The Rendell-McGuckian Wool R&D Project Evaluation model, based on ABS 2001 Farm Census data, employs a weaning rate of 75 per cent for both the fine and medium Merino wool production systems specified within the model. A similar approach was followed here in assuming equal weaning rates for the wheat-sheep and high rainfall zones. A Merino lamb weaning rate of 66 per cent in the wheat-sheep and high rainfall zones was calculated as the total number of Merino lambs weaned less the number of pastoral zone lambs weaned, divided by the total number of Merino ewes joined to Merino rams in the two zones. This rate was then applied to the number of Merino ewes joined to Merino rams in each zone to identify the number of Merino lambs weaned in each zone. The difference between the number of Merino lambs weaned and the closing number of lambs determined the number of Merino lambs sold for slaughter from each zone.

As demonstrated in the supply and use calculations of sheep in the pastoral zone, the closing number of Merino hoggets was deducted from the opening number of Merino lambs to estimate the number of lambs/hoggets sold for slaughter or live export from the high rainfall and wheat-sheep zones. Opening Merino wether hogget numbers were added to opening wether numbers to obtain the total number of Merino wethers in each zone.

[2] Refer to Section 3.1.2 on the supply and use of non-Merino sheep for the derivation of this number.

Closing wether numbers were subtracted to obtain the numbers of wethers sold for either slaughter or live export.

Figure 2: Supply and use of Merino sheep in the Australian pastoral zone (millions)

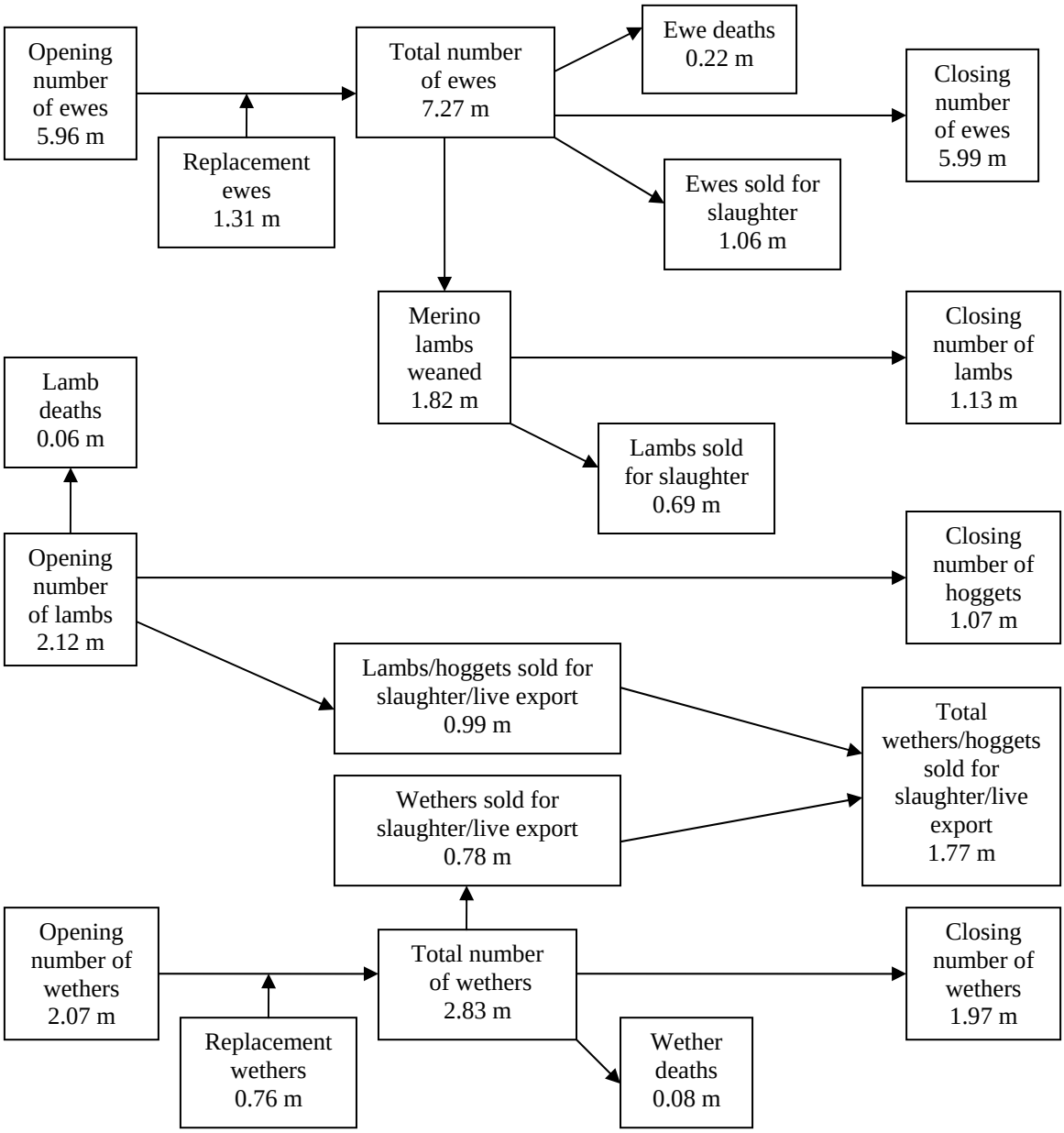


Figure 3: Supply and use of Merino sheep in the Australian wheat-sheep zone (millions)

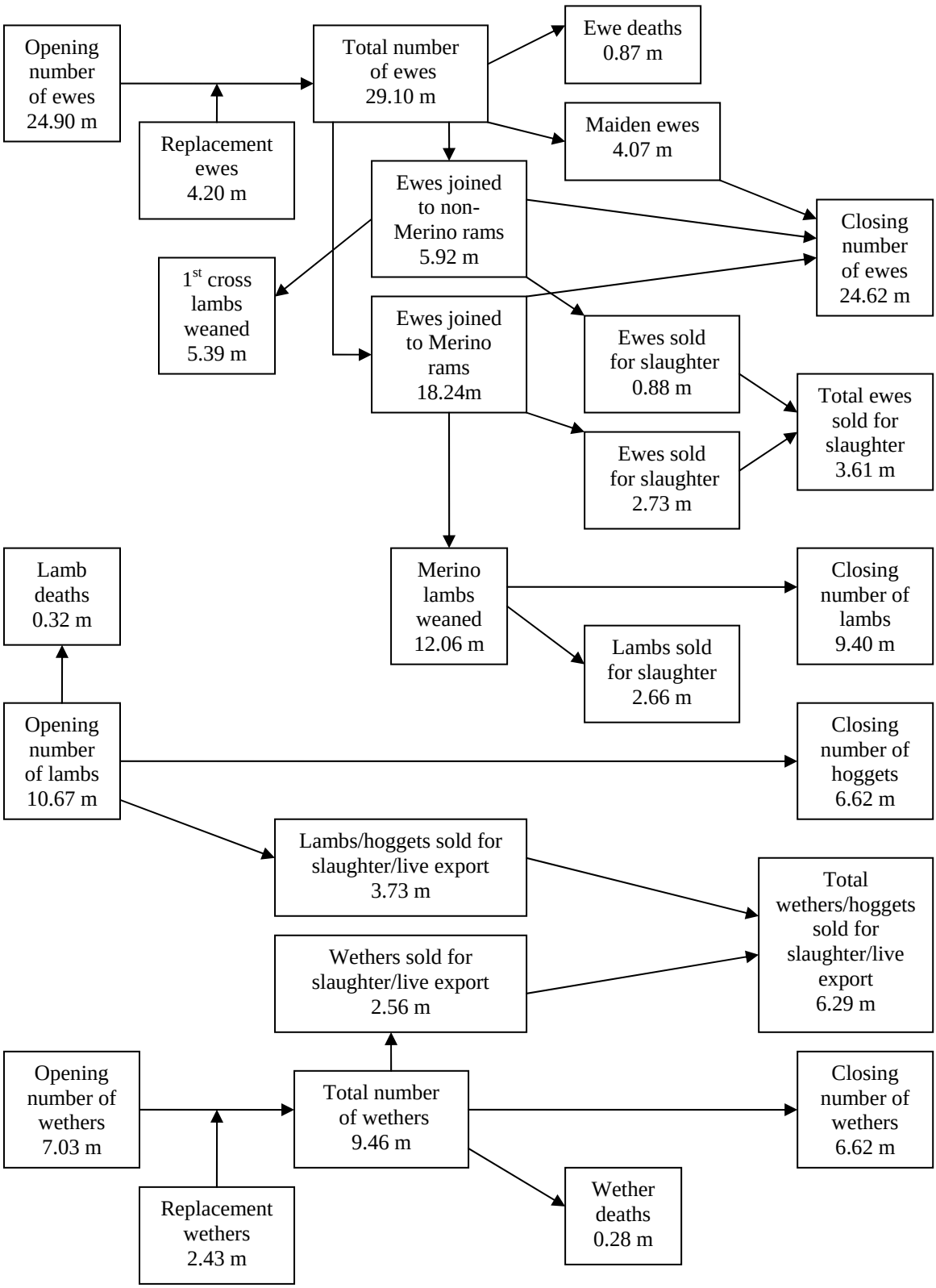
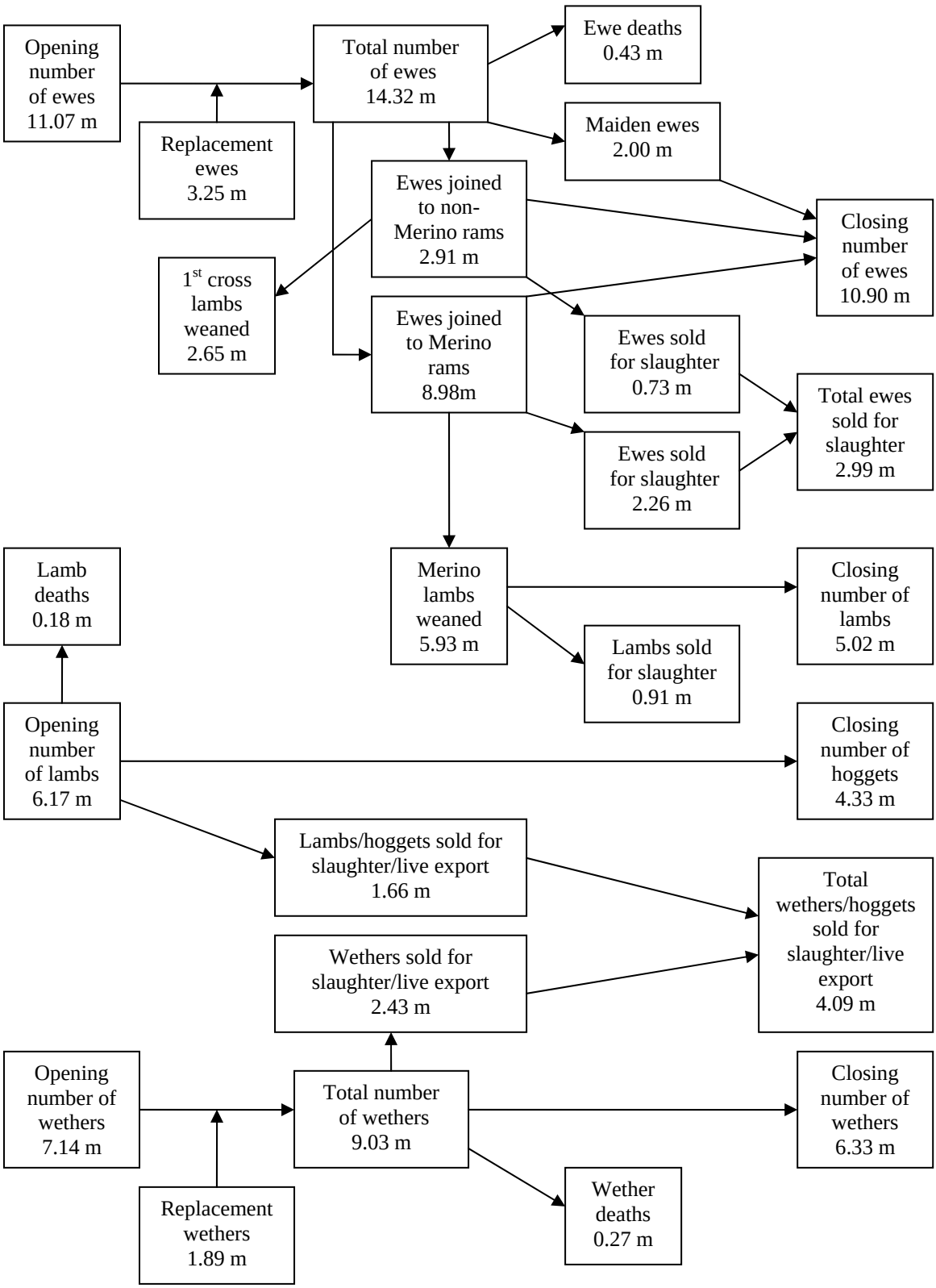


Figure 4: Supply and use of Merino sheep in the Australian high rainfall zone (millions)



3.2 Wool Production

3.2.1 Categories of Wool

Quarterly wool export figures by wool type and diameter category are published by ABS. The diameter categories are 19 µm and finer, 20-23 µm, 24-27 µm and 28 µm or broader. The ABS export wool types in the EDM are wool top and noil, scoured, carbonised and greasy wool. Wool production by agricultural zone was disaggregated according to the same diameter categories to comply with the ABS classifications.

Wool statistical areas (WSA) are primarily used by the wool industry to record the origin of wool production. Australian Wool Exchange (AWEX) auction data were split by diameter profile according to WSA and matched to an agricultural zone using an approach similar to Templeton (2002). Table 2 shows annual shorn wool production for 2002-03 of 502 kilo tonnes (kt) split by agricultural zone according to the wool category percentages estimated from the AWEX data. Also listed are percentages of Merino and non-Merino wool production in the high rainfall and wheat-sheep zones, as derived from Martin *et al*. (2004).

The shares of non-Merino wool and Merino wool in 2002-03 total high rainfall zone shorn wool production were 6.46 per cent (12.08 kt) and 93.54 per cent (174.96 kt), respectively. Wool greater than or equal to 28 µm produced in Australia can be attributed to non-Merino breeds of sheep. Therefore, 12.08 kt of 28 µm or broader wool produced in the high rainfall zone was non-Merino wool. The total amount of shorn wool production in the wheat-sheep zone was 269.42 kt comprising 6.70 per cent (18.06 kt) of non-Merino wool and 93.30 per cent (251.36 kt) of Merino wool. Based on AWEX estimates, 3.83 per cent (10.32 kt) of wool produced in the wheat-sheep zone was 28 µm or broader. The remaining 7.74 kt of non-Merino wool produced in the wheat-sheep zone is assumed to be in the 24-27 µm diameter category.

Estimation of the number of sheep in each zone that are shorn, as opposed to those not shorn, is impossible from the available data. Adult sheep are typically shorn once a year but sheep slaughtered for mutton may be either sold off shears or sold in the wool.[3] Prime lambs are generally sold with the wool on but may also be sold off shears. Merino lambs may or may not be shorn before twelve months of age. This depends on a number of factors including wool type and prevailing seasonal and economic conditions. For example, finer micron lambs are usually shorn for the first time as hoggets whereas broader wool types, particularly in the wheat-sheep and pastoral zones, are more likely to be shorn as lambs, particularly if blowfly strike is seen as a potential problem.

