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Are we killing the Golden Sheep? The changing size and composition of the Australian sheep flock: implications for production and profitability

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> ONE day a countryman going to the nest of his Goose found there an egg all yellow and glittering. When he took it up it was as heavy as lead and he was going to throw it away, because he thought a trick had been played upon him. But he took it home on second thoughts, and soon found to his delight that it was an egg of pure gold. Every morning the same thing occurred, and he soon became rich by selling his eggs. As he grew rich he grew greedy; and thinking to get at once all the gold the Goose could give, he killed it and opened it only to find — nothing.
>
> "GREED OFT O'ERREACHES ITSELF."
> Aesop, *The Goose with the Golden Egg*

Abstract

The changing fortunes of the Australian sheepmeat and wool sectors have led to dramatic changes to the national flock. In recent years the profitability of the sheepmeat sector has provided mixed signals to producers to simultaneously sell to capitalise on high prices, particularly for mutton and breeding stock, while also shifting enterprises towards dual purpose (meat and wool) and specialist lamb production systems.

This essay provides a summary of changes to the Australian sheep flock in the past twenty years, including the growth of the sheepmeat sector and the decline of the wool sector. It considers drivers of profitability in the sheep industry, comparing the recent economic performance of prime lamb, dual purpose, and wool flocks. It is suggested that there are a number of common factors evident in the most profitable sheep businesses. A discussion about risk management and volatility helps explain the rise of dual production systems, the persistence of risk-averse wool enterprises, and highly productive but volatile returns for specialist prime lamb producers. Flock structure is identified a major determinant of profitability, with breeding ewes critical to production.

The challenges posed will also shape the future of the Australian sheep flock. Fertility and drought-induced sell-off are noted as major factors affecting changes to the Australian flock, which could be exacerbated by an increasingly variable and extreme climate.

Finally, this essay considers the future size and composition of the Australian sheep flock. A flock structure model is used to estimate the effects of hypothetical changes to marking and slaughter rates.

It is concluded that it remains possible to sustain production and kill the 'Golden Sheep', provided there is a focus on productivity and reproduction efficiency to 'optimise' the remaining flock.

1 Introduction

It is often said that Australia 'rode the sheep's back' to prosperity. For the early colonies wool provided a valuable commodity that could be exported back to Britain and the rest of the world. Australia became the land of the 'Golden Fleece', bringing great prosperity to many of the early sheep graziers and giving rise to a new class of economic elite, the squattocracies'.

In recent decades major structural changes, notably the removal of the wool reserve price scheme, and lackluster global demand have contributed to a decline in the wool sector. But there is a new wave of prosperity in the sheep industry. The growth of the prime lamb sector, from a by-product of the wool sector, into an export-orientated sector supplying over seventy countries has changed the composition of the Australian sheep flock.

This essay broadly discusses how the decline of the wool sector and the growth of the prime lamb sector have changed the structure and dynamics of the Australian sheep flock. In the last twenty-five years the Australian sheep flock has shrunk from around 170 million to the current level of around 73 million (ABARES 2011). During this time there have been major structural changes to the sheepmeat and wool industries. At an individual enterprise level sheep producers have changed the structure of their flocks, and in many cases have changed their land use and shifted out of sheep production to cropping or beef enterprises.

1.1 Research questions

There has been recognition for some time that, with a declining flock size, the Australian sheep industry needs to carefully examine how it can continue to improve productivity and be able to capture global market opportunities. The sustainability of the Australian sheep flock has been discussed on a number of occasions in the past two decades (see for example Curtis 2009; Rowe 2010). Broadly there have been two major changes to the composition of the Australian flock:

- An increase in the proportion of Merino ewes joined to terminal sires; and
- A sharp decrease in numbers of Merino wethers relative to ewes.

This essay is premised on a concern that the current profitability of the Australian sheepmeat sector may be inadvertently undermining the sheep industry's long-term prosperity. This may sound an affront to sheep producers, revelling in high lamb and (particularly) mutton prices, but there are concerns that high slaughter rates are eroding the size and capacity of the Australian sheep flock. High prices for mature animals (ewes and wethers) provide mixed-messages for producers. On the one hand, they suggest that producers keep ewes longer as it will be difficult to re-purchase at a later date. On the other hand, they provide a good opportunity for producers to get out of sheep. The extent to which the latter has contributed to the decline in the national sheep flock warrants further discussion beyond this essay.

And so, with decreasing supply and sustained strong demand for mutton as well as lamb, there may have been unintended consequences for the national flock. This essay begs the question, are high slaughter rates, which have accompanied the growth of the sheepmeat sector, a case of 'killing the golden sheep'?

Within this discussion are a number of implicit questions:

- How are changes to profitability affecting the productivity and management of the sheep flock?
- Is the Australian sheep flock at a sustainable level?
- What can be done to 'optimise' the Australian flock?

This essay explores the need to 'optimise' the national sheep flock. The notion of 'optimising' suggests that it is not absolute size, but relative efficiency, which determines productivity and profitability. To determine what 'optimal' means, this essay examines key drivers of change in the sheep flock and considers future challenges such as climate variability and change, which will affect the productivity of the sheep industry.

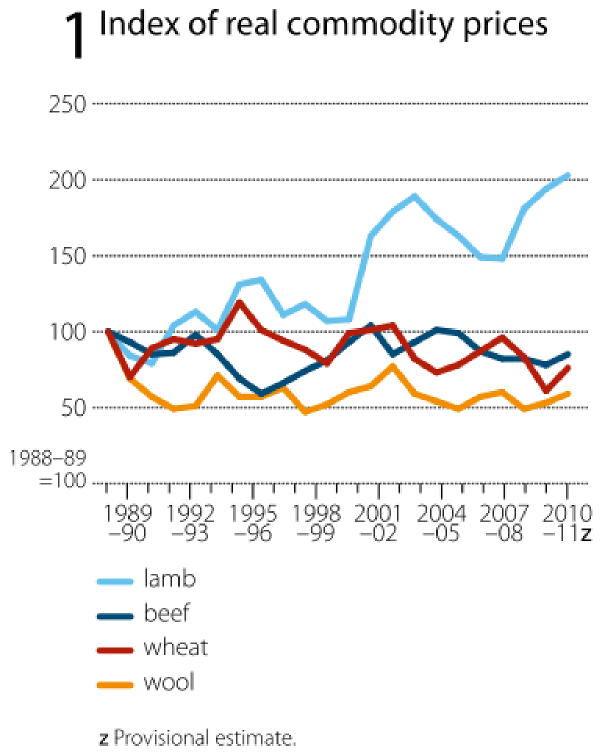
2 Trends in production

The sheep industry has undergone significant change over the last two decades. Key features of those changes include a major reduction in flock size, increase in the proportion of ewes and a fundamental shift in the relative contribution to farm income from wool towards lamb and surplus sheep. The growth in the lamb sector is one of the biggest changes. For the lamb sector the supply challenge is a balance between kilograms of lamb produced annually, ewe flock maintenance/rebuilding, market maintenance and development, and consistency in prices received by producers and paid by consumers (Rowe 2010). Major changes to the sheep flock have accelerated in the last five years, including:

- The number of sheep in Australia has fallen and continues to fall;
- The number of sheep producers across Australia has also fallen;
- The mix of sheep has changed with ewes dominating the flock structure;
- The diameter of the wool being produced has fallen over the last 15 years;
- The gross value of sheepmeat production is now roughly equivalent to the gross value of wool (Rowe 2010).

Over the past 20 years the real price of lamb has increased substantially. During this period the real prices for other key broadacre commodities (wool, wheat and beef) have decreased, see Figure 1 below.