The numbers of adult sheep sold for slaughter or live export as a proportion of the total number of adult sheep in the national flock was calculated to be less than 20 per cent. A significant number of these would be sold off shears. Conversely, as the majority of lambs would not be shorn prior to 12 months of age, the apportionment of wool in each zone to classification of sheep was based on adult sheep only. The total numbers of adult

[3] Some non-Merino sheep breeds may be shorn more often whereas other breeds shed their wool.

Merino sheep in each agricultural zone in 2002-03 and the proportions of the totals for each enterprise type are listed in Table 3.

Table 2: 2002-03 Greasy shorn wool production (Australia)

	%	kt
Annual total wool production		502.00
High rainfall zone wool production	37.26	187.04
Wheat-sheep zone wool production	53.67	269.42
Pastoral zone wool production	9.07	45.54
High rainfall zone non-Merino wool production	6.46	12.08
High rainfall zone Merino wool production	93.54	174.96
Wheat-sheep zone non-Merino wool production	6.70	18.06
Wheat-sheep zone Merino wool production	93.30	251.36
High rainfall zone wool 19 micron & finer	44.11	82.51
High rainfall zone wool 20-23 micron	43.02	80.46
High rainfall zone wool 24-27 micron	6.41	11.99
High rainfall zone wool 28 micron & broader	6.46	12.08
Wheat-sheep zone wool 19 micron & finer	25.05	67.48
Wheat-sheep zone wool 20-23 micron	64.08	172.64
Wheat-sheep zone wool 24-27 micron	7.04	18.98
Wheat-sheep zone wool 28 micron & broader	3.83	10.32
Pastoral zone wool 19 micron and finer	23.38	10.65
Pastoral zone wool 20-23 micron	71.67	32.64
Pastoral zone wool 24-27 micron	4.95	2.25

Table 3: 2002-03 Number and percentage of adult Merino sheep by zone (Australia)

	%	(million)
High rainfall zone		
Total adult sheep		29.52
Merino ewes joined/intended to non-Merino rams	11.89	3.51
Merino ewes joined/intended to Merino rams	36.62	10.81
Merino wethers	30.59	9.03
Merino hoggets	20.90	6.17
Wheat-sheep zone		
Total adult sheep		49.23
Merino ewes joined/intended to non-Merino rams	14.49	7.13
Merino ewes joined/intended to Merino rams	44.65	21.97
Merino wethers	19.16	9.46
Merino hoggets	21.70	10.67
Pastoral zone		
Total adult sheep		12.22
Merino ewes joined/intended to Merino rams	59.50	7.27
Merino wethers	23.10	2.83
Merino hoggets	17.40	2.12

Greasy fleece weight estimates per head were needed to allocate the volumes of each diameter category of wool in Table 2 to the Merino sheep enterprises listed in Table 3. The Rendell McGuckian Wool R&D Project Evaluation model provides estimates of adult and young sheep greasy wool cuts per head for each of the production systems within the model. These production systems are defined as fine Merino with an average

micron of 18.6, medium Merino with an average micron of 21.5, pastoral with an average micron of 23 and terminal which is a joint farming system running 60 per cent non-Merino ewes and 40 per cent Merino ewes. These greasy per head fleece weight estimates for the fine, medium and pastoral systems, adjusted for differences in average weight between the 2000-01 and 2002-03 seasons, are used as estimates of the 19 µm and finer, 20-23 µm and 24-27 µm diameter categories specified in the EDM.

3.2.2 Relative Fleece Weights

In order to account for the seasonal differences in average fleece weights, an adjusted or relative fleece weight for each category had to be estimated. The Rendell McGuckian average greasy fleece weights for the fine, medium and pastoral systems are reproduced in Table 4.

Table 4: Rendell McGuckian greasy wool cut (kg/hd)

	Fine wool (18.6 micron)	Medium wool (21.5 micron)	Pastoral wool (23 micron)
Ewes	4.8	5.0	5.8
Wethers	5.5	6.0	6.2
Hoggets	3.5	4.5	4.5
Weights correspond to diameter category	≤ 19 micron	20 – 23 micron	24 – 27 micron

Source: Rendell McGuckian model

The average annual greasy fleece weights per sheep shorn for the years 2000-01 and 2002-03 were 4.42 kg and 4.28 kg, respectively. The weights were calculated as annual Australian shorn wool production divided by the number of sheep shorn (ABARE 2006).

The relative fleece weight for each sheep type was calculated as the Rendell McGuckian 2001 fleece weight divided by the 2000-01 average cut per head, multiplied by the 2002-03 average cut per head. For example, the relative fleece weight per head for fine wool ewes is (4.8/4.42)*4.28 = 4.65 kg. The 2002-03 relative fleece weights for the sheep enterprises and diameter categories are presented in Table 5.

Table 5: 2002-03 Relative greasy wool cut (kg/hd)

	Fine wool (18.6 micron)	Medium wool (21.5 micron)	Pastoral wool (23 micron)
Ewes	4.65	4.84	5.62
Wethers	5.33	5.81	6.00
Hoggets	3.39	4.36	4.36
Weights correspond to diameter category	≤ 19 micron	20 – 23 micron	24 – 27 micron

The percentages of ewes, wethers and hoggets within each fibre diameter category in each zone are assumed to be the same as the percentages of ewes, wethers and hoggets for the entire zone. The percentages for the high rainfall zone, taken from Table 3, are:

Merino ewes 48.51 per cent
Merino wethers 30.59 per cent
Merino hoggets 20.90 per cent

Given these percentages, and the relative greasy fine wool fleece weights calculated above, 19 µm and finer Merino wool production for the high rainfall zone in 2002-03 was estimated as follows. For every 100 sheep shorn the proportions of wool were calculated as:

48.51 ewes @ 4.65 kg wool per head = 225.57 kg = 49.09 per cent
30.59 wethers @ 5.33 kg wool per head = 163.04 kg = 35.49 per cent
20.90 hoggets @ 3.39 kg wool per head = 70.85 kg = 15.42 per cent

The wool production percentages, calculated above, and the 82.51 kt of 19 µm and finer shorn wool produced in the high rainfall zone were used to estimate the quantities of wool attributable to ewes, wethers and hoggets:

49.09 per cent of wool from Merino ewes = 40.51 kt
35.49 per cent of wool from Merino wethers = 29.28 kt
15.42 per cent of wool from Merino hoggets = 12.72 kt.

Using the medium and pastoral relative greasy fleece weights from Table 5, the quantities of 20-23 µm and 24-27 µm Merino wool produced from Merino ewes, wethers and hoggets in the high rainfall zone were estimated by the same approach. The process was repeated to ascertain the quantities of wool in each diameter category produced from each Merino sheep enterprise in the wheat-sheep and pastoral zones. Wool production by sheep enterprise type in each zone is summarised in Table 6.

Table 6: 2002-03 Greasy shorn wool production (kt) by sheep and zone (Australia)

	≤ 19 micron	20 – 23 micron	24 – 27 micron	≥ 28 micron
High rainfall zone				
Merino ewes joined/intended to non-Merino rams	9.92	9.19	1.46	
Merino ewes joined/intended to Merino rams	30.59	28.33	4.51	
Merino wethers	29.28	28.39	4.03	
Merino hoggets	12.72	14.55	1.99	
Non-Merino ewes				12.08
Wheat-sheep zone				
Merino ewes joined/intended to non-Merino rams	10.09	24.61	1.69	
Merino ewes joined/intended to Merino rams	31.09	75.83	5.20	
Merino wethers	15.28	39.03	2.39	
Merino hoggets	11.02	33.17	1.96	
Non-Merino ewes			7.74	10.32
Pastoral zone				
Merino ewes joined/intended to Merino rams	6.42	18.88	1.37	
Merino wethers	2.86	8.80	0.57	
Merino hoggets	1.37	4.96	0.31	

3.3 Lamb, Mutton and Live Sheep Export Production

3.3.1 Lamb Production

Data are not available on numbers or percentages of first-cross, second-cross/meat and Merino lambs in the total amount of lambs slaughtered annually. Meat and Livestock Australia (MLA) Lamb Surveys provide estimates of the numbers of lambs 'expected to be sold' each year. The surveys show lamb numbers by season, inclusive of lambs for sale to re-stockers. First-cross, second-cross/meat and Merino lambs as percentages of the total number of expected lamb sales were calculated for each of the years 2002 to 2005. Average percentages over the four years for each of the lamb types were used to approximate the numbers of each type of lamb slaughtered (see Table 7).

Table 7: Percentages of expected lamb sales 2002-2005 (Australia)

	2002	2003	2004	2005	Average
First-Cross	43	40	41	41	41
Second-Cross	34	39	32	30	34
Merino	23	21	27	29	25

The 4.26 million Merino lambs slaughtered (Section 3.1.3), made up 25 per cent of the 17.1 million total lambs slaughtered in 2002-03, the same as the average listed in Table 7. The resulting estimates of the numbers of first-cross and second-cross lambs slaughtered in 2002-03 using the averages from Table 7 were 7.02 million and 5.82 million, respectively. MLA (2005) survey numbers of first-cross lambs sold or intended for sale by statistical region were cross matched with agricultural zones to obtain estimates of 68 per cent and 32 per cent of first-cross lambs originating in the wheat-sheep and high rainfall zones, respectively. The percentages were used to estimate the number of first-cross lambs slaughtered from the wheat-sheep and high rainfall zones as 4.77 million and 2.25 million, respectively.

The average carcass weight (cwt) for lamb in 2002-03 was 19.26 kg/hd, calculated as the annual Australian lamb production divided by the number of lambs slaughtered (ABS 2005a; ABARE 2006). The average dressing percentage for second-cross lambs, based on a mid range fat score of three, is 45 per cent, with first-cross and Merino lambs tending to dress 1.5 to 3.5 percentage points less than second-cross lambs (DPI VIC 2006). An average 2.5 percentage points less than the dressing percentage for second-cross lambs was used to establish a dressing percentage for first-cross lambs and Merino lambs of 42.5 per cent. This was calculated to be 94.4 per cent of the dressing percentage for second-cross lambs. The total carcass weight amounts of first-cross and Merino lambs, and second-cross lambs were calculated as:

$$11.28*(0.944X) + 5.82*(X) = 329.40 \text{ kt lamb}$$

Solving for X, the total amount of second-cross lamb produced was 116.43 kt at an average carcass weight of 20.0 kg/hd. The total carcass weight amount of first-cross and Merino lamb produced was 212.97 kt at an average carcass weight of 18.88 kg/hd. This

average carcass weight was multiplied by the number of lambs sold for slaughter in each zone to obtain the total carcass weight of Merino lamb and first-cross lamb produced in each zone (Table 8).

Table 8: 2002-03 Total carcass weight of lamb production (Australia)

	Number (million)	cwt (kt)
Second-cross/meat	5.82	116.43
First-cross high rainfall zone	2.25	42.48
First-cross wheat-sheep zone	4.77	90.06
Merino high rainfall zone	0.91	17.18
Merino wheat-sheep zone	2.66	50.22
Merino pastoral zone	0.69	13.03
Total	17.10	329.40

3.3.2 Mutton Production and Live Sheep Exports

Average live sale weights for the different sheep types within each production system in the Rendell McGuckian model (Table 9) were converted into 2002-03 relative average carcass weights to estimate the quantities of mutton produced from each agricultural zone.[4]

Dressing percentage can vary depending on the type and fat score of the sheep. Sheep sold for slaughter range in fat score values from one to five. The Victoria Department of Primary Industries (DPI VIC) estimated dressing percentages of 42 per cent for ewes and 43 per cent for wethers based on a fat score of three. The average dressing percentage across all sheep types in the Rendell McGuckian model is 46 per cent. Average carcass weight equivalents across all sheep types were derived using a dressing percentage of 44, taken as an average of the lowest and highest rate mentioned (Table 10).

Table 9: Rendell McGuckian average sale weights (kg/hd live weight)

	Fine	Medium	Pastoral	Terminal
Ewes	46	51	57	51
Wethers	46	51	57	-
Hoggets	43	48	54	-

Relative dressed weights for 2002-03 were calculated from the carcass weight equivalents in Table 10. The average annual 2000-01 and 2002-03 carcass weights for mutton were 21.06 kg and 18.37 kg, respectively. These weights were calculated as the annual Australian mutton production divided by the number of sheep slaughtered (ABS 2005a; ABARE 2006). The relative dressed weights for 2002-03 in Table 11 were calculated as the product of the 2002-03 average carcass weight and the Rendell McGuckian 2001

[4] These weights were similar to live body weight estimates provided for different sheep types in NSW DPI gross margin budgets.

carcass weight equivalent for each sheep type, divided by the 2000-01 average carcass weight.

Table 10: Rendell McGuckian dressed weight equivalents (kg/hd carcass weight)

	Fine	Medium	Pastoral	Terminal
Ewes	20.24	22.44	25.08	22.44
Wethers	20.24	22.44	25.08	-
Hoggets	18.92	21.12	23.76	-

Table 11: 2002-03 Relative dressed weights (kg/hd carcass weight)

	Fine	Medium	Pastoral	Terminal
Ewes	17.65	19.57	21.87	19.57
Wethers	17.65	19.57	21.87	-
Hoggets	16.50	18.42	20.72	-

The terminal, fine, medium and pastoral relative dressed weights in Table 11 were used as dressed weight estimates of sheep sold for slaughter from the non-Merino, high rainfall, wheat-sheep and pastoral zone Merino sectors specified in the EDM. The numbers of sheep sold for slaughter from each zone were multiplied by the respective relative dressed weights to yield the total carcass weight of mutton produced.

Live sheep exports are included in the total carcass weights of wethers and hoggets from each zone. To separate live sheep exports from wethers and hoggets slaughtered for mutton, the total carcass weights of wethers and hoggets from each zone were converted into live weight equivalents using the average 44 per cent dressing percentage for adult sheep.

There are no published figures on live sheep exports by agricultural zone of origin. The majority of live sheep exports (between 50 and 85 per cent of the total supplied in any one year since 1990) have originated in Western Australia (Livecorp 2005). The percentages of export numbers by state for 2002 and 2003 were averaged to obtain a percentage estimate per state for 2002-03. These estimates were calculated as 60.5, 19.5, 17.5 and 2.5 per cent for Western Australia, South Australia, Victoria and the rest of Australia, respectively. The percentages were used to obtain the numbers of live sheep exports originating from each state in 2002-03. State Livestock Managers from Landmark were consulted to provide estimates of the percentage of live sheep exports originating from each zone within the state. In Western Australia approximately 85 per cent of live sheep exports were sourced from the wheat-sheep zone, 13 per cent from high rainfall zone and only 2 per cent originated in the pastoral zone (Medcalf, C. 2005 pers. comm.). As estimates from South Australia were not forthcoming, the percentages by zone were assumed to be the same as Western Australia. The same assumption was applied to the rest of Australia. In Victoria, approximately 85 per cent of live sheep exports are supplied from the high rainfall regions with the remainder coming from the wheat-sheep zone (Bolton, R. 2005 pers. comm.). Based on these estimates, the numbers of live sheep exports originating from the wheat-sheep, high rainfall and pastoral zones in 2002-03

were 4.23 million, 1.51 million and 0.10 million, respectively. Total live weight quantities for each zone were found by multiplying the numbers of sheep by the average 46.75 kg per head live weight.[5] Live sheep exports for 2002-03, by volume, for the wheat-sheep, high rainfall and pastoral zones were estimated as 197.75 kt, 70.59 kt and 4.66 kt, respectively. The live sheep export weights were subtracted from the total wether and hogget live weights for each zone to determine the levels of mutton production.