Figure 1: Index of real commodity prices 1989-2011

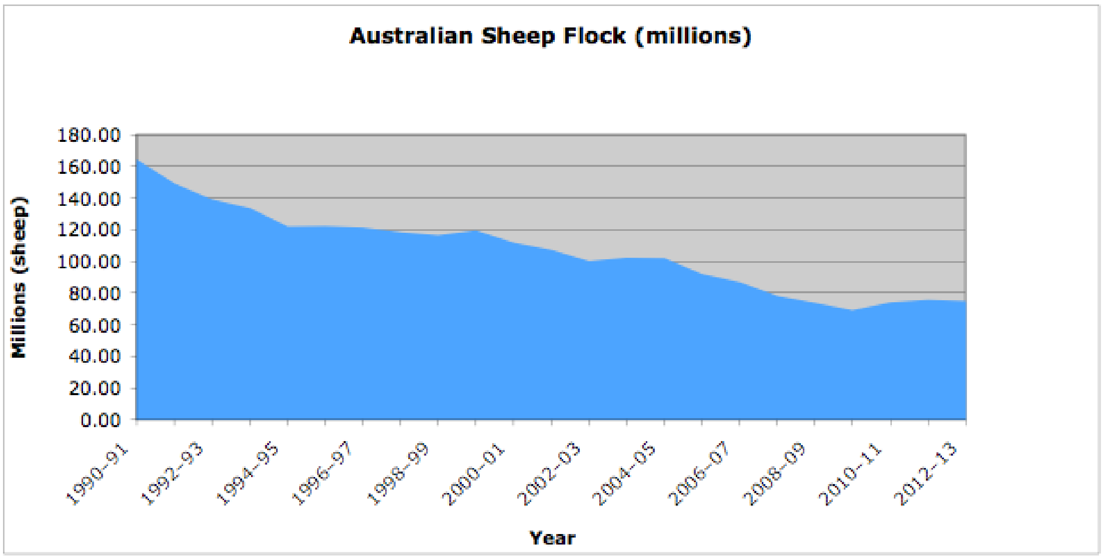


Source: ABARES 2011

Over the 20-year period between 1991 and 2011 there have been dramatic changes in the distribution of sheep around the country. Table 1 provides a breakdown of sheep distribution by state. One of the biggest falls in sheep numbers has been in Queensland. In 1991 there were 17.44 million sheep in Queensland, representing 10.68% of the national flock. By 2011, this number had fallen to 3.65 million, or 5% of the national flock.

The Australian sheep flock has shrunk from around 163 million in 1991, to around 111 million in 2001 and to 73 million in 2011 (see Figure 2 below).

Figure 2: The Australian sheep flock 1991-2013



Source: ABARES

Table 1: Total sheep and lambs by state (1991 vs. 2001 vs. 2011)

Total sheep and lambs

	NSW		VIC		QLD		SA		WA		TAS		AUS
	Million	% N.F.	million	% N.F.	million	% N.F.	million	% N.F.	million	% N.F.	million	% N.F	million
1991	59.763	36.61	27.494	16.84	17.440	10.68	17.153	10.51	36.465	22.34	4.804	2.94	163.238
2001	40.887	36.86	22.272	20.08	8.660	7.81	12.585	11.34	23.129	20.85	3.284	2.96	110.928
2011	26.825	36.70	15.212	20.81	3.653	5.00	11.009	15.06	14.000	19.15	2.344	3.21	73.099

Source: ABARES

2.1 The global market context - wool is a luxury, and lamb a premium product

The Australian sheep meat and wool industries represent a small component of total global protein and fibre markets, respectively. However, Australia, alongside New Zealand, is the dominant exporter of both products. Sheep meat constitutes around 3% of global meat production (FAOSTAT 2009) and wool just over 1.5% of the textile fibre market (Wissenberg and Engelhardt 2010). It is clear that wool will never compete effectively either on price or volume with cotton and synthetics in the global textile market. Similarly, lamb cannot compete in terms of price or volume with poultry and pork in global meat markets (Rowe 2010). As a consequence, both commodities are marketed as premium products.

2.2 Australia is in a prime position to capture growing global demand for sheepmeat

With an improving outlook for lucrative sheepmeat exports like the United States and the Middle East, and the development of the Chinese market, Australia and New Zealand are the only countries well positioned to supply consumers.

2.3 The shrinking flock has created problems of structural over-capacity, particularly for the wool sector

> "It is increasingly important that the sheepmeat sector retains significant scale and market presence in comparison to competing meats to remain viable and capitalise on the longer-term growth opportunities." (Rabobank 2013)

A declining national sheep flock has consequences for other parts of the sheepmeat and wool value chains. It is particularly important to consider demand implications of reduced supply for the processing sector. As the supply of raw wool decreases, the efficiency of processing facilities changes. In the highly competitive global textiles market there is growing pressure on wool textile machinery change to processing other fibres (ABARES/ Ashton 2003).

Sheep meat and wool growing are often undertaken in the same farming enterprises. Specialist prime lamb production is concentrated in the high rainfall areas of Victoria and New South Wales. Historically, sheep meat was seen as a by-product of wool production, but in recent decades the decline of the wool sector has seen a trend towards more specialised sheep meat production (Vic DPI 2013).

Figure 3 illustrates the major zones for sheep production in Australia. The three zones, the pastoral, wheat-sheep and high rainfall, reflect different climatic zones (largely based on rainfall). Sheep production in South-eastern Australia occurs in both the high rainfall and wheat-sheep zones. As a generalisation there is likely to be more specialised production in the high rainfall zones (including specialist prime lamb farms) and a more diverse production system in the wheat sheep zone (including mixed farms incorporating sheep, cattle and cropping production) (Harle and Howden 2007).

Only around 30% of Australia's sheep are grazed on properties, whose sole enterprise is sheep production (sheepmeat or wool) (ABARES). The majority of sheep are grazed in mixed-livestock (sheep and cattle) or mixed-farming (cropping and livestock) systems.

2.4 The expansion of cropping has driven a decline in sheep production (and vice-versa), particularly in Western Australia

One of the best examples of major structural adjustments in broadacre land use affecting sheep production is Western Australia. Here there have been large shifts in land use from livestock enterprises to cropping. Figures 4 highlights how the growth in winter cropping has occurred alongside a decline in the sheep flock. Figure 5 shows differences in the percentage of cropland area in sheep production systems.

As noted, the largest proportion of sheep production comes from the wheat-sheep,

mixed-enterprise sector of the industry. There are several reasons that explain why the decline in sheep production has occurred alongside an expansion in cropping, including:

- property consolidation, enterprises moving completely out of sheep;
- the labour intensity of sheep enterprises (ageing owner-operators);
- the availability of land suitable for large scale cultivation (substantially more in WA than for eastern states); and
- the comparative lack of scales for sheep compared to grains

(see Villano et al 2010).

In summary, sheep production competes with other land uses. Any changes to production in mixed-farming enterprises have major impacts on the national flock.

Case Study 1 in the Text Box (see page 7) discusses how a downturn in the live sheep export sector, a market for sheep that remains crucial to the profitability of the industry, has shaped the size and structure of the Australian sheep flock.

Figure 3: Sheep production competes with other broadacre agricultural enterprises f land use across Australia

K.J. Harle et al. / Agricultural Systems 93 (2007) 61–89 63

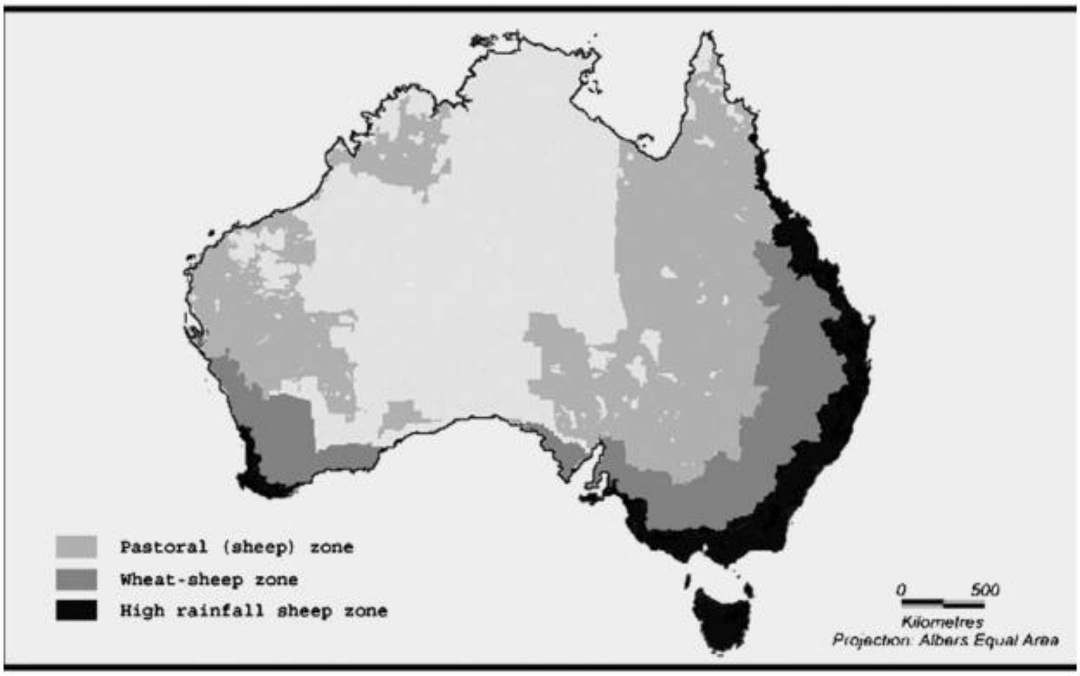
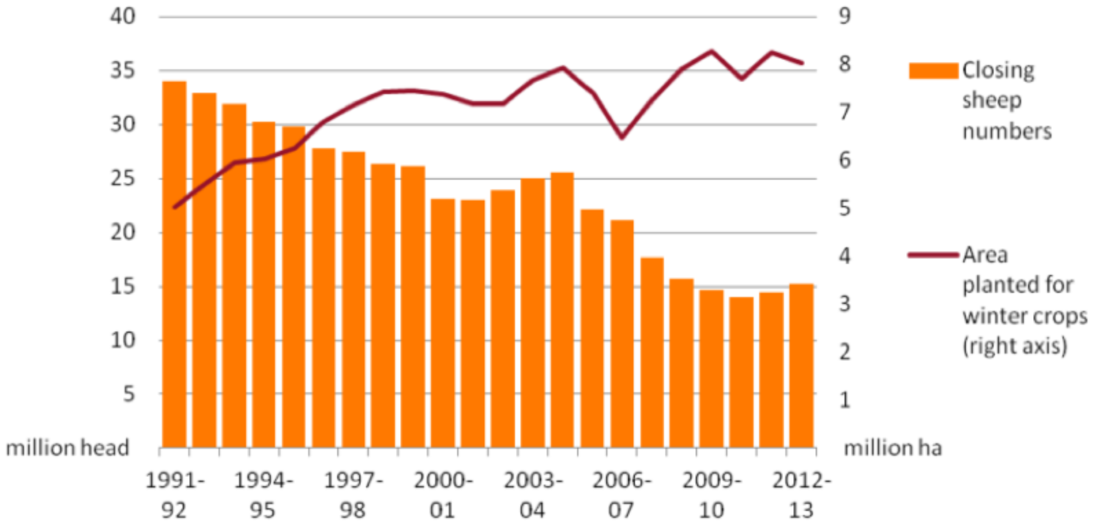


Fig. 1. Sheep producing zones in Australia (adapted from Australian Natural Resources Atlas).

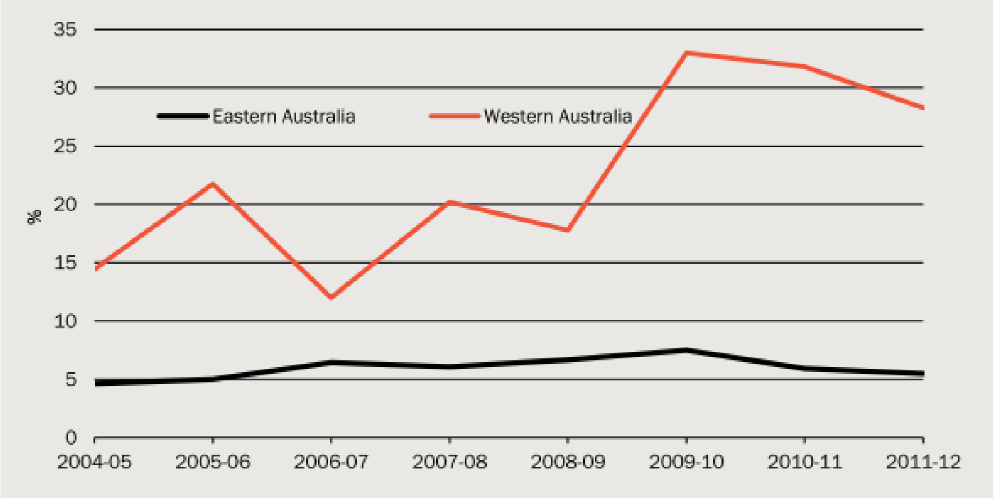
Source: Harle et al. 2007

Figure 4: Sheep numbers and hectares planted to winter crops, Western Australia



Source: ABARES

Figure 5: Cropping land in total land operated by sheep enterprises



Data source: ABARES MLA Farm survey.

Source: CIE 2014

Case Study 1: The live sheep export sector

There has been a decline in the live sheep exports, but this trade remains crucial to the Australian sheep sector.

Live sheep exports fell from 20% of the gross value of sheepmeat production in 2002-03 to 9% in 2012-13 (CIE 2014). The live sheep export sector is heavily concentrated in WA. According to ABARES surveys approximately 38% of farms in WA sold sheep for live export in 2012-13, compared with 3% of farms in Vic.

The decline in sheep numbers, particularly merino wethers, has reduced the supply of sheep available for export.

The existence of the live sheep export trade has influenced flock structure for some producers, who maximise production of wethers suitable for shipping rather than prime lambs or wool. As Kingwell (2011) identifies, production of shipping wethers, rather than prime lambs, has suited to the crop-dominated farmers, due to less labour and management costs. Another important factor, is that shipping wethers have a longer selling window than prime lambs and on average, have lower finishing costs, particularly in the face of varying seasonal conditions.

Recent economic analysis from the Centre for International Economics (CIE) has helped quantify the value of the live sheep trade to all sheep producers. The 2014 CIE report 'The contribution of live exports to the Australian wool sector' calculated impacts on market prices in WA and Australia wide.

The impact on woolgrowers was calculated by comparing the market outcomes observed in 2011-12, such as production and prices, with what they would have otherwise been with the closure of live exports.

The report suggested that if the live trade were to close, average saleyard prices across Australia would fall by:

- $4.07 per head or 4.5% for lambs
- $13.20 per head or 34.4% for older sheep

In other words, prices would have been $4 and $13 lower than those observed in 2011-12 across all Australian regions- as a result of closing live exports.

The impact would be particularly devastating in Western Australia. If live exports to close, average saleyard prices would fall in WA by:

- $32 per head for lambs or a fall in the saleyard price of 35.1%
- $36 per head for older sheep or a fall in the saleyard price of 66.2%

NOTE:
Western Australia has limited domestic processing capacity. The 2014 CIE study assumed that without live exports to underpin prices, the Western Australian price paid by processors would default to the eastern states (South Australian) price less the transport cost. This transport cost will be most likely in the range of $25 to $30 per head,to be borne in the first instance while the supply side adjusts, by sheep producers. The impacts of a close of the live trade is significantly less in the eastern states because of the lower contribution of live exports of sheep to the industry and a larger number of marketing options for producers.

3 Trends in profitability

This section examines drivers of profitability in the sheep industry, comparing the recent economic performance of prime lamb, dual purpose, and wool flocks. Comparisons are made to the profitability of other broadacre commodities, notably beef and cropping, which are common alternative land uses to sheep production. This discussion considers economic drivers of profitability for individual producers, noting that while there are significant variations in the profitability of sheep enterprises there are common features in the most profitable enterprises.

The complexity of farm production systems reveals a limitation in economic benchmarking. Nevertheless, there are common factors evident in the most profitable sheep businesses. A discussion about risk management and volatility helps explain the rise of dual production systems, the persistence of risk averse wool enterprises, and the highly productive but volatile returns from prime lamb production.

The recent MLA Prime Lamb Situation Analysis (MLA 2014) reinforces the results from previous reports (2008 and 2011) that having a dual-purpose flock is a successful strategy for producers to improve the profitability of their wool flock allowing them to;

i. take advantage of higher sheep meat prices;
ii. source cheap replacement genetics from merino wool flocks; and
iii. take advantage of (recent) higher merino wool prices.

Appendix 1 provides a table with summary definition of each broadacre production system analysed in the MLA 2014 Prime Lamb Situation Analysis report.