The total live weight of Merino wethers and hoggets sold for slaughter or live export was calculated as 515.12 kt. The total gross weight of live sheep exports for 2002-03 was 273.00 kt (ABS 2005a). The 242.12 kt difference is the total gross weight of wethers and hoggets slaughtered for mutton. The carcass weight equivalent was calculated as 106.52 kt. Adding this to the total 164.39 kt carcass weight of all ewes slaughtered for mutton yields a total 270.91 kt of mutton.[6] The number of sheep slaughtered and carcass weight volumes are summarised in Table 12.

Table 12: 2002-03 Numbers and carcass weight of sheep slaughtered Australia

	Number (millions)	Carcass Weight (kt)
Non-Merino Ewes	0.91	17.80
Merino Ewes		
Pastoral Zone	1.06	23.18
Wheat-sheep Zone (joined to Merino rams)	2.73	53.42
Wheat-sheep Zone (joined to non-Merino rams)	0.88	17.22
High Rainfall Zone (joined to Merino rams)	2.26	39.89
High Rainfall Zone (joined to non-Merino rams)	0.73	12.88
Merino Wethers and Hoggets		
Pastoral Zone	1.67	35.51
Wheat-sheep Zone	2.06	31.79
High Rainfall Zone	2.58	39.22

[5] Live sheep exports for 2002-03 were 5.84 million with a gross live weight of 273.00 kt.
[6] The quantity of mutton produced in 2002-03 was 268.20 kt ABS (2005a). The calculation of 270.91 kt of mutton produced overestimates this amount by approximately 1 per cent.

4 Average Annual Flock Composition and Production 2002-03 to 2004-05

Listed in this section are the average annual flock composition and production figures for 2002-03 to 2004-05 specified in the EDM. The figures were derived using the methods presented in Section 3.[7]

Average annual Australian sheep flock composition numbers for 2002-03 to 2004-05 are detailed in Table 13. The average annual supply and use of non-Merino and Merino sheep in each zone are depicted in Figures 5 to 8. Sheep deaths were estimated to be 4.5 per cent of the average annual opening sheep numbers and assumed to be constant for all categories of sheep enterprises across all agricultural zones.

In Section 3, a 2002-03 weaning percentage for Merino lambs in the pastoral zone was calculated from a weighted average lambing rate estimated from Martin *et al*. (2004). Merino lamb weaning percentages in the wheat-sheep and high rainfall zones were assumed to be the same and were calculated as a residual by subtracting the number of lambs weaned in the pastoral zone from the total number of lambs weaned. In the absence of similar information on weaning rates for other years, weaning percentages specified in the Rendell McGuckian Wool R&D Project Evaluation model were used as estimates of average annual Merino lamb weaning rates for each zone. These were 55 per cent for the pastoral zone and 75 per cent for the wheat-sheep and high rainfall zones.

Table 14 shows average annual shorn wool production for 2002-03 to 2004-05 of 483.97 kilo tonnes (kt), split according to the percentages of 19 µm and finer, 20-23 µm, 24-27 µm and 28 µm and broader wool categories produced in each zone, as estimated from AWEX data. The numbers and percentages of adult Merino sheep by zone are listed in Table 15.

The relative greasy fleece weight estimates in Table 16 were calculated using the average greasy fleece weights specified in the Rendell McGuckian Wool R&D Project Evaluation model and an average annual greasy fleece weight for 2002-03 to 2004-05 of 4.37 kg. Greasy shorn wool production estimates, by sheep enterprise and zone, were derived using wool production percentages calculated from the relative greasy fleece weights in Table 16 and the adult sheep distribution figures listed in Table 15. The wool production estimates are summarised in Table 17.

Total carcass weight amounts of lamb production are detailed in Table 18. Average annual carcass weight lamb production for 2002-03 to 2004-05 was 341.70 kt with an average 16.77 million lambs slaughtered annually. The average carcass weight for Merino and first-cross lambs was estimated as 19.98 kg/hd and for second-cross lambs as 21.15 kg/hd.

[7] Unless stated otherwise, the same assumptions used in Section 3 are applicable to the figures stated in this section. Data sources are also the same as those given in Section 3.

Table 13: 2002-03 to 2004-05 Average annual Australian flock composition

	Opening Numbers (m)	%	Closing Numbers (m)	%
Total Sheep	102.27	100	101.10	100
Merino Sheep	87.54	85.6	85.53	84.6
Non-Merino sheep	14.73	14.4	15.57	15.4
Merino Flock Profile				
Pastoral Zone				
Ewes	5.74	48.8	6.09	59.0
Wethers	1.99	16.9	2.00	19.4
Lambs	2.04	17.4	1.14	11.1
Hoggets	2.00	16.9	1.09	10.5
Total	**12.11**	100	**10.32**	100
(Ewe Lambs)	1.02		0.57	
(Wether lambs)	1.02		0.57	
(Ewe Hoggets)	1.26		0.69	
(Wether Hoggets)	0.73		0.40	
Wheat-Sheep Zone				
Ewes	23.96	50.6	25.08	52.1
Wethers	6.73	14.2	6.74	14.0
Lambs	10.28	21.7	9.58	19.9
Hoggets	6.39	13.5	6.74	14.0
Total	**47.36**	100	**48.14**	100
(Ewe Lambs)	5.14		4.79	
(Wether lambs)	5.14		4.79	
(Ewe Hoggets)	4.04		4.26	
(Wether Hoggets)	2.35		2.48	
High Rainfall Zone				
Ewes	10.66	37.5	11.10	41.0
Wethers	6.88	24.2	6.44	23.8
Lambs	5.94	20.9	5.12	18.9
Hoggets	4.94	17.4	4.41	16.3
Total	**28.42**	100	**27.07**	100
(Ewe Lambs)	2.97		2.56	
(Wether lambs)	2.97		2.56	
(Ewe Hoggets)	3.12		2.79	
(Wether Hoggets)	1.82		1.62	
Merino Adult Age Distribution				
Ewes under 4 years		51.8		52.7
Ewes 4 years and over		48.2		47.3

Table 13: 2002-03 to 2004-05 Average annual Australian flock composition (m)

	Opening Numbers (m)	%	Closing Numbers (m)	%
Wethers under 4 years		67.6	10.32	70.2
Wethers 4 years and over		32.4		29.8
Non-Merino Flock Profile				
Wheat-Sheep Zone				
Ewes	3.67	39.0	3.95	39.8
Wethers	0.29	3.1	0.42	4.2
Lambs	4.66	49.5	5.50	45.4
Hoggets	0.79	8.4	1.05	10.6
Total	**9.41**	100	**10.92**	
(Ewe Lambs)	2.33		2.25	
(Wether Lambs)	2.33		2.25	
High Rainfall Zone				
Ewes	2.07	39.0	2.25	39.8
Wethers	0.16	3.1	0.24	4.2
Lambs	2.64	49.5	2.56	45.4
Hoggets	0.45	8.4	0.60	10.6
Total	**5.32**	100	**5.65**	
(Ewe Lambs)	1.32		1.28	
(Wether Lambs)	1.32		1.28	
Non-Merino Age Distribution				
Ewes under 4 years		49.3		49.9
Ewes 4 years and over		50.7		50.1

Relative dressed weights for adult sheep slaughtered for mutton are given in Table 19. The numbers of sheep sold for slaughter and the carcass weight amounts of mutton produced from each zone are summarised in Table 20. The 250.00 kt average annual calculated quantity of mutton produced, overestimates the 241.40 kt average annual quantity of mutton produced by approximately 3.5 per cent. The 8.60 kt difference was split according to the estimated percentage of mutton produced from each enterprise in each zone and adjusted downwards accordingly.

Figure 5: Supply and use of non-Merino sheep (Australia) (millions)

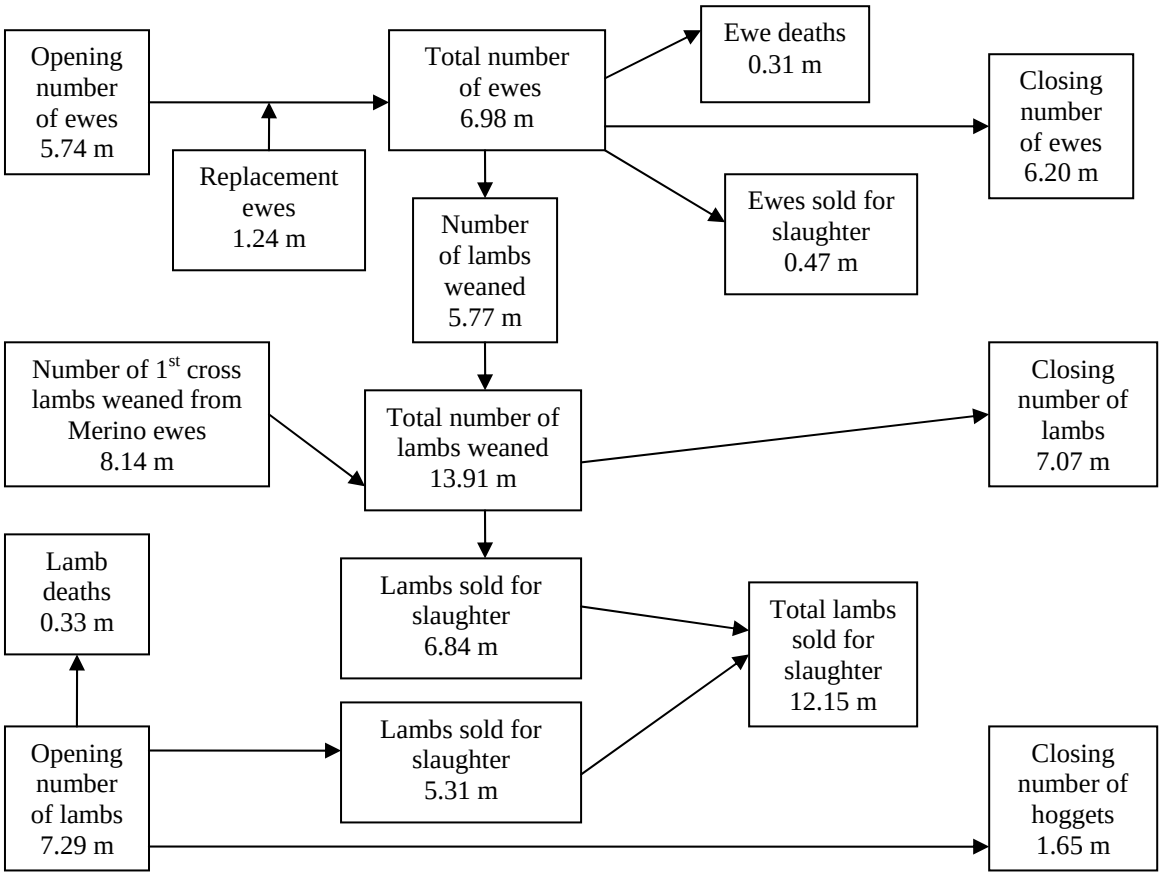


Table 14: 2002-03 to 2004-05 Greasy shorn wool production (Australia)

	%	kt
Annual total wool production		483.97
High rainfall zone wool production	36.76	177.91
Wheat-sheep zone wool production	54.03	261.49
Pastoral zone wool production	9.21	44.57
High rainfall zone non-Merino wool production	6.46	11.49
High rainfall zone Merino wool production	93.54	166.41
Wheat-sheep zone non-Merino wool production	6.70	17.52
Wheat-sheep zone Merino wool production	93.30	243.97
High rainfall zone wool 19 micron & finer	46.66	83.02
High rainfall zone wool 20-23 micron	39.51	70.29
High rainfall zone wool 24-27 micron	6.55	11.65
High rainfall zone wool 28 micron & broader	7.28	12.95
Wheat-sheep zone wool 19 micron & finer	26.24	68.62
Wheat-sheep zone wool 20-23 micron	62.65	163.82
Wheat-sheep zone wool 24-27 micron	7.34	19.19
Wheat-sheep zone wool 28 micron & broader	3.77	9.86
Pastoral zone wool 19 micron and finer	17.29	7.71
Pastoral zone wool 20-23 micron	73.86	32.92
Pastoral zone wool 24-27 micron	8.85	3.94

Figure 6: Supply and use of Merino sheep in the Australian pastoral zone (millions)

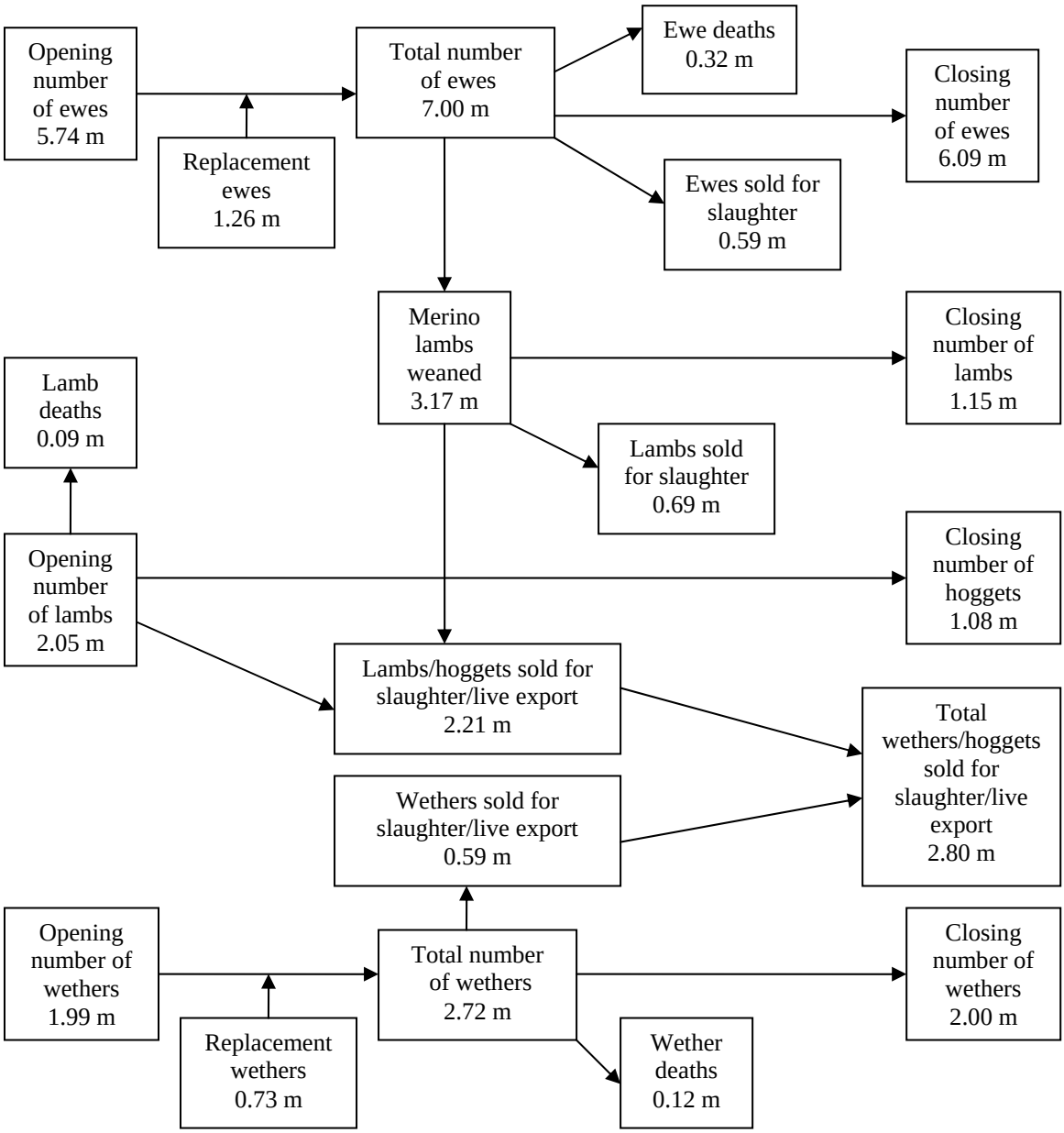


Figure 7: Supply and use of Merino sheep in the Australian wheat-sheep zone (millions)