There are a wide variety of production systems employed in lamb production, including target market, enterprise mix and the environment in which the enterprises are run.

MLA (2014) concludes that more profitable businesses within both the dual purpose and prime lamb groups have a superior combination of:

- higher productivity (kg of lamb and wool per DSE);
- lower cost of production (they produce each kilogram cheaper); and
- a higher price received for lamb.

Over the last decade the average wool and beef cost of production has been a lot closer to the lowest price deciles over the same period than for lamb, wheat or canola. This suggests these businesses appear as if they are in a more resilient price position for fluctuations in the current market than either lamb or the crops. Table 2 below shows price percentiles (2008 to 2012) and 2012 prices for common broadacre commodities, and Figure 6 shows variability in profit (per hectare per 100mm) for broadacre commodities between 1998 and 2012.

Figures 7 & 8 illustrate the average net profit per hectare per 100mm of annual rainfall (nominal) for cropping (wheat and canola), wool flocks, beef herds, dual purpose and prime lamb flocks between 1998-2012 and 2008-2012. It is important to note the variance of profitability within an enterprise is higher than the variance between the average profitability for different enterprises. In Figures 7 & 8 dual-purpose flocks were the most profitable enterprise per hectare per 100mm in both timeframes, but during the later period wool returns increased dramatically to rival prime lamb profitability.

3.1 Flock structure affects profitability

The analysis from the MLA (2014) reveals that some flock structures, particularly those reliant on replacement ewes, face greater exposure to market risk than self-replacing merino flocks. The reliance of some prime lamb producers on purchasing merino breeding ewes has contributed to high sheep prices in recent years.

Table 2: Price percentiles (2002 to 2012) and 2012 prices for common broadacre commodities

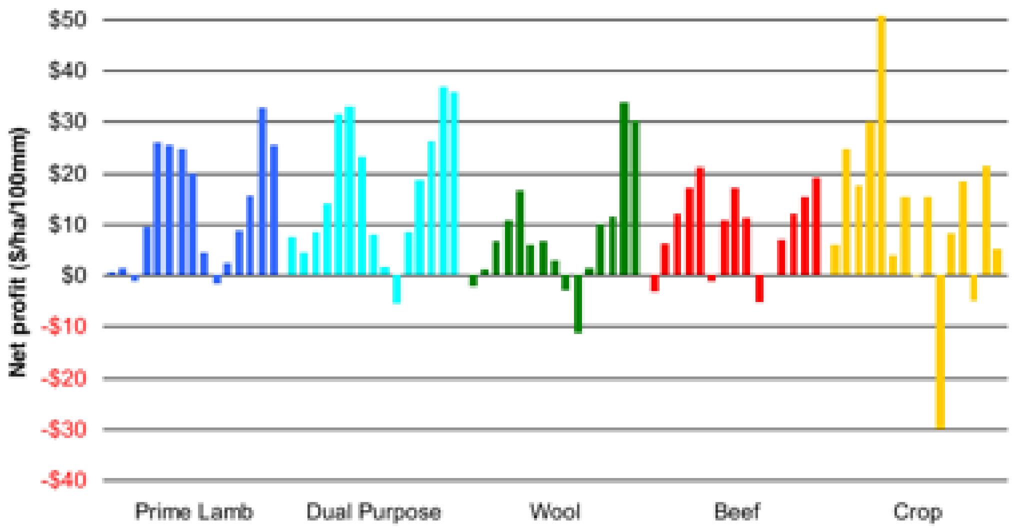
Percentile	17.5 Micron c/kg Clean	19 Micron c/kg Clean	21 Micron c/kg Clean	Lamb c/kg Dwt	Sheep meat c/kg Dwt	Steers c/kg Lwt	Cows c/kg Lwt	Wheat $/tonne	Canola $/tonne
100%	2275	1772	1526	690	504	223	178	490	800
90%	1606	1424	1286	514	412	207	156	335	609
80%	1384	1281	1103	482	316	198	152	283	568
70%	1306	1146	997	452	272	191	149	270	543
60%	1245	1085	963	413	217	187	145	247	510
50%	1183	1044	898	382	199	181	140	229	474
40%	1132	1005	854	357	186	176	137	201	424
30%	1070	963	809	344	172	171	134	192	406
20%	1027	936	758	331	161	166	131	174	369
10%	984	908	736	307	139	157	125	160	338
0%	852	774	652	181	18	123	95	129	270
2012 Price	1609	1444	1319	468	348	204	147	208	530
2012 CoP		838		370		120	120	212	530

Nearest percentile to 2008 price

Source: Information Commodity Services

Source: MLA 2014

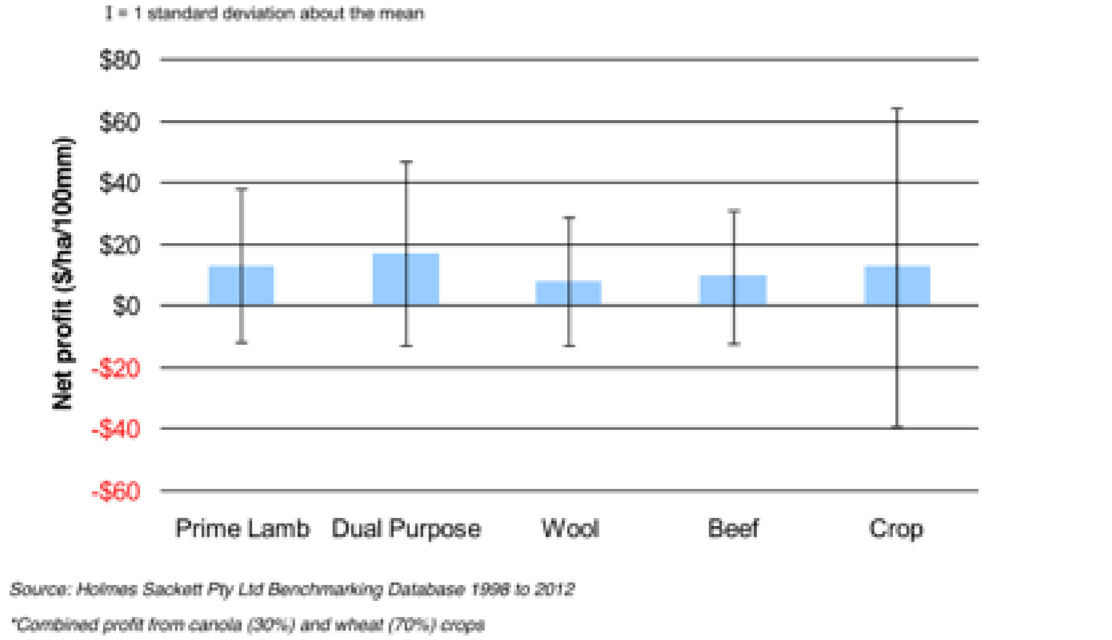
Figure 6: Profit per hectare per 100mm annual rainfall 1998 to 2012



Source: Holmes Sackett Pty Ltd Benchmarking Database 1998 - 2012

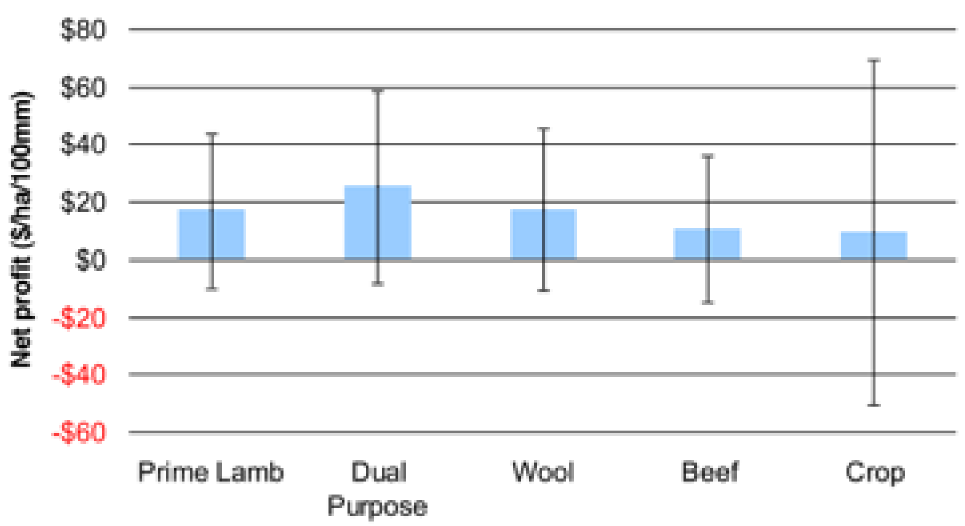
Source: MLA 2014

Figure 7: Variability in net profit ($/ha/100mm) for broadacre1998 to 2012



Source: MLA 2014

Figure 8: Profit per hectare per 100mm annual rainfall 2008 to 2012



Source: MLA 2014

Kopke et al (2008) identify a number of factors/ limitations of this breeding model and individual flock structure. These factors include:

i. *Difficulty in meeting breeding objectives.* It is very difficult to develop and achieve breeding objectives for a flock structure that requires the purchase of replacement ewes;

ii. *Supply risk.* There may be times when the supply of good ewes is either limited or expensive;

iii. *Flock structure inflexibility.* The flexibility of switching between prime lamb production and specialist wool production does not exist for a flock structure which buys replacement ewes as it does for a self- replacing ewe flock (O'Connell, 2003); and

iv. *Seasonality risk.* The quantity of supplementary feed required for a specialist prime lamb flock is considerably greater than that for a self-replacing Merino flock. There is potential for cost blow- outs in poor production years are therefore lower with a self-replacing Merino flock (O'Connell, 2003).

3.2 Benchmarking does not tell the full story

> "Benchmarking provides a skewed sample of the industry and results of this analysis need to be interpreted in light of that fact" (McEachern et al 2014)

There are obvious limitations in benchmarking studies, including sample size and bias. More data from low rainfall prime lamb flocks, eg. Dorper systems, would be a useful addition to help test findings from the 2014 report about wool flocks' superior profitability in low rainfall environments. Another factor that needs to be considered further are the reasons behind greater variance within enterprises than between enterprises.

There are a number of characteristics of farming systems, which help to explain the diversity of management approaches and reflect the complexity of analysing farming systems. As the MLA (2014) report suggests:

> 'Choice of market, genetics, lambing and sale time, soil fertility, pastures, labour and all other inputs into the system are all a means to achieving a better combination of production, cost of production, and price than currently exists. The complexity of the interactions between these three things means that any one cannot be looked at in isolation.'

Insights from the 'farming systems' literature could be used to highlight how a range of factors influence a farmer's decision-making. According to Hayman and others (2012) 'farming systems' are:

- Purposeful (they select goals and allocate resources to achieve these goals);
- Dynamic (change over time in response to internal or external influences);
- Stochastic (future behaviour is uncertain and difficult to predict);
- Open (they interact with their environment); and
- Abstract (they are conceptual rather than purely physical in nature)

(Hayman et al 2012, based on Dillion (1992)).

4 Climate change and sheep production

> "...in the future, managing climate variability will be more important for managing risks than it has been in the past. In addition, managing for climate variation will better equip producers for adapting to climate change as it occurs" (Harle and Howden 2007)

This section discusses a growing challenge for sheep production, the risks posed by a variable and extreme climate. The example of heat stress and sheep fertility is used to highlight how a known implication of climate change, increased temperatures, will continue to have fundamental impacts on the sheep industry. Further, the impacts of climate variability on fertility and drought-induced sell-off are major factors affecting change to the Australian flock.

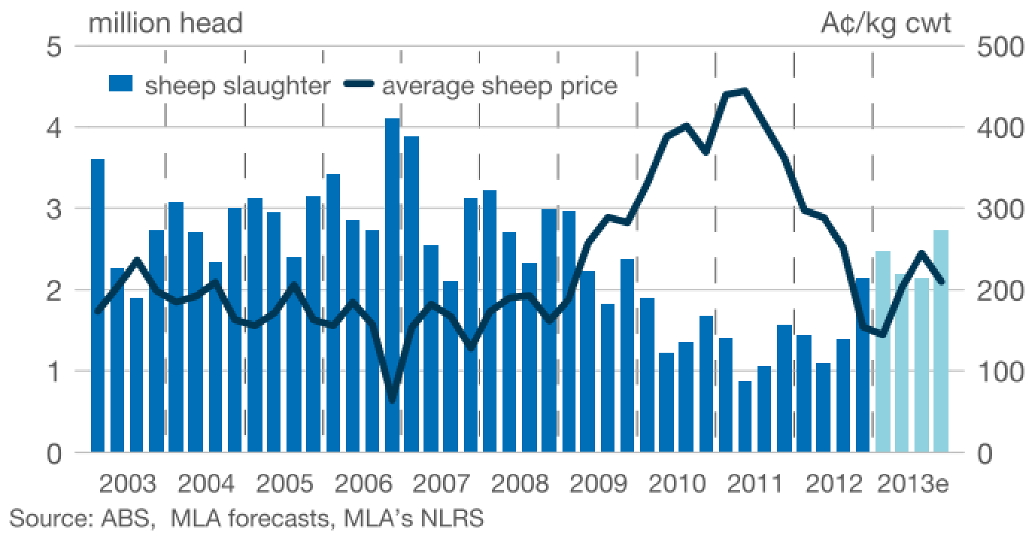
The future of the sheep industries (meat and wool) in South-eastern Australia will require adaptation to a range of interconnected impacts linked to climate change: higher temperatures, changes in rainfall amounts, intensity, and patterns; requirement for greenhouse gas mitigation; potential competition for rural land resources for production of human food, animal feed, biofuels, and carbon sequestration; increasing input costs due to water pricing and higher energy costs; and expectations that sustainable production and environmental stewardship be not only practised but demonstrated (Henry et.al 2012).

A significant factor in the decline of the sheep flock in recent years was an extended period of drought affecting most of South-eastern Australia between 2002 and 2007. Favourable seasonal conditions since 2009–10 have improved pasture growth and fodder production, encouraging producers to increase breeding numbers to maintain or increase future lamb production.

4.1 Climate variability causes market volatility

Figure 9 compares quarterly sheep slaughter levels with average sheep saleyard prices. There is a clear inverse relationship between supply and price, with big jumps in sheep prices between 2009-2012 corresponding to very low sheep slaughter levels. This is a case of climate variability driving market volatility, or the availability of grass determining supply and therefore market outcomes.

Figure 9: Quarterly sheep slaughter and saleyard prices



Source: MLA 2014

4.2 Climate change impacts on sheep production

Heat stress

Climate change is expected to affect sheep production through direct impacts such as thermal stress on reproduction, and indirect effects on animal health and growth, including via nutrition. Many of the general effects of high temperatures on animal production has been known for decades. For example, temperatures can lead to reduced growth rates as an animal's appetite becomes suppressed (Harle et al 2007).

Studies in pastoral sheep production zones have indicated that heat stress is a major factor in lowering reproductive performance. Heat stress can affect both ram fertility (through increased failure of fertilisation due to defective gametes) and neo-natal mortality in lambs (Entwistle 1974). It is believed that heat stress does not directly affect oestrus activity in sheep. However, there are a number of indirect effects on reproduction and fertility associated with heat stress. In hot conditions sheep may face increased nutritional stress due to limited time spend grazing, and often poorer quality summer pastures.

Sheep poorly adapted to heat stress often suffer increased levels of embryonic mortality and reduced foetal growth. However, sheep that may have been bred to adapt to long periods of hot conditions are less likely to be impacted upon by increased temperatures and suffer from the impacts associated with increased temperatures.

Periods of hot dry conditions may impact pasture availability and quality, which also affects the reproduction of sheep. Nutrition in the last six weeks of pregnancy is particularly important to reducing toxemia and especially in twin-bearing ewes.

Changes in heat stress associated with climate variability and change, could potentially affect normal behavioural, immunological, and physiological functions of sheep (Mader 2003). In addition, when animals are exposed to thermal stress, metabolic and digestive functions are often compromised due to altered or impaired feeding activity (Mader 2003). These changes will affect the productivity of sheep production and will necessitate some management changes.