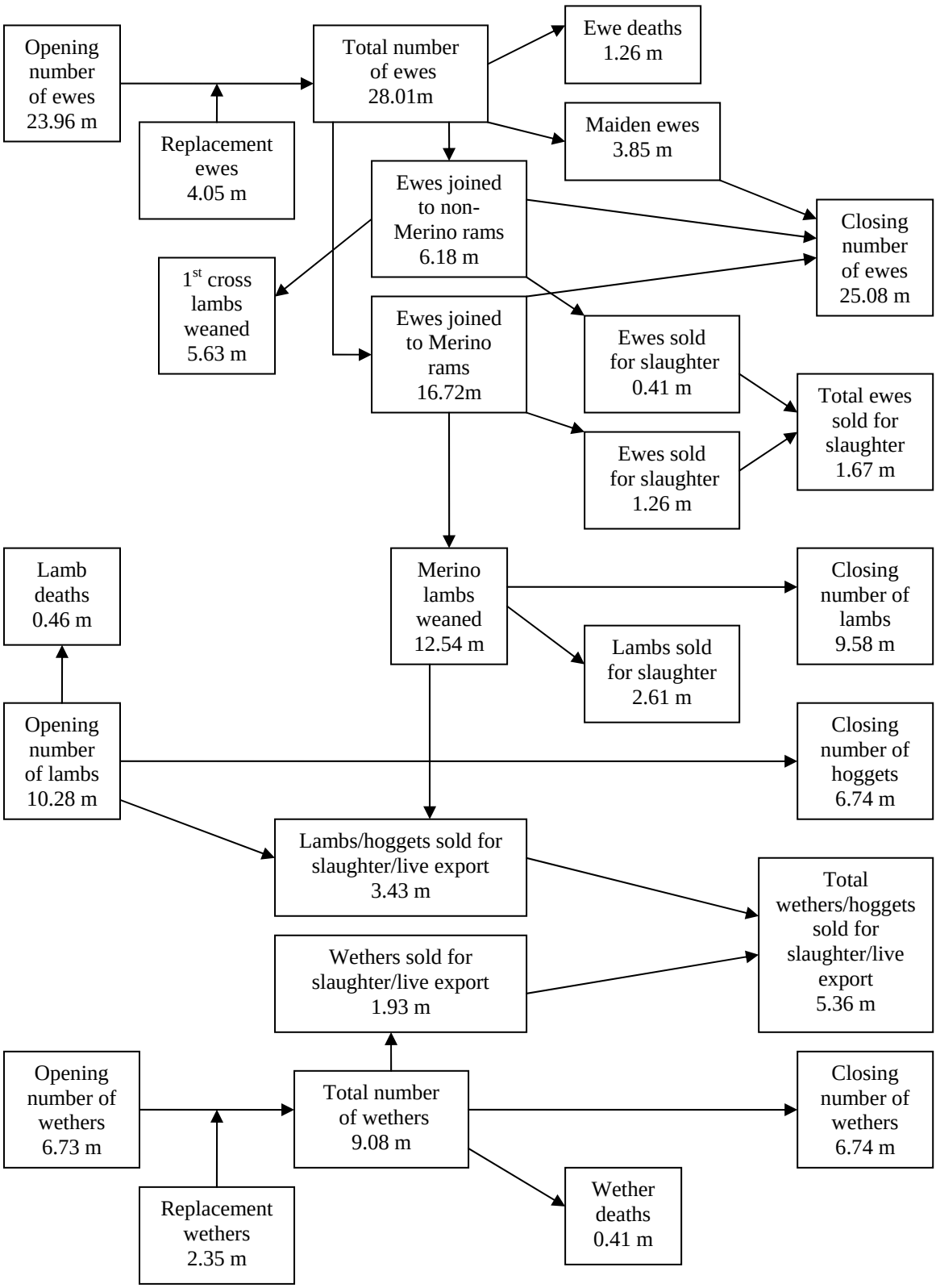


Figure 8: Supply and use of Merino sheep in the Australian high rainfall zone (millions)

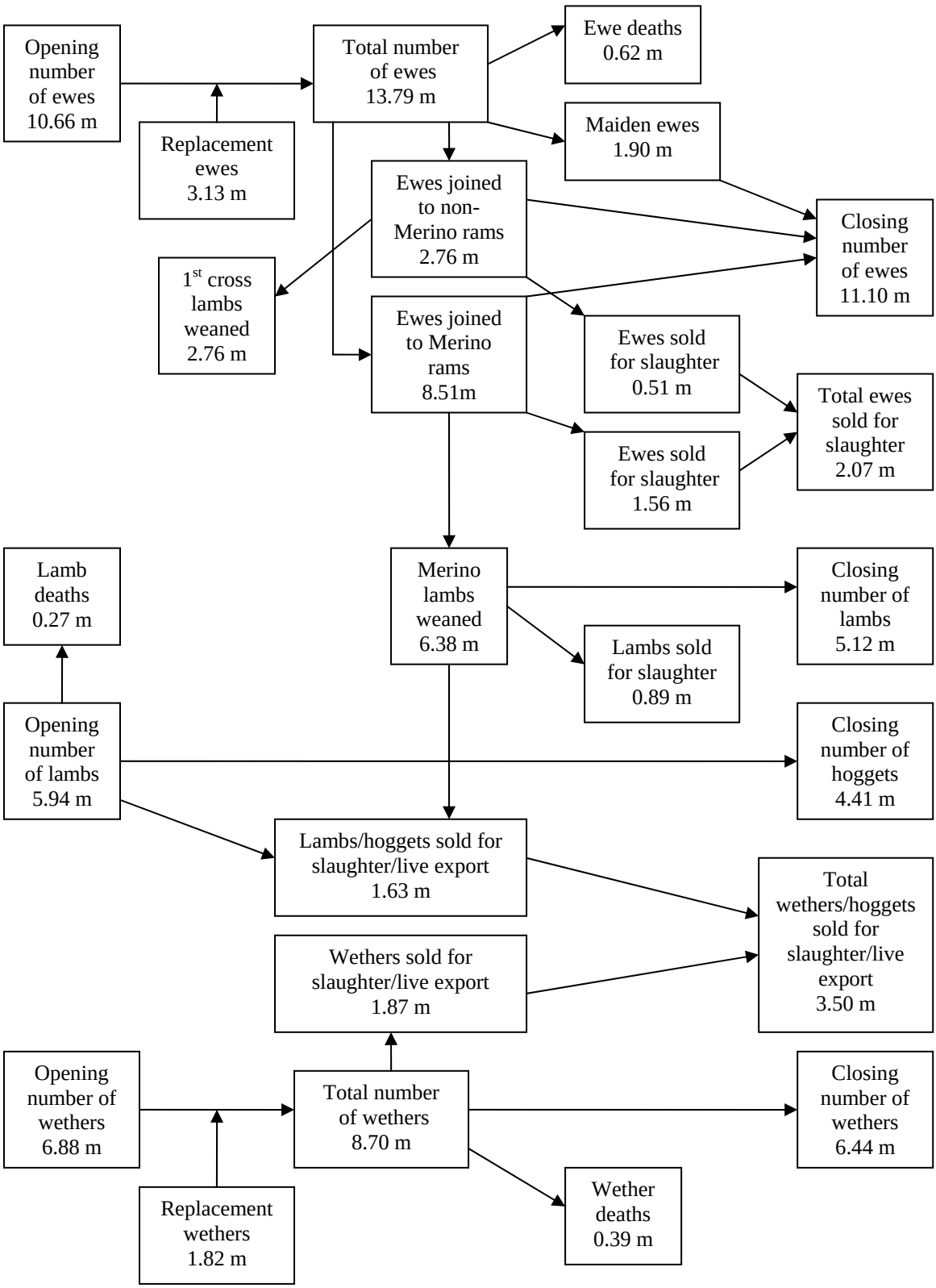


Table 15: Number and percentage of adult Merino sheep by zone (Australia)

	%	(million)
High rainfall zone		
Total adult sheep		28.43
Merino ewes joined/intended to non-Merino rams	11.89	3.38
Merino ewes joined/intended to Merino rams	36.62	10.41
Merino wethers	30.59	8.70
Merino hoggets	20.90	5.94
Wheat-sheep zone		
Total adult sheep		47.37
Merino ewes joined/intended to non-Merino rams	15.96	7.56
Merino ewes joined/intended to Merino rams	43.17	20.45
Merino wethers	19.17	9.08
Merino hoggets	21.70	10.28
Pastoral zone		
Total adult sheep		11.77
Merino ewes joined/intended to Merino rams	59.47	7.00
Merino wethers	23.11	2.72
Merino hoggets	17.42	2.05

Table 16: 2002-03 to 2004-05 Relative greasy wool cut (kg/hd)

	Fine wool (18.6 micron)	Medium wool (21.5 micron)	Pastoral wool (23 micron)
Ewes	4.75	4.95	5.74
Wethers	5.44	5.94	6.13
Hoggets	3.46	4.45	4.45
Weights correspond to diameter category	≤ 19 micron	20 – 23 micron	24 – 27 micron

Table 17: 2002-03 to 2004-05 Greasy shorn wool production (kt) by sheep and zone (Australia)

	≤ 19 micron	20 – 23 micron	24 – 27 micron	≥ 28 micron
High rainfall zone				
Merino ewes joined/intended to non-Merino rams	9.99	8.03	1.43	
Merino ewes joined/intended to Merino rams	30.77	24.75	4.29	
Merino wethers	29.45	24.80	4.13	
Merino hoggets	12.80	12.71	1.80	
Non-Merino ewes				12.95
Wheat-sheep zone				
Merino ewes joined/intended to non-Merino rams	11.31	25.73	1.89	
Merino ewes joined/intended to Merino rams	30.57	69.58	5.67	
Merino wethers	15.54	37.04	2.94	
Merino hoggets	11.20	31.47	2.49	
Non-Merino ewes			6.20	9.86
Pastoral zone				
Merino ewes joined/intended to Merino rams	4.65	19.04	2.40	
Merino wethers	2.07	8.87	1.00	
Merino hoggets	0.99	5.01	0.54	

Table 18: 2002-03 to 2004-05 Total carcass weight of lamb production (Australia)

	Number (million)	cwt (kt)
Second-cross/meat	5.70	120.60
First-cross high rainfall zone	2.20	43.95
First-cross wheat-sheep zone	4.68	93.40
Merino high rainfall zone	0.89	17.84
Merino wheat-sheep zone	2.61	52.18
Merino pastoral zone	0.69	13.74
Total	16.77	341.70

Table 19: 2002-03 to 2004-05 Relative dressed weights (kg/hd carcass weight)

	Fine	Medium	Pastoral	Terminal
Ewes	19.44	21.56	24.09	21.56
Wethers	19.44	21.56	24.09	-
Hoggets	18.17	20.29	22.82	-

Table 20: 2002-03 to 2004-05 Numbers and carcass weights of sheep slaughtered (Australia)

	Number (millions)	Carcass Weight (kt)
Non-Merino Ewes	0.47	10.13
Merino Ewes		
Pastoral Zone	1.92	44.82
Wheat-sheep Zone (joined to Merino rams)	1.61	34.22
Wheat-sheep Zone (joined to non-Merino rams)	0.41	8.83
High Rainfall Zone (joined to Merino rams)	1.93	37.09
High Rainfall Zone (joined to non-Merino rams)	0.51	9.84
Merino Wethers and Hoggets		
Pastoral Zone	1.39	32.66
Wheat-sheep Zone	1.88	36.96
High Rainfall Zone	2.11	35.96

5 Specification of Prices and Quantities

5.1 Sheep

Sheep are combined with land, labour, capital and many other overheads and recurrent inputs to produce wool, lamb and mutton. The EDM developed by Mounter *et al*. (2007) classifies inputs into farm production as two separate groups, 'sheep' and all 'other inputs'. A fundamental problem associated with treating sheep as a distinct input is being able to specify the cost of using that input in any one particular year. Sheep are recognised as being a 'durable or semi-durable' input as the flow of services they provide into production can span a number years. Therefore, the cost of using sheep as an input flow into production for a particular year needs to be established, as opposed to the total capital value of the sheep in that same year. Lawrence and McKay (1980) proposed that the annual service flow cost from a semi-durable input can be derived by dividing the cost into three components comprising depreciation, maintenance and opportunity costs. This method of measurement has subsequently been used by others (e.g. O'Donnell 1991; O'Donnell and Woodland 1995) to estimate the cost of the annual service flow from durable inputs such as land, physical capital and livestock.

Depreciation is the decrease in value of a capital good due to wear and tear and represents the amount of the good used in production in any one year. Under the assumption that the national sheep flock is self-replacing and correctly maintained, depreciation of the sheep flock is zero.

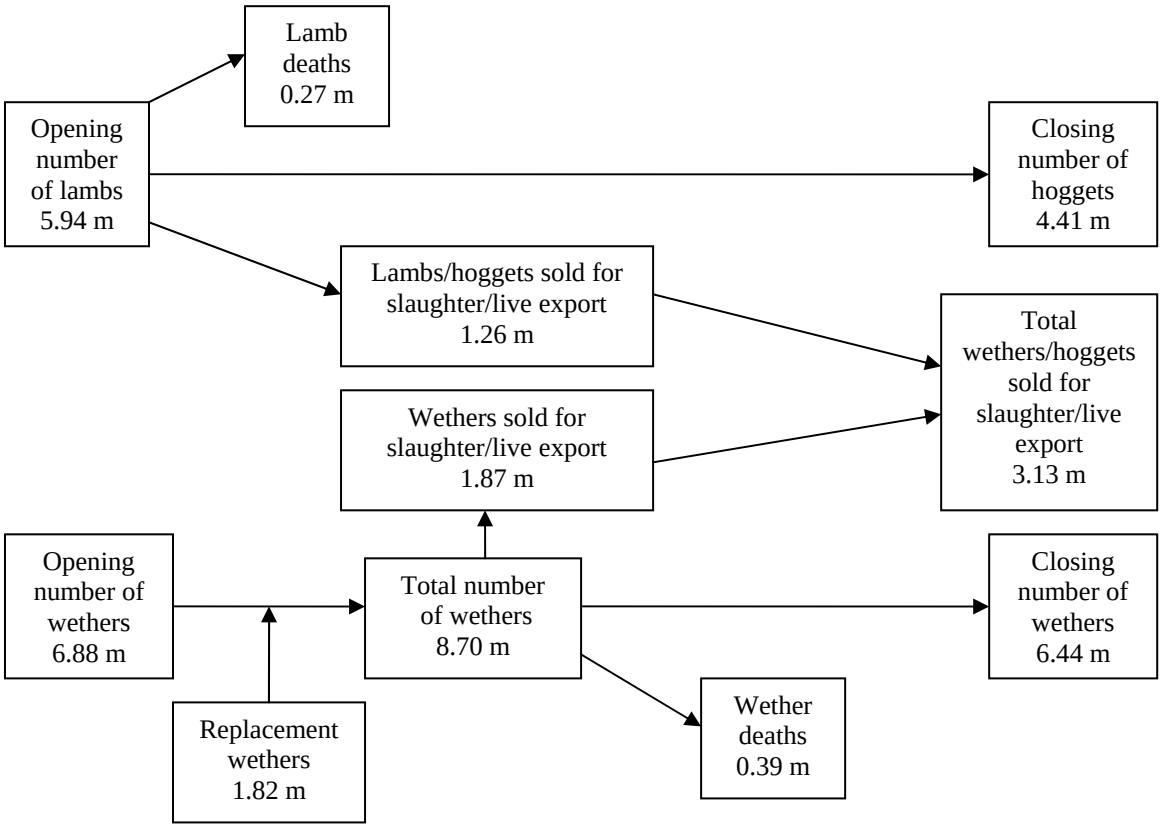
The maintenance input costs necessary for zero depreciation fall into two categories. The first are costs associated with normal sheep husbandry practices such as labour costs and the purchase of supplies and materials. In the EDM, input costs of this type are included in the 'other inputs' group. The second category of flock maintenance input costs are replacement costs attributed to sheep deaths and disposals. These costs are measured as sheep purchases plus the absolute value of livestock operating gains, where operating gains are defined as the difference between closing and opening numbers multiplied by the closing price (Lawrence and McKay 1980).