Sheep normally maintain their body temperature within a fairly narrow range (0.58C) over the course of a day (Henry et al 2012). Exposure to high heat load causes a heat stress response as the animal attempts to maintain homeostasis. When environmental conditions change, an animal's ability to cope with (or adapt to) the new conditions is determined by its ability to maintain performance and oxidative metabolism (Henry et al 2012). The stress response is influenced by a number of factors including: species, breed, previous exposure, health status, level of performance, body condition, mental state, and age.

Animal response to stress usually results in a loss of performance (e.g. growth or reproduction). Under extreme conditions, there may be an increase in mortality rates. All of these changes lead to economic loss (St-Pierre et al. 2003).

Adaptation to heat stress

Heat stress is considered a highly likely impact on livestock industries in Australia in the future. The sheep industry of South-eastern Australia will clearly need to adapt in order to remain a viable industry.

To adapt to the impact of heat stress on their sheep, producers will need to consider;

- The type of animals used (e.g. breed and gender);
- The genotypes used;
- Changes in facilities and housing; and
- Redistribution of livestock and livestock species in a region

(see Gaughan et al. 1999, 2009)

These impacts mean that farmers will have to make decisions over time about how they want to adapt. The breeding of animals better adapted at not only surviving, but being productive at times of high temperature could be a way to ensure that the farm is ready sooner to adapt to the future climate by responding to current climate variability and the warming trend. Case Study 2 provides an example of current research examining livestock adaptation to climate change.

Case Study 2: Future Ready Animals - animal genetics and the environment

Summary: Modifying the animal (e.g. genetics) or its environment (e.g. shade, shelter, nutrition) to better meet climate change challenges (enhanced reproduction, productivity, animal welfare, profitability and flexibility).

Case Study: Ram fertility in a warming climate.

Why?: Demonstrates a gap in research limiting current best practice management and an issue likely to be exacerbated by climate change.

In a hotter environment farmers need to know how best to manage rams prior to and during joining and the timing of joining to ensure the highest fertility rate possible. It is known that "heat stress can affect sperm production and viability" (Sheep Connect South Australia 2013). Hot weather with temperatures over 32 degrees Celsius for long periods or very high temperature over 38C for short bursts can affect sperm production" (Sheep Connect South Australia 2013).

Currently there is a lack of knowledge about how to manage ram fertility during periods of high temperatures. However, there are a number of potential options, many of which are related to best management practice, including changing the joining time; shearing rams before joining; providing shade and shelter; and joining rams in small paddocks/ confinement lots. Genetic and genomic research potentially provides longer-term solutions, particularly given some sheep breeds are known to be better adapted to heat stress.

There are many different ways the sheep industry will be able to adapt to future climate change predictions, however it is important that a holistic approach be taken to incorporate multiple adaptation techniques. The Southern Livestock Adaptation 2030 website states as one of its key findings, “it is unlikely that one adaptation alone will remove all the negative impacts of climate change – combinations of adaptations are found to work best”. It is therefore critical that farmers approach adaptation in an integrated manner to ensure that a range of adaptation strategies are incorporated to best adapt in the future.

5 Rebuilding and optimising the Australian sheep flock

> *Simple projections based on recent performance of the flock suggest that the Australian sheep population may well continue to decline unless current turn off levels are reduced. At its most basic level, the number of lambs born in recent years has been less than the total of lambs slaughtered, sheep slaughtered and live sheep exports. That cannot continue in a stable population. (Curtis 2009)*

Predicting changes to the size and composition of the national flock is a difficult task. There are a range of factors that influence the decisions made by individual producers to sell, buy or breed stock. However, changes to the national flock follow a fairly simple equation. The change in sheep numbers during any given year is defined by:

> (Number of ewes mated + lambs marked) *minus* (slaughterings, live exports and deaths)

Curtis (2009) has discussed the declining Australian sheep flock on numerous occasions, including his well publicized paper ‘The disappearing flock’ (2009). More recently, Curtis has updated his ‘flock stocktake model’ to estimate changes to the composition, size and productivity of the Australian sheep flock. By using ABARES datasets and making changes to slaughter levels and lamb marking rates, it is possible to explore how sheepmeat production changes under different scenarios. Over the past decade there has been a noticeable decline in the number of merino ewes joined to merino lambs, and an increase in the use of non-merino use to breed prime lambs (Figures 10-12).

Table 3 highlights these trends. Of note is that for the past four years (2009-2013) the percentage of pure merino lambs has remained fairly static, with around 47-49% of ewes in Australia being merino ewes joined to merino rams.

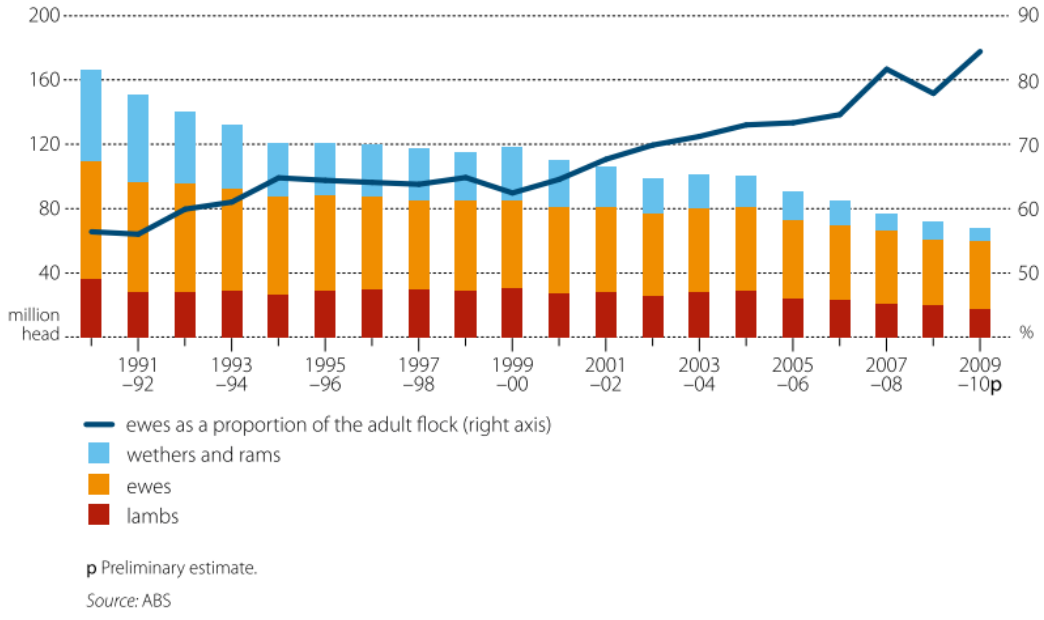
Table 3 demonstrates how the average marking rate of the Australian sheep flock has increased due to changes in flock composition. Breeds of sheep have different reproductive efficiencies. Merinos have lower fertility than most sheepmeat breeds, and crossbreeding is known to increase marking rates. As the number of purebred Merino lambs decreased from 61% to 49% of total lambs between 2004-05 and 2012-13, accompanied by an increase in other breeds, the weighted average marking rate of the Australian sheep flock has increased by 3.8%.

There have been similar trends in changes to flock structure in all states (Figure 13). Breeding ewes are an increasing proportion of the flock in all states. It is worth noting in the graph below, that for QLD (red area) there was a reversal in this trend during the mid 1990s-2000s. One contributing factor was a choice by many sheep producers to move towards cattle production due to declining wool prices, while those with sheep often retaining easier to manage wethers.