The third cost component of the annual service flow from a durable input is opportunity cost. Opening numbers are used to represent livestock input quantity and the opportunity cost is calculated as the current market value of livestock multiplied by the rate of return corresponding to the relevant year. Lawrence and McKay (1980) used the maximum annual overdraft rate to approximate the prevailing rate of return in the economy whilst O'Donnell and Woodland (1995) opted for an average yield on government securities as a measure of the rate of return.

The 2002-03 to 2004-05 average annual supply and use of wethers and hoggets in the high rainfall zone, shown in Figure 9, is used as an example of how the annual service flow costs are derived. The sheep numbers for the high rainfall zone are listed in Table 21.

Lawrence and McKay (1980) used average per property data to represent a typical farm in the sheep industry. Using this microeconomic approach, average livestock purchases for the representative farm are included in maintenance costs. This typically includes purchases of rams and young sheep for use as flock replacements. However, at an industry level sheep purchases are zero as the Australian flock is assumed to be self-replacing.[8] Therefore, using sheep purchases as a partial measurement of annual service flow costs is not applicable at an industry level.

Figure 9: Supply and use of Merino wethers and hoggets in the Australian high rainfall zone



As Figure 9 indicates, opening Merino wethers including replacements were 8.70 million. Closing numbers totaled 6.44 million. Based on an average per head calculated carcass weight of 19.44 kg, the difference between opening and closing numbers is 43.73 kt. At the end of June 2003, 29.8 per cent of wethers were aged 4 years and older and 70.2 per cent were under 4 years of age (Table 22) (Martin *et al*. 2004). Using these estimates, 13.03 kt were apportioned to wethers 4 years and older and 30.70 kt assigned to 2 and 3 year old wethers.

The difference of 1.53 million between opening lamb numbers and closing hogget numbers represents the supply and use of hoggets over a 12-month period. The total carcass weight difference, calculated at an average 18.17 kg per head, was 27.75 kt.

[8] Purchases of sheep from outside Australia are a minuscule component of the national sheep flock.

Table 21: Opening and closing sheep numbers (high rainfall zone: Australia)

High Rainfall Zone	Opening Numbers (m)	%	Closing Numbers (m)	%
Ewes	10.66	37.5	11.10	41.0
Wethers	6.88	24.2	6.44	23.8
Lambs	5.94	20.9	5.12	18.9
Hoggets	4.94	17.4	4.41	16.3
Total	28.42	100	27.07	100
(Ewe Lambs)	2.97		2.56	
(Wether lambs)	2.97		2.56	
(Ewe Hoggets)	3.12		2.79	
(Wether Hoggets)	1.82		1.62	

Table 22: Age distribution of adult sheep

	%
Merino ewes under 4 years	52.7
Merino ewes 4 years and over	47.3
Merino wethers under 4 years	70.2
Merino wethers 4 years and over	29.8
Non-Merino ewes under 4 years	49.9
Non-Merino ewes 4 years and over	50.1

Source: Martin, King and Shafron (2004).

(Based on 2002-03 AAGIS closing percentages).

It is reasonable to expect that young sheep values are higher than older sheep values because of the difference in productive years remaining. In the absence of a closing price (or value) for wethers, the average annual 2002-03 to 2004-05 sale yard mutton price of $1.75 kg carcass weight was used as an estimate of the market value of wethers aged 4 years and older. A weighted average mutton price of $2.47 kg carcass weight for hogget sales was estimated using MLA (2006) average annual mutton prices for hogget sales in New South Wales, South Australia and Victoria.[9] The mid-range value between the two prices of $2.11 was used as an approximation of the market price for 2-3 year old wethers. Total absolute negative livestock operating gains for the high rainfall zone wethers and hoggets sector were estimated as $156.12 million.

In calculating the opportunity cost component of the annual service flow for the sheep input, the average market yield on three-year government bonds was used as an approximation of the rate of return in the economy. For 2002-03 to 2004-05 the average yield was 5.12 per cent (RBA 2006). The market values of wethers and hoggets were approximated using the same prices and average per kg carcass weights as above.

[9] Calculation of this price is given in Section 5.3.1.

Opening numbers of sheep in carcass weight represent livestock input quantities and these are distributed by age according to the same percentages used in deriving maintenance costs. The total market value of sheep in the high rainfall hogget/wether sector was $605.05 million with an annual opportunity cost of $30.98 million, calculated as 5.12 per cent of the market value.

The cost of the annual service flow from high rainfall zone hoggets and wethers was estimated as $187.10 million. The average price per kg carcass weight was obtained by dividing the annual service flow cost by the total opening combined carcass weight of wethers and hoggets. The average three-year input cost calculations for all sheep enterprises in the model are detailed in Table 23.

5.2 Wool

Data on wool export quantities and prices by diameter category and wool type were collected from the Australian Bureau of Statistics (ABS 2006). Export wool types included in the model are greasy shorn wool, scoured wool, carbonised wool and wool top and noils. For the three-year period 2002-03 to 2004-05, average annual wool production and greasy equivalent average annual wool exports were 483.97 kilo tonnes and 451.63 kilo tonnes, respectively. Of the difference between the two amounts, a very small proportion would be used in later-stage domestic processing sectors while the balance would be unsold wool or wool passed in at auction. A separate sector for unsold wool is not included in the EDM. Estimation of the total returns from alternative R&D or promotion investment scenarios relies on the total value of average annual production. Unsold quantities of wool are valued at auction prices and are included in the greasy shorn wool export categories.

The export prices for each greasy shorn wool category were obtained by dividing the greasy free-on-board (FOB) export values by the export volumes of greasy shorn wool. The FOB export values include all costs up to and including loading the wool onto a carrier for export. Examples of post-auction sale costs for greasy shorn wool up to the FOB point of valuation include transport, shipment preparation and wharfage. For 2002-03 to 2004-05, the average annual cost for post-auction services was 30 c/kg (AWI 2006). Subtracting this amount from the c/kg greasy FOB export price provides an average annual greasy wool auction price for each greasy shorn wool export category.

Table 23: Annual service flow costs for sheep enterprises

	Opening Weight kt cwt	Closing Weight kt cwt	Diff. kt cwt	Market Price $/kg	Neg. Op. Gains	Total market Value $m	Opp. Cost $m	Annual Service Flow Cost $m	($/kg)
Non-Merino Ewes (X1)	150.47	135.03	15.44						
Non-Merino Ewes under 4 yrs	75.08	67.38	7.70	2.11	16.26	158.43			
Non-Merino Ewes 4 yrs & over	75.39	67.65	7.74	1.75	13.54	131.92			
					29.79	290.35	**14.87**	**44.66**	**0.30**
Merino Ewes (X23)	268.02	215.79	52.23						
Merino Ewes under 4 yrs	141.25	113.72	27.53	2.11	58.08	298.03			
Merino Ewes 4 yrs & over	126.77	102.07	24.70	1.75	43.23	221.85			
					101.31	519.88	**26.62**	**127.93**	**0.48**
Merino Ewes (X45)	603.80	540.60	63.20						
Merino Ewes under 4 yrs	318.20	284.90	33.31	2.11	70.28	671.41			
Merino Ewes 4 yrs & over	285.60	255.70	29.89	1.75	52.31	499.80			
					122.59	1171.20	**59.97**	**182.56**	**0.30**
Merino Ewes (X61)	168.65	146.74	21.91						
Merino Ewes under 4 yrs	88.88	77.33	11.55	2.11	24.36	187.53			
Merino Ewes 4 yrs & over	79.77	69.41	10.36	1.75	18.14	139.60			
					42.50	327.13	**16.75**	**59.25**	**0.35**
Merino Wethers/hoggets (X71)	276.93								
Merino Wethers	168.99	125.26	43.73						
Merino Wethers under 4 yrs	118.63	87.93	30.70	2.11	64.77	250.31			
Merino Wethers 4 yrs & over	50.36	37.33	13.03	1.75	22.81	88.13			
Merino Hoggets	107.94	80.19	27.75	2.47	68.54	266.61			
					156.12	605.05	**30.98**	**187.10**	**0.68**
Merino Wethers/hoggets (X81)	404.06								
Merino Wethers	195.56	145.27	50.29						
Merino Wethers under 4 yrs	137.28	101.98	35.30	2.11	74.49	289.67			
Merino Wethers 4 yrs & over	58.28	43.29	14.99	1.75	26.23	101.98			
Merino Hoggets	208.50	136.72	71.78	2.47	177.30	515.00			
					278.01	906.65	**46.42**	**324.43**	**0.80**
Merino Wethers/hoggets (X91)	112.21								
Merino Wethers	65.49	48.25	17.24						
Merino Wethers under 4 yrs	45.97	33.87	12.10	2.11	25.54	97.01			
Merino Wethers 4 yrs & over	19.52	14.38	5.14	1.75	8.99	34.15			
Merino Hoggets	46.72	24.74	21.98	2.47	54.29	115.40			
					88.82	246.56	**12.62**	**101.44**	**0.90**

In wool processing, the yield is the amount of clean wool fibre expressed as a percentage of the raw greasy wool. For example, 0.64 kg of scoured wool produced from 1 kg of raw greasy wool gives a yield of 64 per cent. Conversely, the greasy wool yield from scoured wool would be 156 per cent (1.00/0.64). Conversion rates from The Woolmark Company's (TWC) Harvest database were used to change processed wool export quantities into greasy wool equivalents. The yields used in the database are 155.21 per cent for scoured wool, 155.21 per cent for wool top and noil and 147.45 per cent for carbonised wool (K. Curtis, DAWA, per. comm. 2006). Within the EDM, all diameter categories of carbonised wool were combined, as were all diameter categories of wool noils. Greasy equivalent export quantities and FOB export values were used to calculate c/kg greasy equivalent FOB export prices for each processed wool type. Post-sale cost items, published in Sheep's Back to Mill (AWI 2006), were estimated on the basis of greasy wool only and it was assumed that, on a greasy equivalent basis, processed wool costs were the same as greasy wool for those items. Therefore, transport, shipment preparation, wharfage and other costs for all processed wool exports were considered to be the same as for greasy shorn wool exports. Domestically processed scoured wool, carbonised wool, and wool top and noil greasy equivalent prices were estimated as the respective c/kg greasy equivalent FOB export prices minus these costs.

Information on domestic processing costs is necessary to derive costs for wool and non-wool inputs into each of the domestic processing sectors. In a model of the world market for wool, Verikios (2007) used cost share estimates of approximately 88 per cent for greasy wool in the scouring industry, 79 per cent for scoured wool in the carbonising industry and 74 per cent for scoured wool in the topmaking industry. The estimates were based on 1995 data and were global rather than country-specific estimates. Industry indicative wool processing costs in Australia were judged to be 50 cents per kg of scoured wool, 150 cents per kg of carbonised wool and 150 cents per kg of top and noil (P. Carey, Chargeurs Wool, per. comm. 2006). Given the above estimates, non-wool input cost shares for the domestic scouring, carbonising and topmaking sectors within the EDM were approximately 7 per cent, 16 per cent and 11 per cent respectively, compared with 12 per cent, 21 per cent and 26 per cent for the 1995 global industry estimates. For the domestic processing sectors, wool input prices were derived using the Australian industry indicative costs mentioned above.[10]

AWEX wool auction data provided by the Department of Agriculture Western Australia (DAWA) were used to estimate wool production figures from each agricultural zone. The data were aggregated into four diameter categories corresponding to the ABS wool export diameter categories. The micron of each lot of wool in the data is the diameter rounded to one micron. For example, wool 19 µm in diameter includes wool 18.5 µm to 19.4 µm, 20 µm wool includes 19.5 µm to 20.4 µm and so on. Thus, wool in the $\leq$ 19 µm category includes wool up 19.4 µm in diameter, the 20-23 µm category includes wool 19.5 µm to 23.4 µm, the 24-27 µm category includes wool 23.5 µm to 27.4 µm and wool in the $\geq$ 28 µm category is 27.5 µm or greater.

[10] Wool input costs were also derived using the 1995 global cost share estimates (Table 25). Results from various investment scenarios using the different wool processing cost shares are compared in Mounter *et al*. (2007).

The AWEX data records the origin of wool production using wool statistical areas (WSA) which were devised by the Australian Wool Corporation (AWC) in the late 1980s. Wool production was determined by assigning each WSA to an agricultural zone. A limitation of using AWEX auction data is that it only covers approximately 85 per cent of production and may not include wool sold privately or direct sales to processors or exporters. A more comprehensive account of all wool harvested is maintained by Australian Wool Testing Authority (AWTA) but details are recorded where the test sampling occurred rather than where the wool was produced. Though not complete, the AWEX auction data do provide a good representation of wool production, as the difference in diameter profile of AWEX auction data and AWTA test data is likely to be small when aggregated over a whole year (K. Curtis, DAWA, pers. comm. 2006).

The AWEX data contains information on the greasy weight, clean weight and the c/kg clean price of wool offered for auction. A greasy equivalent c/kg auction price for each wool type in each zone was calculated by dividing the product of the clean weight and price by the greasy weight.[11] The average auction prices for wool estimated from the AWEX auction data are listed in Table 24.

A cross check was used to ascertain if the greasy auction prices of wool used in the domestic processing sector, derived by using the industry indicative wool processing costs, were similar to the estimated average AWEX auction prices. The greasy shorn wool FOB export values, exclusive of post-auction sale costs, were subtracted from the total AWEX estimated auction value of production for each wool type. The remaining auction value was divided by the amount of greasy wool used in the domestic processing sector to derive a c/kg auction price. A comparison of the prices is shown in Table 25. Also included in Table 25 is the estimated auction prices calculated using the global wool-processing cost share percentages, as used by Verikios (2007).

Table 24: AWEX estimated wool auction prices (c/kg greasy)

	High Rainfall Zone	Wheat Sheep Zone	Pastoral Zone
≤ 19 micron	687	576	543
20-23 micron	617	544	497
24-27 micron	470	457	439
≥ 28 micron	358	358	-

Table 25: Comparison of domestic processing wool auction prices (c/kg greasy)

	AWEX Estimated Price	c/kg Indicative Processing Cost Price	Global Cost Share Price
≤ 19 micron	522	522	446
20-23 micron	540	443	393
24-27 micron	450	470	401
≥ 28 micron	231	238	238

With the exception of the 20-23 µm category, the auction prices estimated using industry indicative c/kg processing costs and the estimated AWEX prices are the same for the ≤ 19 µm wool category and similar for the other categories. The fact that AWEX auction data

[11] Wool of the same fibre diameter category originating from different sheep enterprises within the same agricultural zone is assumed to be homogeneous in quality and price.

are not a complete set could explain the inconsistency between the 20-23 µm prices. Excluding the ≥ 28 µm category, the auction prices estimated using the global non-wool input cost share percentages are considerably less than the AWEX estimated prices.

The AWEX estimated auction prices for the 20-23, 24-27 and ≥ 28 µm categories in each zone (Table 24) were adjusted to correspond with the auction prices estimated using industry indicative c/kg processing costs.[12] For example, the total auction value of 20-23 µm greasy shorn wool exports was $1070.45 million and the total auction value of greasy wool for use in the domestic processing sector, estimated using industry indicative c/kg processing costs, was $343.64 million, making a combined total auction value of $1414.09 million. Using the AWEX estimated auction prices in Table 24 and the associated levels of production (Table 14 in Section 4), the total auction value of 20-23 µm wool was $1490.12 million. The difference between the two total values was divided by the 267.03 kt of 20-23 µm wool produced to derive a 28 c/kg difference in price. This was subtracted from AWEX estimated prices in Table 24 to derive auction prices for 20-23 µm wool in the three different agricultural zones. The same procedure was followed to estimate auction prices for the 24-27 and ≥ 28 µm categories of wool.

There are numerous sales costs for wool sold at auction including warehousing, insurance, handling, wool testing and broker's commission. On average, for 2002-03 to 2004-5 the costs were approximately 24 c/kg of greasy wool (AWI 2006). A farm price for each diameter category of wool in each zone was obtained by subtracting wool selling costs from the auction price.[13]

5.3 Lamb and Mutton

The carcass weight quantities of lamb and mutton production were sourced from Livestock Products (ABS 2005a). Average sale yard carcass weight prices for lamb and mutton were taken from Australian Commodity Statistics (ABARE 2006). The quotations are for monthly average fat stock prices in each major market, weighted by the monthly production of each meat in the respective states. Prices for lamb weighing 18-20 kilograms carcass weight with a fat score of three are used to represent the sale yard carcass weight prices received for first-cross and second-cross/meat lambs. A weighted average mutton price of $2.47 kg carcass weight for hogget sales, estimated using MLA (2006) data, was used to represent the sale yard carcass weight price for Merino lamb sales.[14] Sale yard mutton prices are based on 18-24 kilograms carcass weight, with a fat score of three.

Domestic processed lamb carcass prices were based on NSW wholesale lamb carcass prices supplied by MLA (MLA 2006). For consistency with sale yard lamb weights, wholesale prices were for lamb weighing 18-20 kilograms carcass weight with a fat score of three. In the EDM, supplies of similar lamb types across all three agricultural zones are assumed to be homogeneous in quality. It is reasonable to assume the cost per kilogram of slaughtering and processing a live lamb into a lamb carcass is the same for lamb destined for either the domestic or export market (S. Marshall, Country Fresh Australasia,

[12] Adjustment to the ≤ 19 micron prices was not necessary as auction prices were the same.
[13] The farm price includes freight and insurance from the sheep's back to the wool store.
[14] See Section 5.3.1 below for the calculation of this price.

pers. comm. 2006). Under this assumption the wholesale export carcass price for lamb is assumed to be the same as the domestic carcass price for lamb.

Information on wholesale mutton prices is not collected. Two methods were used to approximate a wholesale price for mutton. The first method was to assume the same percentage price mark-up applicable to lamb. The price mark-up for lamb from saleyard price to wholesale price was approximately 33 per cent. The second method involved simple regression analysis to explain sale yard mutton prices by sale yard lamb prices.[15] A predicted wholesale mutton price was obtained by substituting the wholesale lamb price into the estimated regression equation. The mutton wholesale price predicted from the regression equation was used in preference to the price mark-up though the difference between the two prices was reasonably small.[16]

The Department of Agriculture, Fisheries and Forestry (DAFF) and ABS both report mutton and lamb meat exports as shipped weight quantities. Conversion factors are available to estimate carcass weight equivalents but it is possible for discrepancies to exist between the two sets of data. Estimates from ABS are typically higher than DAFF estimates for a number of reasons. For example, ABS uses export quantity, which includes packaging, whereas DAFF reports export weight. Furthermore, all exports exiting through customs are captured in ABS data while DAFF statistics do not capture exports without health certificates. Though ABS data provide more detail, DAFF data are timelier and are preferred for use by MLA (K. Jones, MLA, pers. comm. 2006). Estimated carcass weight exports of lamb and mutton provided by MLA (2006) were used as the export volumes in the model. Lamb and mutton FOB export values, collected by ABS and obtained from MLA (2006), were divided by the MLA carcass weight estimates of exported lamb and mutton to calculate per kilogram carcass weight FOB export prices.

The carcass weight volume of lamb sold in the domestic retail market was converted into an equivalent sale weight of retail cuts of lamb using a saleable yield percentage. An average saleable yield of 68 per cent was estimated from MLA (2006) data measuring saleable retail cuts of lamb as a proportion of the carcass weight of lamb from a number of different suppliers.[17] In the absence of similar estimates for mutton, the average saleable yield for mutton was considered to be the same as for lamb.

Average retail prices of lamb published in *Australian Commodity Statistics* (ABARE 2006) are based on retail prices of selected cuts of lamb. The prices, sourced from *Average Retail Prices of Selected Items* (ABS 2005b), relate to per kilogram prices for leg, loin chops and forequarter chops. Combined, these retail cuts comprise on average around 68 per cent of the saleable yield, with racks of cutlets accounting for 9 per cent and trims and shanks contributing the remaining 23 per cent (MLA 2006). Based on MLA (2006) retail price information, the prices for leg, shortloin and forequarters are similar, and are approximately half the retail price of racks of cutlets and double the price of shanks and trim. This information was used to construct an average annual retail price for lamb from the average retail prices of lamb reported in *Australian Commodity*

[15] Details of the regression analysis are contained in Section 5.3.2 below.
[16] The regression price was approximately 5 c/kg or 2 per cent higher than the mark-up price.
[17] In all cases the carcass weight cost per kilogram from each of the suppliers was the same.

Statistics. The ABARE retail lamb price was multiplied by the equivalent saleable weight of retail cuts for each of the years concerned to obtain the total retail value of lamb sold in the domestic market from 2002-03 to 2004-05. This figure was divided by the total quantity of saleable retail cuts to obtain an average annual retail price of 1039 c/kg. Using the MLA retail price information, a weighted average annual retail price was estimated as

$$1039*0.68 + (1039*2)*0.09 + (1039/2)*0.23 = 1015 \text{ c/kg}$$

Retail prices for mutton are not recorded. An average annual retail price for mutton was estimated by applying the wholesale-retail price mark-up percentage for lamb to the estimated wholesale price for mutton.[18]

The gross weight and gross FOB value of live sheep exports were obtained from *Livestock Products* (ABS 2005a). The export statistics are collated by ABS from information provided by exporters to the Australian Customs Service. Sheep exported for breeding purposes are not included in the data. For consistency within the EDM, gross live weights were converted to equivalent carcass weights using the same dressing percentage specified for mutton. The gross FOB value was divided by the carcass weight equivalent to estimate a price in terms of cents per kg carcass weight FOB.

5.3.1 Hogget Price

An estimate of the mutton price for Merino hoggets was required for certain calculations in the EDM. Price estimates of hogget sales by agricultural zone were not available. A weighted average carcass weight mutton price for hogget sales was estimated using average annual mutton prices for hogget sales in New South Wales, South Australia and Victoria sourced from MLA. Estimates for sales in other Australian states were not available. The average prices in each state for 2003 to 2005 are shown in Table 26.

Table 26: Average carcass prices for hoggets (c/kg)

	2003	2004	2005	Average
NSW	281	244	216	247
SA	257	230	224	237
VIC	273	251	236	253

Source: MLA unpublished data

Information on the number of hoggets sold for mutton in each state was not available. Assuming the proportions of hoggets in the sheep flocks of all three states are similar, the numbers of sheep in each state were used to derive a weighting for the prices in each state. State sheep numbers corresponding to the average yearly prices in Table 26 are listed in Table 27.

[18] A predicted retail price for mutton was also estimated by substituting the retail lamb price into the regression equation that was used to obtain a predicted wholesale mutton price. The price derived using a mark-up percentage was approximately 4 per cent higher than the estimated regression price.

Table 27: Sheep numbers by state (million)

	2003	2004	2005	Total	%
NSW	33.71	35.23	35.57	104.51	51.3
SA	13.06	12.92	12.38	38.36	18.8
VIC	20.39	19.98	20.52	60.89	29.9
Total	67.16	68.13	68.47	203.76	100

Source: ABARE (Livestock holdings on establishments with an estimated EVAO of $5,000 or more, as at 30 June)

Sheep in each state as a percentage of total sheep numbers in the three states combined is shown in the last column of Table 27. A simple average of the three-year prices for each state were weighted by the corresponding percentage for each state to obtain a weighted average mutton price for hogget sales:

$$247*0.513 + 237*0.188 + 253*0.299 = 247 \text{ c/kg carcass weight}$$

5.3.2 Wholesale Mutton Price

Information on wholesale mutton prices is not collected. Average monthly mutton sale yard prices for the period June 2001 to June 2005 (ABARE 2006) were regressed on monthly lamb sale yard prices to determine if lamb prices were a significant indicator of mutton prices. Simple regression using ordinary least squares (OLS) was performed using the Eviews statistical software program.

A low Durbin-Watson (DW) statistic of 0.54 suggested evidence of positive serial correlation in the residuals. A correlogram of the residuals revealed exponentially decaying autocorrelations with significant spikes at lags 1 and 2 and one dominant non-zero partial autocorrelation at lag one. The Q statistics were significant at all lags with small p-values indicating serial correlation in the residuals. The inability to test for higher order correlation among errors is a limitation of the DW test. To check for higher order serial correlation, a Breusch-Godfrey Lagrange Multiplier test was implemented. The null hypothesis of no serial correlation up to lag 2 was rejected at the 5 per cent level of significance. An autoregressive model of order one (AR (1)) was specified to account for the autocorrelation. A second Breusch-Godfrey Lagrange Multiplier test found no evidence to suggest the existence of serial correlation. The series were then checked for stationarity using the Augmented Dickey-Fuller (ADF) unit root test. The null hypothesis of a unit root was rejected for lamb, as the test statistic was less than the test critical values. The ADF test statistic for mutton was less than the 10 per cent and 5 per cent critical values but greater than the 1 per cent test critical value. A unit root test was also performed on the errors. The ADF test statistic was considerably less than the test critical values indicating a stationary long-run equilibrium relationship between the two variables. White's test was used to test for heteroskedasticity in the residuals with the null hypothesis of no heteroskedasticity not rejected. The regression model was estimated as

$$p_m = 7.510 + 0.485p_l + e$$

Substituting the wholesale carcass weight lamb price of 476 c/kg into the equation for p_l, the wholesale carcass weight mutton price, p_m, was estimated to be 239 c/kg. The regression output is provided in Table 28.

Table 28: Regression output

Dependent Variable: MUTTON
Method: Least Squares

Sample (adjusted): 2 49
Included observations: 48 after adjustments
Convergence achieved after 11 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.510422	23.70424	0.316839	0.7528
LAMB	0.485207	0.062994	7.702409	0.0000
AR(1)	0.719419	0.101920	7.058668	0.0000

R-squared	0.745269	Mean dependent var	177.8479
Adjusted R-squared	0.733947	S.D. dependent var	29.80947
S.E. of regression	15.37581	Akaike info criterion	8.363930
Sum squared resid	10638.70	Schwarz criterion	8.480880
Log likelihood	-197.7343	F-statistic	65.82838
Durbin-Watson stat	1.741018	Prob(F-statistic)	0.000000

Inverted AR Roots	.72

5.4 Base Equilibrium Prices and Quantities

The average base equilibrium prices and quantities for the period 2002-03 to 2004-05 are listed in Table 29, as are the cost and revenue shares for all sectors. Definitions are given in Table 30.

Table 29: Base equilibrium prices, quantities, cost shares and revenue shares

Prices and Quantities	Total Value	Cost Shares	Revenue Shares
Sheep			
$X_1 = 150.47$, $w_1 = 0.30$	$TV_{X1} = 45.14$		
$X_{21} = 65.67$, $w_{23} = 0.48$	$TV_{X21} = 31.52$		
$X_{31} = 202.36$, $w_{23} = 0.48$	$TV_{X31} = 97.13$		
$X_{41} = 163.03$, $w_{45} = 0.30$	$TV_{X41} = 48.91$		
$X_{51} = 440.77$, $w_{45} = 0.30$	$TV_{X51} = 132.23$		
$X_{61} = 168.65$, $w_{61} = 0.35$	$TV_{X61} = 59.03$		
$X_{71} = 276.93$, $w_{71} = 0.68$	$TV_{X71} = 188.31$		
$X_{81} = 404.06$, $w_{81} = 0.80$	$TV_{X81} = 323.25$		
$X_{91} = 112.21$, $w_{91} = 0.90$	$TV_{X91} = 100.99$		
Farm Sector			
$Y_{13W} = 6.20$, $v_{13W} = 4.39$ $Y_{14W} = 22.81$, $v_{14W} = 3.37$ $Y_{1L} = 120.60$, $v_{1L} = 3.58$ $Y_{1M} = 8.42$, $v_{1M} = 1.75$	$TV_{Y1} = 550.57$	$k_{X1} = 0.08$, $k_{X1W} = 0.92$	$\gamma_{Y13W} = 0.05$, $\gamma_{Y14W} = 0.14$ $\gamma_{Y1L} = 0.76$, $\gamma_{Y1M} = 0.05$
$Y_{21W} = 9.99$, $v_{21W} = 6.63$ $Y_{22W} = 8.03$, $v_{22W} = 5.62$ $Y_{23W} = 1.43$, $v_{23W} = 4.51$ $Y_{2L} = 43.95$, $v_{2L} = 3.58$ $Y_{2M} = 9.56$, $v_{2M} = 1.75$	$TV_{Y2} = 290.98$	$k_{X21} = 0.11$, $k_{X21W} = 0.89$	$\gamma_{Y21W} = 0.23$, $\gamma_{Y22W} = 0.15$ $\gamma_{Y23W} = 0.02$, $\gamma_{Y2L} = 0.54$ $\gamma_{Y2M} = 0.06$
$Y_{31W} = 30.77$, $v_{31W} = 6.63$ $Y_{32W} = 24.75$, $v_{32W} = 5.62$ $Y_{33W} = 4.29$, $v_{33W} = 4.51$ $Y_{3L} = 17.84$, $v_{3L} = 2.47$ $Y_{3M} = 36.03$, $v_{3M} = 1.75$	$TV_{Y3} = 469.56$	$k_{X31} = 0.21$, $k_{X31W} = 0.79$	$\gamma_{Y31W} = 0.43$, $\gamma_{Y32W} = 0.30$ $\gamma_{Y33W} = 0.05$, $\gamma_{Y3L} = 0.09$ $\gamma_{Y3M} = 0.13$
$Y_{41W} = 11.31$, $v_{41W} = 5.52$ $Y_{42W} = 25.73$, $v_{42W} = 4.93$ $Y_{43W} = 1.89$, $v_{43W} = 4.39$ $Y_{4L} = 93.40$, $v_{4L} = 3.58$ $Y_{4M} = 8.57$, $v_{4M} = 1.75$	$TV_{Y4} = 546.95$	$k_{X41} = 0.09$, $k_{X41W} = 0.91$	$\gamma_{Y41W} = 0.11$, $\gamma_{Y42W} = 0.23$ $\gamma_{Y43W} = 0.02$, $\gamma_{Y4L} = 0.61$ $\gamma_{Y4M} = 0.03$
$Y_{51W} = 30.57$, $v_{51W} = 5.52$ $Y_{52W} = 69.58$, $v_{52W} = 4.93$ $Y_{53W} = 5.67$, $v_{53W} = 4.39$	$TV_{Y5} = 721.97$	$k_{X51} = 0.18$, $k_{X51W} = 0.82$	$\gamma_{Y51W} = 0.23$, $\gamma_{Y52W} = 0.48$ $\gamma_{Y53W} = 0.03$, $\gamma_{Y5L} = 0.18$ $\gamma_{Y5M} = 0.08$