The analysis by Curtis (2014) assumes continued lower marking rates for Merinos than other sheep breeds. As the marking rate entered for pure-bred Merino lambs (offspring of Merino ewes mated to Merino rams) is lower than that reported for first-cross Merino lambs and other breed lambs, Curtis’ flock optimisation model chooses to minimise the number of Merino ewes mated to Merino rams. In effect this involves sales of excess Merino ewe lambs declining to zero:

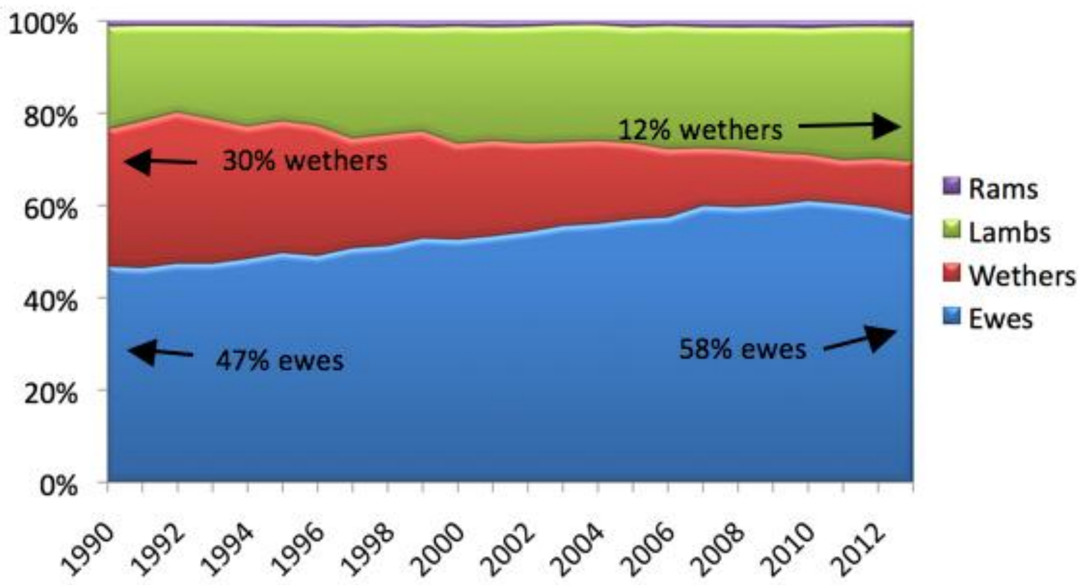
> ‘*The optimum solution is to mate just enough Merino ewes to Merino rams to produce sufficient Merino ewe lambs to exactly replace those Merino ewes that are culled and die on farm plus enough to cover Merino ewe lamb deaths. Thus there are no Merino ewe lambs for sale.‘* (Curtis 2014)

Figure 10: Composition of the Australian Sheep Flock



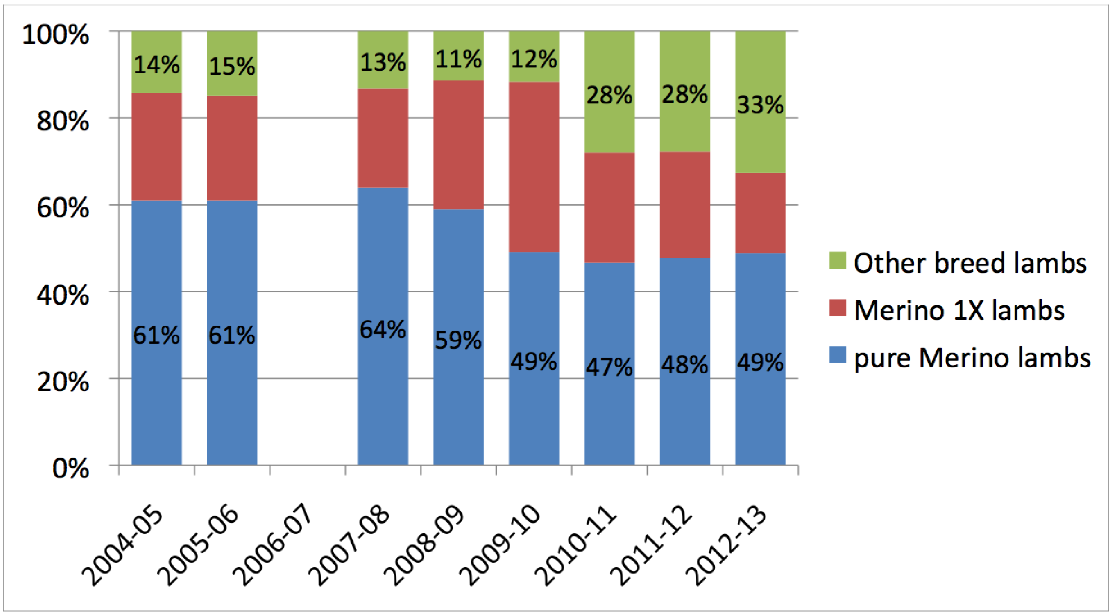
Source: ABARES 2011

Figure 11: Australian Flock Composition



Source: Curtis 2014 (Based on: ABARES AgSurf, DAFWA analysis)

Figure 12: Ewe mating choice



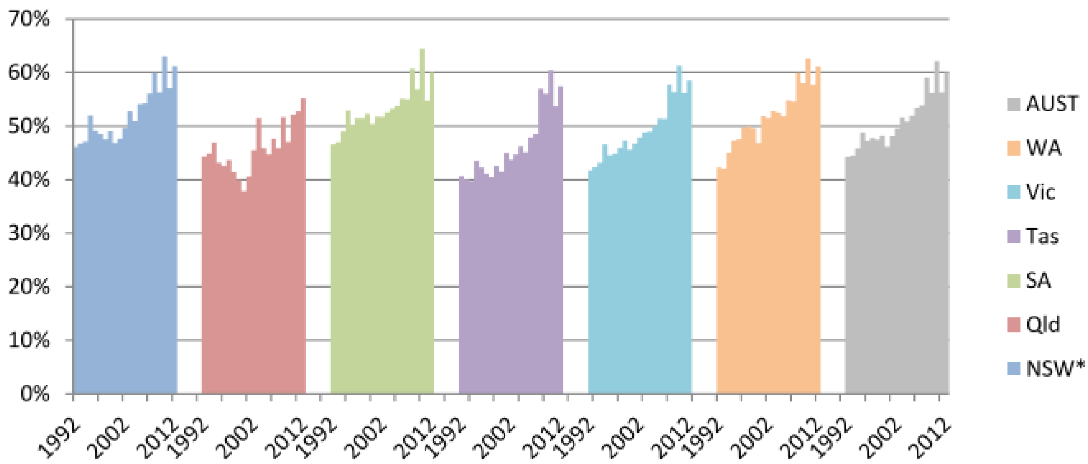
Source: Curtis 2014 (Based on ABS and DAFWA data, DAFWA analysis)

Table 3: Increased marking rate due to change in flock composition

Ewe breed by ram breed	Lamb type produced	Percent of breeding ewes 2004-05	2012-13	Marking rate
Merino x Merino	pure Bred Merino	61%	49%	**85%**
Merino x Other breed	first cross Merino	25%	18%	**90%**
Other breed x Other breed	Other breed (meat, 2nd cross)	14%	33%	**107%**
	Weighted average marking rate	**89%**	**93%**	**+3.8%**

Source: Curtis 2014.
Based on MLA/AWI sheep meat and wool surveys, DAFWA analysis. The calculation of the impact of the chan in breeding ewe composition and mating choice uses average marking rates.
Marking rates derived from the MLA/AWI sheep meat and wool survey data for 2011 to 2014.

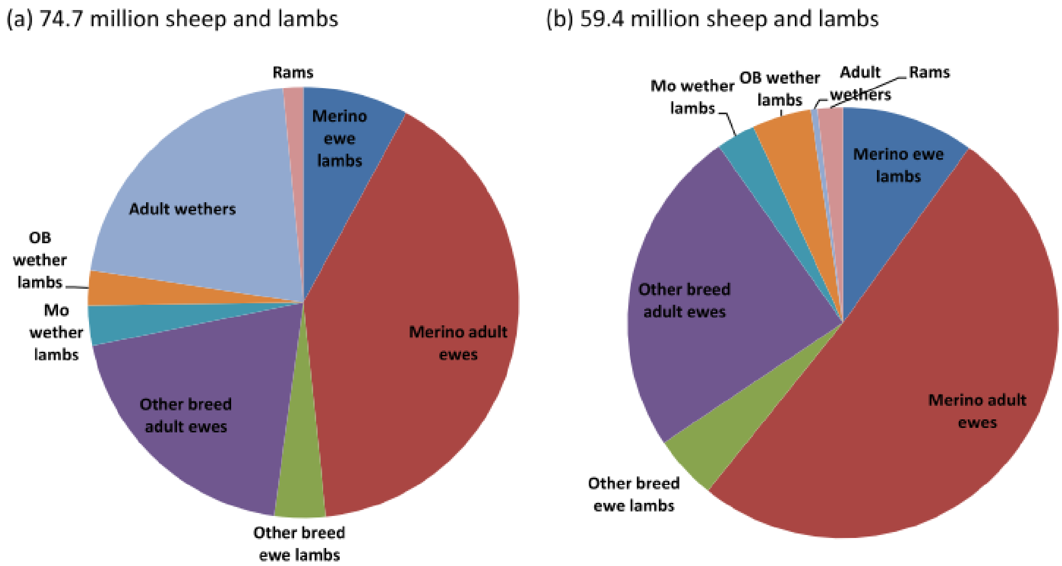
Figure 13: Percent breeding ewes in the flock by year and state



(NSW* includes ACT.)