$Y_{5L} = 52.18$, $v_{5L} = 2.47$ $Y_{5M} = 33.24$, $v_{5M} = 1.75$			
$Y_{61W} = 4.65$, $v_{61W} = 5.19$ $Y_{62W} = 19.04$, $v_{62W} = 4.48$ $Y_{63W} = 2.40$, $v_{63W} = 4.20$ $Y_{6L} = 13.74$, $v_{6L} = 2.47$ $Y_{6M} = 43.53$, $v_{6M} = 1.75$	$TV_{Y6} = 229.63$	$k_{X61} = 0.26$, $k_{X61W} = 0.74$	$\gamma_{Y61W} = 0.11$, $\gamma_{Y62W} = 0.37$ $\gamma_{Y63W} = 0.04$, $\gamma_{Y6L} = 0.15$ $\gamma_{Y6M} = 0.33$
$Y_{71W} = 42.25$, $v_{71W} = 6.63$ $Y_{72W} = 37.51$, $v_{72W} = 5.62$ $Y_{73W} = 5.93$, $v_{73W} = 4.51$ $Y_{7E} = 23.55$, $p_{SE} = 3.19$ $Y_{7M} = 34.44$, $v_{7M} = 1.75$	$TV_{Y7} = 653.06$	$k_{X71} = 0.29$, $k_{X71W} = 0.71$	$\gamma_{Y71W} = 0.43$, $\gamma_{Y72W} = 0.32$ $\gamma_{Y73W} = 0.05$, $\gamma_{Y7E} = 0.11$ $\gamma_{Y7M} = 0.09$
$Y_{81W} = 26.74$, $v_{81W} = 5.52$ $Y_{82W} = 68.51$, $v_{82W} = 4.93$ $Y_{83W} = 5.43$, $v_{83W} = 4.39$ $Y_{8E} = 66.73$, $p_{SE} = 3.19$ $Y_{8M} = 35.90$, $v_{8M} = 1.75$	$TV_{Y8} = 785.53$	$k_{X81} = 0.41$, $k_{X81W} = 0.59$	$\gamma_{Y81W} = 0.19$, $\gamma_{Y82W} = 0.43$ $\gamma_{Y83W} = 0.03$, $\gamma_{Y8E} = 0.27$ $\gamma_{Y8M} = 0.08$
$Y_{91W} = 3.06$, $v_{91W} = 5.19$ $Y_{92W} = 13.38$, $v_{92W} = 4.48$ $Y_{93W} = 1.55$, $v_{93W} = 4.20$ $Y_{9E} = 1.52$, $p_{SE} = 3.19$ $Y_{9M} = 31.72$, $v_{9M} = 1.75$	$TV_{Y9} = 144.93$	$k_{X91} = 0.70$, $k_{X91W} = 0.30$	$\gamma_{Y91W} = 0.11$, $\gamma_{Y92W} = 0.43$ $\gamma_{Y93W} = 0.05$, $\gamma_{Y9E} = 0.03$ $\gamma_{Y9M} = 0.38$
Wool Warehouse Sector			
$Z_{1W} = 20.72$, $u_{1W} = 3.73$ $Z_{1S} = 2.09$, $u_{1S} = 2.38$	$TV_{Z1} = 82.26$	$k_{Y14W} = 0.93$, $k_{YNM} = 0.07$	$\gamma_{Z1W} = 0.94$, $\gamma_{Z1S} = 0.06$
$Z_{2W} = 124.67$, $u_{2W} = 6.63$ $Z_{2S} = 34.67$, $u_{2S} = 5.52$	$TV_{Z2} = 1007.54$	$k_{Y21W} = 0.06$, $k_{Y31W} = 0.20$ $k_{Y41W} = 0.06$, $k_{Y51W} = 0.17$ $k_{Y61W} = 0.02$, $k_{Y71W} = 0.28$ $k_{Y81W} = 0.15$, $k_{Y91W} = 0.02$ $k_{YFM} = 0.04$	$\gamma_{Z2W} = 0.82$, $\gamma_{Z2S} = 0.18$
$Z_{3W} = 189.46$, $u_{3W} = 5.65$ $Z_{3S} = 77.57$, $u_{3S} = 4.43$	$TV_{Z3} = 1414.09$	$k_{Y22W} = 0.03$, $k_{Y32W} = 0.10$ $k_{Y42W} = 0.09$, $k_{Y52W} = 0.24$ $k_{Y62W} = 0.06$, $k_{Y72W} = 0.15$	$\gamma_{Z3W} = 0.76$, $\gamma_{Z3S} = 0.24$

		$k_{Y82W} = 0.24$, $k_{Y92W} = 0.04$ $k_{YMM} = 0.05$	
$Z_{4W} = 26.60$, $u_{4W} = 4.63$ $Z_{2S} = 8.19$, $u_{4S} = 4.70$	$TV_{Z4} = 161.65$	$k_{Y13W} = 0.17$, $k_{Y23W} = 0.05$ $k_{Y33W} = 0.14$, $k_{Y43W} = 0.05$ $k_{Y53W} = 0.14$, $k_{Y63W} = 0.06$ $k_{Y73W} = 0.18$, $k_{Y83W} = 0.12$ $k_{Y93W} = 0.04$, $k_{YBM} = 0.05$	$\gamma_{Z4W} = 0.76$, $\gamma_{Z4S} = 0.24$
Scouring Sector			
$Z_{CW} = 29.55$, $u_{CW} = 3.68$ $F_{1S} = 1.38$, $s_{1S} = 2.68$ $F_{2S} = 15.14$, $s_{2S} = 5.78$ $F_{3S} = 33.71$, $s_{3S} = 5.30$ $F_{4S} = 2.98$, $s_{4S} = 5.09$ $Z_{2T} = 15.84$, $u_{2T} = 5.67$ $Z_{3T} = 20.16$, $u_{3T} = 5.16$ $Z_{4T} = 3.76$, $u_{4T} = 5.78$	$TV_{CS} = 609.35$	$k_{Z1S} = 0.01$, $k_{Z2S} = 0.30$ $k_{Z3S} = 0.56$, $k_{Z4S} = 0.06$ $k_{ZCS} = 0.07$	$\gamma_{ZCW} = 0.18$, $\gamma_{F1S} = 0.01$ $\gamma_{F2S} = 0.14$, $\gamma_{F3S} = 0.29$ $\gamma_{F4S} = 0.02$, $\gamma_{Z2T} = 0.15$ $\gamma_{Z3T} = 0.17$, $\gamma_{Z4T} = 0.04$
Carbonising Sector			
$F_{CW} = 29.55$, $s_{CW} = 4.36$	$TV_{FCW} = 128.84$	$k_{ZCW} = 0.84$, $k_{ZCB} = 0.16$	
Topmaking Sector			
$F_{2T} = 14.67$, $s_{2T} = 6.67$ $F_{3T} = 15.70$, $s_{3T} = 6.93$ $F_{4T} = 3.17$, $s_{4T} = 7.44$ $F_{NW} = 6.21$, $s_{NW} = 1.76$	$TV_{FT} = 241.16$	$k_{Z2T} = 0.37$, $k_{Z3T} = 0.43$ $k_{Z4T} = 0.09$, $k_{ZWT} = 0.11$	$\gamma_{F2T} = 0.41$, $\gamma_{F3T} = 0.45$ $\gamma_{F4T} = 0.10$, $\gamma_{FNW} = 0.04$
Wool Export Sector			
$Q_{1W} = 20.72$, $p_{1W} = 4.03$	$TV_{Q1W} = 83.50$	$k_{Z1W} = 0.93$, $k_{ZNM} = 0.07$	
$Q_{2W} = 124.67$, $p_{2W} = 6.93$	$TV_{Q2W} = 863.96$	$k_{Z2W} = 0.96$, $k_{ZFM} = 0.04$	
$Q_{3W} = 189.46$, $p_{3W} = 5.95$	$TV_{Q3W} = 1127.29$	$k_{Z3W} = 0.95$, $k_{ZMM} = 0.05$	
$Q_{4W} = 26.60$, $p_{4W} = 4.93$	$TV_{Q4W} = 131.14$	$k_{Z4W} = 0.94$, $k_{ZBM} = 0.06$	
$Q_{CW} = 29.55$, $p_{CW} = 4.66$	$TV_{QCW} = 137.70$	$k_{FCW} = 0.94$, $k_{FCB} = 0.06$	
$Q_{1S} = 1.38$, $p_{1S} = 2.98$	$TV_{Q1S} = 4.11$	$k_{F1S} = 0.90$, $k_{FNS} = 0.10$	
$Q_{2S} = 15.54$, $p_{2S} = 6.08$	$TV_{Q2S} = 92.05$	$k_{F2S} = 0.95$, $k_{FFS} = 0.05$	
$Q_{3S} = 33.71$, $p_{3S} = 5.60$	$TV_{Q3S} = 188.78$	$k_{F3S} = 0.95$, $k_{FMS} = 0.05$	
$Q_{4S} = 2.98$, $p_{4S} = 5.39$	$TV_{Q4S} = 16.06$	$k_{F4S} = 0.95$, $k_{FBS} = 0.05$	
$Q_{2T} = 14.67$, $p_{2T} = 6.97$	$TV_{Q2T} = 102.25$	$k_{F2T} = 0.96$, $k_{FFT} = 0.04$	
$Q_{3T} = 15.70$, $p_{3T} = 7.23$	$TV_{Q3T} = 113.51$	$k_{F3T} = 0.96$, $k_{FMT} = 0.04$	

Q_{4T} = 3.17, p_{4T} = 7.74	TV_{Q4T} = 24.54	k_{F4T} = 0.96, k_{FBT} = 0.04	
Q_{NW} = 6.21, p_{NW} = 2.06	TV_{QNW} = 12.79	k_{FNW} = 0.85, k_{FNE} = 0.15	
Sheepmeat Processing Sector			
Z_{LE} = 130.57, u_{LE} = 4.76	TV_{ZL} = 1626.49	k_{Y1L} = 0.27, k_{Y2L} = 0.10	γ_{ZLE} = 0.38, γ_{ZLD} = 0.62
Z_{LD} = 211.14, u_{LD} = 4.76		k_{Y3L} = 0.03, k_{Y4L} = 0.20	
		k_{Y5L} = 0.08, k_{Y6L} = 0.02	
		k_{YSL} = 0.30	
Z_{ME} = 176.70, u_{ME} = 2.39	TV_{ZM} = 437.50	k_{Y1M} = 0.05, k_{Y2M} = 0.03	γ_{ZME} = 0.73, γ_{ZMD} = 0.27
Z_{MD} = 64.70, u_{MD} = 2.39		k_{Y3M} = 0.11, k_{Y4M} = 0.02	
		k_{Y5M} = 0.09, k_{Y6M} = 0.13	
		k_{Y7M} = 0.10, k_{Y8M} = 0.10	
		k_{Y9M} = 0.10, k_{YSM} = 0.27	
Sheepmeat Marketing Sectors			
Q_{LE} = 130.57, p_{LE} = 4.83	TV_{QLE} = 630.65	k_{ZLE} = 0.98, k_{Z1L} = 0.02	
Q_{LD} = 143.57, p_{LD} = 10.15	TV_{QLD} = 1457.22	k_{ZLD} = 0.69, k_{Z2L} = 0.31	
Q_{ME} = 176.70, p_{ME} = 2.45	TV_{QME} = 432.92	k_{ZME} = 0.98, k_{Z1M} = 0.02	
Q_{MD} = 44.00, p_{MD} = 5.22	TV_{QMD} = 229.66	k_{ZMD} = 0.67, k_{Z2M} = 0.33	
Live Sheep Exports			
Q_{SE} = 92.00, p_{SE} = 3.19	TV_{QSE} = 293.49		

Table 30: Definition of prices, quantities, cost shares and revenue shares

Endogenous Variables	
X_1	Quantity of non-Merino ewes
X_{21}	Quantity of Merino ewes for non-Merino lamb production (HRZ)
X_{31}	Quantity of Merino ewes for Merino lamb production (HRZ)
X_{23}	Total quantity of Merino ewes, $X_{23} = X_{21}+X_{31}$ (HRZ)
X_{41}	Quantity of Merino ewes for non-Merino lamb production (WSZ)
X_{51}	Quantity of Merino ewes for Merino lamb production (WSZ)
X_{45}	Total quantity of wheat-sheep zone Merino ewes, $X_{45} = X_{41}+X_{51}$ (WSZ)
X_{61}	Quantity of pastoral zone Merino ewes (PZ)
X_{71}	Quantity of Merino wethers and hoggets (HRZ)
X_{81}	Quantity of Merino wethers and hoggets (WSZ)
X_{91}	Quantity of Merino wethers and hoggets (PZ)

w_1, w_{23}, w_{45}, w_{61}, w_{71}, w_{81}, w_{91}	Prices of X_1, X_{23}, X_{45}, X_{61}, X_{71}, X_{81}, X_{91}
X_{1W}	Quantity of other inputs to the non-Merino farm sector
X_{21W}	Quantity of other inputs to the Merino ewe, non-Merino lamb farm sector (HRZ)
X_{31W}	Quantity of other inputs to the Merino ewe, Merino lamb farm sector (HRZ)
X_{41W}	Quantity of other inputs to the Merino ewe, non-Merino lamb farm sector (WSZ)
X_{51W}	Quantity of other inputs to the Merino ewe, Merino lamb farm sector (WSZ)
X_{61W}	Quantity of other inputs to the Merino ewe farm sector (PZ)
X_{71W}	Quantity of other inputs to the Merino wether and hogget farm sector (HRZ)
X_{81W}	Quantity of other inputs to the Merino wether and hogget farm sector (WSZ)
X_{91w}	Quantity of other inputs to the Merino wether and hogget farm sector (PZ)
w_{1W}, w_{21W},…,w_{91W}	Prices of X_{1W}, X_{21W},…,X_{91W}
Y_{13W}, Y_{14W}	Quantities of 24-27 and ≥28 micron wool, respectively (non-Merino farm sector)
v_{13W}, v_{14W}	Prices of Y_{13W}, Y_{14W}
Y_{21W}, Y_{22W}, Y_{23W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (HRZ-Merino ewe, non-Merino lamb farm sector)
v_{21W}, v_{22W}, v_{23W}	Prices of Y_{21W}, Y_{22W}, Y_{23W}
Y_{31W}, Y_{32W}, Y_{33W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (HRZ-Merino ewe, Merino lamb farm sector)
v_{31W}, v_{32W}, v_{33W}	Prices of Y_{31W}, Y_{32W}, Y_{33W}
Y_{41W}, Y_{42W}, Y_{43W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (WSZ-Merino ewe, non-Merino lamb farm sector)
v_{41W}, v_{42W}, v_{43W}	Prices of Y_{41W}, Y_{42W}, Y_{43W}
Y_{51W}, Y_{52W}, Y_{53W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (WSZ-Merino ewe, Merino lamb farm sector)
v_{51W}, v_{52W}, v_{53W}	Prices of Y_{51W}, Y_{52W}, Y_{53W}
Y_{61W}, Y_{62W}, Y_{63W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (PZ-Merino ewe, farm sector)
v_{61W}, v_{62W}, v_{63W}	Prices of Y_{61W}, Y_{62W}, Y_{63W}
Y_{71W}, Y_{72W}, Y_{73W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (HRZ-Merino wether and hogget farm sector)
v_{71W}, v_{72W}, v_{73W}	Prices of Y_{71W}, Y_{72W}, Y_{73W}
Y_{81W}, Y_{82W}, Y_{83W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (WSZ-Merino wether and hogget farm sector)
v_{81W}, v_{82W}, v_{83W}	Prices of Y_{81W}, Y_{82W}, Y_{83W}
Y_{91W}, Y_{92W}, Y_{93W}	Quantities of ≤19, 20-23 and 24-27 micron wool, respectively (PZ-Merino wether and hogget farm sector)
v_{91W}, v_{92W}, v_{93W}	Prices of Y_{91W}, Y_{92W}, Y_{93W}
Y_{1L}, Y_{1M}	Quantities of lamb and mutton, respectively (non-Merino farm sector)
v_{1L}, v_{1M}	Prices of Y_{1L}, Y_{1M}