Source: Curtis 2014 (Based on ABS data)

Figure 14:
A comparison between estimated current flock composition and the composition that maximises turn-off while holding the total number of breeding ewes constant, and maintaining the proportion of Merino breeding ewes at 67%



Source: Curtis 2014

Figure 14 above shows Curtis' (2014) estimated current flock composition, and the composition that maximises turn-off while holding the total number of breeding ewes constant at the current level. This analysis involves maintaining the proportion of Merino breeding ewes at 67%. As part of these changes the proportion of wethers would fall leaving a higher proportion of breeding ewes.

The two pie charts compare (a) the estimated current flock composition, with (b) the composition that maximises turn-off while holding the total number of breeding ewes constant, and maintaining the proportion of Merino breeding ewes at 67%. Note that the composition that maximises turn-off (b) has a significantly smaller total sheep and lamb population.

Using the Excel spreadsheet model developed by Curtis (2014) it is possible to estimate hypothetical changes to the Australian sheep flock. As a static model there are a number of variables that are assumed to remain constant. One potential scenario that demonstrates both the usefulness and limitations of the Curtis model is to propose increased marking rates for all sheep breeds, with the largest relative increase for purebred Merino sheep. This may well be a reasonable scenario, given reproductive efficiencies in other breeds may stabilising at natural limits, and in line with the growth of the sheepmeat sector Merino breeders are now heavily focusing on fertility and survivability traits.

Scenario One. Increased marking percentage

This analysis illustrates how the turn off/ sheepmeat production of the national flock can change dramatically increase with changes to marking rates, but no change to overall flock size. Scenario One involves an increase in marking rates for all breeds:

Merino 85% (+5%)
Merino x Other 91% (+2%)
Other Breeds 100 % (+2%

This scenario could also reflect a 'good' season, where climatic conditions and pasture availability support an increase in marking rates. Under the higher reproductive efficiency scenario there are significant changes to turnoff, particularly lamb turnoff. Under this scenario:

- There is a significant increase in total lamb turn off +1.117 million.
- There is a slight increase in total sheep turn off +0.078 million
- The total turn off increases by +1.286 million
- The majority of the increases in turn off come from the Merino breed:
  Merino Turn Off +0.943 million
  Other Breed Turn Off +0.346 million

In effect there is a lift in production from the same total flock size. This demonstrates that it is possible for the current historically small national flock to be highly productive and efficient for sheepmeat production. This simple static model does not predict changes in wool production or profitability, but it is useful for illustrating the potential sheepmeat production / sheep turnoff of the current flock.

Table 4: Base vs more productive/fertile flock (Scenario One)

Summary	Scenario One	Base	Scenario One	Base	Scenario One	Base
Lamb Turn off	Ewes	Ewes	Wethers	Wethers	Total	Total
Merino	2.126	1.674	5.667	5.348	7.794	7.02
Other Breed	7.133	6.941	7.990	7.836	15.123	14.777
Total	9.259	8.615	13.657	13.185	22.916	21.799
Sheep Turn off	Ewes	Ewes	Wethers	Wethers	Total	Total
Merino	4.350	4.350	3.199	3.030	7.549	7.380
Other Breed	2.109	2.109			2.109	2.109
Total	6.458	6.458	3.199	3.030	9.657	9.489
Ram Turn Off					0.206	0.206
Total Turn Off	16.856	15.718	16.215	15.073	32.780	31.494

6 Conclusion

There have been fundamental changes to the Australian sheep flock in the last two decades. Changes to the size and composition of the Australian sheep flock can be understood in terms of relatively easily observable economic trends. However, the much more difficult challenge is understanding how the 'dynamics' of the Australian sheep flock has changed.

This essay has provided a literature review from a range of sources. By attempting to combine insight from different bodies of research, including; industry benchmarking; economic modelling; and, climate change adaptation research; it has demonstrated the complexity of predicting future impacts, even when there are easily observable historical trends. The clear decline in the Australian sheep flock size belies more complex changes to flock structure and dynamics.

An analysis of industry benchmarking studies has identified key areas driving productivity and profitability in the sheep industries. The use of flock 'stocktake' models, allows a simple estimation of what potential changes to flock composition mean for production and the total size of the flock. There are obvious limitations to these steady-state or static models, which assume the persistence of existing price elasticities and premiums between products (eg. sheep and lambs, and wool microns). Nevertheless, as the brief analysis in this essay demonstrates, these models can help improve our understanding and contribute to the discussion about the sustainability of the Australian sheep flock. Further research is needed to explore the implications of changed elasticities and premiums for flock structure and size.

It remains possible to sustain production under a declining flock situation, provided there is a focus on reproduction efficiency in the remaining flock. The decline of the size of the Australian sheep flock can be halted, but even if it cannot it is still possible to increase production. We can continue to 'kill the Golden Sheep', so long as there is a commensurate focus on breeding the 'Golden Sheep'. As discussion of the climate change adaptation literature in this essay has shown, there are many challenges for increasing the reproductive effectiveness of the Australian sheep industry.

Further research is needed, particularly in the area of economic modelling. Current static or steady-state models are helpful in identifying areas of interest, but more sophisticated models are needed in order to incorporate important economic concepts like supply and demand elasticities. The changing relative profitability of the wool and sheepmeat industries will continue to shape the size and composition of the Australian sheep flock.

One possible avenue of research is in scenario-based modelling. This analysis would be relevant for individual producers, but also for industry policy-makers for strategic planning. For example, scenarios could be developed for a range of possible future scenarios, including low, medium and high growth situations for the sheepmeat sector, changing elasticities between lamb and mutton, and the impacts of the re-expansion of the live sheep export sector. Each of these scenarios could include relevant changes to the sheep stocktake model used in this essay.

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Appendix 1

MLA 2014 Prime Lamb Situation Analysis- Broadacre enterprise definitions	
Prime Lamb Flock	These enterprises are those for which both t maternal and terminal breeds are known to specialist prime lamb breeds with little wool val comparative to their sheep meat value. The flocks will include flocks where the mo traditional first cross ewe (Border Leicester Merino) are joined to terminal si (predominantly Poll Dorset and White Suffol and also self-replacing pure bred or compos prime lamb flocks (i.e. Coopworth flocks).
Dual Purpose Flock	These enterprises are those where there significant wool income from the enterprise well as prime lamb. The majority of these floc consist of surplus ewes from specialist wo flocks joined to either a maternal or terminal si There are only a few dual purpose bree represented in this sample.
Wool Flock	These enterprises are predominantly se replacing merino sheep enterprises. Some these flocks keep wethers out to three years age. There is the occasional enterprise whe wethers are purchased in.
Beef Herd	These enterprises are predominantly se replacing beef breeding herds.
Dryland Cropping	The dryland cropping profits were calculated 2/3rd of the average wheat profit and 1/3rd of t average canola profit for each year to reflect t typical rotation emphasis between the two ma crops.

Appendix 2

Curtis 2014- Flock Stocktake Model Assumptions	
Input variable	**Value**
Number of breeding ewes (million)	44.85
Percent of breeding ewes that are Merino	67%
Percent of breeding ewes joined	88%
Percent of breeding ewes joined to Merino rams	71%
Marking rate- pure-bred Merino lambs	80%
Marking rate- first-cross Merino lambs	89%
Marking rate- other breed lambs	98%
Death rate- lambs	6%
Death rate- adult ewes	4%
Death rate- adult wethers	4%
Death rate- rams	8%
Adult culling rate- Merino ewes	15%
Adult culling rate- other breed ewes	15%
Culling rate- rams	20%
Percent of Merino wether lambs sold	75%
Percent of other breed wether lambs sold	85%
Rams as a per cent of breeding ewes	2.5%