Y_{2L}, Y_{2M}	Quantities of lamb and mutton, respectively (HRZ-Merino ewe, non-Merino lamb farm sector)
v_{2L}, v_{2M}	Prices of Y_{2L}, Y_{2M}
Y_{3L}, Y_{3M}	Quantities of lamb and mutton, respectively (HRZ-Merino ewe, Merino lamb farm sector)
v_{3L}, v_{3M}	Prices of Y_{3L}, Y_{3M}
Y_{4L}, Y_{4M}	Quantities of lamb and mutton, respectively (WSZ-Merino ewe, non-Merino lamb farm sector)
v_{4L}, v_{4M}	Prices of Y_{4L}, Y_{4M}
Y_{5L}, Y_{5M}	Quantities of lamb and mutton, respectively (HRZ-Merino ewe, Merino lamb farm sector)
v_{5L}, v_{5M}	Prices of Y_{5L}, Y_{5M}
Y_{6L}, Y_{6M}	Quantities of lamb and mutton, respectively (PZ-Merino ewe, farm sector)
v_{6L}, v_{6M}	Prices of Y_{6L}, Y_{6M}
Y_{7E}, Y_{7M}	Quantities of live sheep exports and mutton, respectively (HRZ-Merino wether and hogget farm sector)
Y_{8E}, Y_{8M}	Quantities of live sheep exports and mutton, respectively (WSZ-Merino wether and hogget farm sector)
Y_{9E}, Y_{9M}	Quantities of live sheep exports and mutton, respectively (PZ-Merino wether and hogget farm sector)
v_{7M}, v_{8M}, v_{9M}	Prices of Y_{7M}, Y_{8M}, Y_{9M}
Y_{NM}, Y_{FM}, Y_{MM}, Y_{BM}	Quantities of other inputs to ≥28, ≤19, 20-23, and 24-27 micron wool warehouse sectors, respectively
v_{NM}, v_{FM}, v_{MM}, v_{BM}	Prices of other inputs to ≥28, ≤19, 20-23, and 24-27 micron wool warehouse sectors, respectively
Z_{1W}, Z_{2W}, Z_{3W}, Z_{4W}	Quantities of ≥28, ≤19, 20-23, and 24-27 micron greasy wool to export shipment sectors, respectively
u_{1W}, u_{2W}, u_{3W}, u_{4W}	Prices of Z_{1W}, Z_{2W}, Z_{3W}, Z_{4W}
Z_{1S}, Z_{2S}, Z_{3S}, Z_{4S}	Quantities of ≥28, ≤19, 20-23, and 24-27 micron greasy wool to domestic scouring sector
u_{1S}, u_{2S}, u_{3S}, u_{4S}	Prices of Z_{1S}, Z_{2S}, Z_{3S}, Z_{4S}
Z_{NM}, Z_{FM}, Z_{MM}, Z_{BM}	Quantities of other inputs to ≥28, ≤19, 20-23, and 24-27 micron greasy wool export shipment sectors, respectively
u_{NM}, u_{FM}, u_{MM}, u_{BM}	Prices of Z_{NM}, Z_{FM}, Z_{MM}, Z_{BM}
Z_{CS}, Z_{CB}, Z_{WT}	Quantities of other inputs to wool scouring, carbonising and topmaking sectors, respectively
u_{CS}, u_{CB}, u_{WT}	Prices of Z_{CS}, Z_{CB}, Z_{WT}
Z_{2T}, Z_{3T}, Z_{4T}	Quantities of ≤19, 20-23, and 24-27 micron wool to domestic topmaking sector
u_{2T}, u_{3T}, u_{4T}	Prices of Z_{2T}, Z_{3T}, Z_{4T}
Z_{CW}, F_{CW}	Quantities of wool to domestic carbonising and export shipment sectors,

	respectively
u_{CW}, s_{CW}	Prices of Z_{CW}, F_{CW}
F_{1S}, F_{2S}, F_{3S}, F_{4S}	Quantities of ≥28, ≤19, 20-23, and 24-27 micron scoured wool to export shipment sectors, respectively
s_{1S}, s_{2S}, s_{3S}, s_{4S}	Prices of F_{1S}, F_{2S}, F_{3S}, F_{4S}
F_{CB}, F_{NS}, F_{FS}, F_{MS}, F_{BS}	Quantities of other inputs to carbonising, ≥28, ≤19, 20-23, and 24-27 micron scoured wool export shipment sectors, respectively
s_{CB}, s_{NS}, s_{FS}, s_{MS}, s_{BS}	Prices of F_{CB}, F_{NS}, F_{FS}, F_{MS}, F_{BS}
F_{2T}, F_{3T}, F_{34T}, F_{NW}	Quantities of ≤19, 20-23, 24-27 micron wool top and noils of wool to export shipment sectors, respectively
s_{2T}, s_{3T}, s_{4T}, s_{NW}	Prices of F_{2T}, F_{3T}, F_{4T}, F_{NW}
F_{FT}, F_{MT}, F_{BT}, F_{NE}	Quantities of other inputs to ≤19, 20-23, and 24-27 micron wool top and noils export shipment sectors, respectively
s_{FT}, s_{MT}, s_{BT}, s_{NE}	Prices of F_{FT}, F_{MT}, F_{BT}, F_{NE}
Y_{SL}, Y_{SM}	Quantities of other inputs to lamb and mutton processing sectors, respectively
v_{SL}, v_{SM}	Prices of Y_{SL}, Y_{SM}
Z_{LE}, Z_{LD}	Quantities of lamb for the export and domestic marketing sectors, respectively
u_{LE}, u_{LD}	Prices of Z_{LE}, Z_{LD}
Z_{ME}, Z_{MD}	Quantities of mutton for the export and domestic marketing sectors, respectively
u_{ME}, u_{MD}	Prices of Z_{ME}, Z_{MD}
Z_{1L}, Z_{2L}	Quantities of other inputs to the export and domestic lamb marketing sectors, respectively
u_{1L}, u_{2L}	Prices of Z_{1L}, Z_{2L}
Z_{1M}, Z_{2M}	Quantities of other inputs to the export and domestic mutton marketing sectors, respectively
u_{1M}, u_{2M}	Prices of Z_{1M}, Z_{2M}
Q_{1W}, Q_{2W}, Q_{3W}, Q_{4W}	Quantities of ≥28, ≤19, 20-23, and 24-27 micron export greasy wool, respectively
p_{1W}, p_{2W}, p_{3W}, p_{4W}	Prices of Q_{1W}, Q_{2W}, Q_{3W}, Q_{4W}
Q_{1S}, Q_{2S}, Q_{3S}, Q_{4S}	Quantities of ≥28, ≤19, 20-23, and 24-27 micron export scoured wool, respectively
p_{1S}, p_{2S}, p_{3S}, p_{4S}	Prices of Q_{1S}, Q_{2S}, Q_{3S}, Q_{4S}
Q_{2T}, Q_{3T}, Q_{4T}	Quantities of ≤19, 20-23, and 24-27 micron export wool tops, respectively
p_{2T}, p_{3T}, p_{4T}	Prices of Q_{2T}, Q_{3T}, Q_{4T}
Q_{CW}, Q_{NW}, Q_{DP}	Quantities of export carbonised wool, noils of wool and wool top for domestic later-stage processing, respectively
p_{CW}, p_{NW}, p_{DP}	Prices of Q_{CW}, Q_{NW}, Q_{DP}
Q_{LE}, Q_{LD}	Quantities of export and domestic lamb, respectively
p_{LE}, p_{LD}	Prices of Q_{LE}, Q_{LD}
Q_{ME}, Q_{MD}	Quantities of export and domestic mutton, respectively
p_{ME}, p_{MD}	Prices of Q_{ME}, Q_{MD}

Q_{SE}	Quantity of live sheep exports
p_{SE}	Price of Q_{SE}
Parameters	
k_x	Cost share of input x (x = X_1, X_{1W}, X_{21},…,X_{91}, X_{21W},…,X_{91W}, Y_{21W},…,Y_{91W}, Y_{22W},…,Y_{92W}, Y_{13W},…,Y_{93W}, Y_{NM}, Y_{BM}, Y_{MM}, Y_{FM}, Y_{1L},…,Y_{6L}, Y_{SL}, Y_{1M},…,Y_{9M}, Y_{SM}, Z_{1W},…,Z_{4W}, Z_{1S},…,Z_{4S}, Z_{CS}, Z_{CB}, Z_{CW}, Z_{WT}, Z_{NM}, Z_{FM}, Z_{MM}, Z_{BM}, Z_{2T},…,Z_{4T}, Z_{1L}, Z_{2L}, Z_{LE}, Z_{LD}, Z_{1M}, Z_{2M}, Z_{ME}, Z_{MD}, F_{1S},…,F_{4S}, F_{CW}, F_{CB}, F_{NS}, F_{FS}, F_{MS}, F_{BS}, F_{2T},…,F_{4T}, F_{NW}, F_{FT}, F_{MT}, F_{BT}, F_{NE}) where $\sum_{i=1,1W} k_{xi} = 1$, $\sum_{i=21,21W} k_{xi} = 1$, $\sum_{i=31,31W} k_{xi} = 1$, $\sum_{i=41,41W} k_{xi} = 1$, $\sum_{i=51,51W} k_{xi} = 1$, $\sum_{i=61,61W} k_{xi} = 1$, $\sum_{i=71,71W} k_{xi} = 1$, $\sum_{i=81,81W} k_{xi} = 1$, $\sum_{i=91,91W} k_{xi} = 1$, $\sum_{i=NM,14W} k_{yi} = 1$, $\sum_{i=FM,21W,...,91W} k_{yi} = 1$, $\sum_{i=MM,22W,...,92W} k_{yi} = 1$, $\sum_{i=BM,13W,...,93W} k_{yi} = 1$, $\sum_{i=SL,1L,...,6L} k_{yi} = 1$, $\sum_{i=SM,1M,...,9M} k_{yi} = 1$, $\sum_{i=NM,1W} k_{Zi} = 1$, $\sum_{i=FM,2W} k_{Zi} = 1$, $\sum_{i=MM,3W} k_{Zi} = 1$, $\sum_{i=BM,4W} k_{Zi} = 1$, $\sum_{i=CS,1S,...,4S} k_{Zi} = 1$, $\sum_{i=CB,CW} k_{Zi} = 1$, $\sum_{i=WT,2T,...,4T} k_{Zi} = 1$, $\sum_{i=LE,1L} k_{Zi} = 1$, $\sum_{i=LD,2L} k_{Zi} = 1$, $\sum_{i=ME,1M} k_{Zi} = 1$, $\sum_{i=MD,2M} k_{Zi} = 1$, $\sum_{i=CB,CW} k_{Fi} = 1$, $\sum_{i=NS,1S} k_{Fi} = 1$, $\sum_{i=FS,2S} k_{Fi} = 1$, $\sum_{i=MS,3S} k_{Fi} = 1$, $\sum_{i=BS,4S} k_{Fi} = 1$, $\sum_{i=FT,2T} k_{Fi} = 1$, $\sum_{i=MT,3T} k_{Fi} = 1$, $\sum_{i=BT,4T} k_{Fi} = 1$, $\sum_{i=NE,NW} k_{Fi} = 1$
γ_Y	Revenue share of output y (y = Y_{21W},…,Y_{91W}, Y_{22W},…,Y_{92W}, Y_{13W},…,Y_{93W}, Y_{1L},…,Y_{6L}, Y_{1M},…,Y_{9M}, Y_{7E},…,Y_{9E}, Z_{1W},…,Z_{4W}, Z_{1S},…,Z_{4S}, Z_{CW}, Z_{2T},…,Z_{4T}, Z_{LE}, Z_{LD}, Z_{ME}, Z_{MD}, F_{1S},…,F_{4S}, F_{2T},…,F_{4T}, F_{NW}, Q_{DP}) where $\sum_{i=13W,14W,1L,1M} \gamma_{Yi} = 1$, $\sum_{i=21W,22W,23W,1L,1M} \gamma_{Yi} = 1$, $\sum_{i=31W,32W,33W,3L,3M} \gamma_{Yi} = 1$, $\sum_{i=41W,42W,43W,4L,4M} \gamma_{Yi} = 1$, $\sum_{i=51W,52W,53W,5L,5M} \gamma_{Yi} = 1$, $\sum_{i=61W,62W,63W,6L,6M} \gamma_{Yi} = 1$, $\sum_{i=71W,72W,73W,7E,7M} \gamma_{Yi} = 1$, $\sum_{i=81W,82W,83W,8E,8M} \gamma_{Yi} = 1$, $\sum_{i=91W,92W,93W,9E,9M} \gamma_{Yi} = 1$, $\sum_{i=1W,1S} \gamma_{Zi} = 1$, $\sum_{i=2W,2S} \gamma_{Zi} = 1$, $\sum_{i=3W,3S} \gamma_{Zi} = 1$, $\sum_{i=4W,4S} \gamma_{Zi} = 1$, $\sum_{i=CW,2T,...,4T,F1S,...,F4S} \gamma_{Zi} = 1$, $\sum_{i=LE,LD} \gamma_{Zi} = 1$, $\sum_{i=ME,MD} \gamma_{Zi} = 1$, $\sum_{i=2T,...,4T,NW,QDP} \gamma_{Fi} = 1$

6. Summary

In a companion *Economics Research Report* (Mounter *et al*. 2007), an equilibrium displacement model (EDM) of the Australian sheep and wool industries is specified, implemented and used to examine some questions relating to the returns from various possible research and development and promotion investments. In this report, the price and quantity data used to implement the model, and particularly the methods and assumptions fundamental to the development of this data set, are described and discussed. The price and quantity data points that are chosen to represent the initial equilibria in these types of models are very important as the estimated benefits or costs from a displacement are closely dependent on the initial prices and quantities.

Details on the market prices and quantities in the model, their respective sources and any calculations and assumptions used in the derivation of estimated price and quantity values, are included in this report. The principles used can be applied to update this model in the future, or to specify a similar model in another region or with a different level of disaggregation.

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