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Evaluating the impact of animal genetics and genomics RD&E investment

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Abstract

MLA's statutory funding agreements with the Commonwealth require a systematic evaluation of RD&E investments made in the red meat industry.

This report provides an analysis of the return on investment for the sheep and beef genetics and genomics program by MLA and co-investors over the period from 2001/02 to 2011/12. MLA invested 28% of the total $323 M (2014 Real, Present Value) over this period. The analysis is based on the counter-factual assuming MLA and co-investors had not invested at all during this period. The benefit streams were estimated from 2002 to 2040 with the appropriate lags for time from research to uptake, and lags to commercial realization applying a discount rate of 7%. The analysis indicates an overall benefit/cost ratio of 4.5 to 1. The report also includes some credibility checks as to the scale of the estimated impact in terms of the value of genetic improvement at an enterprise level and in terms of the gain in industry productivity over time. It also provides a perspective on future MLA investment, and an assessment of the methodology and findings in terms of future MLA investment activities.

Executive summary

This Report provides an estimate of the economic value of benefits realised (or expected) by seed-stock & meat producers from genetics RD&E investment by MLA and its co-investors, against the counter-factual of no MLA investment. Credibility checks are also presented. Attribution of the realised benefits to MLA's investment and the returns to producers are estimated. A perspective on future MLA investment, along with an assessment of the methodology and findings in terms of future MLA investment activities is provided.

Analysis

Benefits are calculated out to 2040 at a 7% discount rate, with lags for periods from investment in RD&E to uptake by breeders, and from breeders to commercial impact. Table ES1 presents the summary (all values are in 2014 Real Present Values). Benefits from improved genetics are cumulative over time as improvements in performance are embedded in retained sire-breeding and commercial stock. The total investment in RD&E in genetics related programs supported in part by MLA (data from MLA records) over the 2002-12 period was estimated at $323 million (M). MLA invested $91 M (28%). Principal co-investors were CSIRO; state departments of primary industry and universities, individually and through the Sheep and Beef CRCs. Breeders invested an estimated $16 M, on which they receive a direct return through sales. The ***base case*** uses investment from 2002-12; the ***counter-factual*** (CF) provides an assessment of the impact that might have occurred should MLA have withdrawn investment from the area in 2001.

Table ES1. Estimated returns ($M) for the base case for assessment and the counter-factual (the CF assumes that there is NIL MLA investment from 2001/02 to 2011/12).

	Base case (Benefits with MLA)	Estimated Benefits from CF	Net benefits due to MLA investment	Total RDE investment	Net return after RDE cost
Sheep	$1,051	$284	$767	$132	$636
Southern beef	$1,023	$394	$629	$143	$486
Northern beef	$79	$30	$49	$48	$1
Total beef	$1,102	$424	$678	$191	$487
Total	**$2,153**	**$708**	**$1,445**	**$323**	**$1,122**

<u>Sheep:</u> ***Base*** - This has been estimated as the value of genetic investment (to 2040) using the 1997 to 2009 genetic trend to estimate benefits from 2001 to 2012, and the 2009 to 2012 genetic trend to estimate benefits between 2013 and 2040. The adoption rate increased from 2000 (to 2012) levels of 6% (18%) for Merinos, 38% (70%) for Terminals and 24% (41%) for Maternals. ***CF*** - This is estimated as the value of genetic investment using genetic trends from 1993 to 1997 to estimate benefits from 2001 to 2040, with lags. Adoption was as per the data (flat at 2000 levels for the entire period, of 6% Merino, 38% Terminal, 24% Maternal).

<u>Southern Beef:</u> ***Base*** - This has been estimated to 2040 using the 1994 to 2006 genetic trend to estimate benefits from 2001 to 2012, and the 2009 to 2012 genetic trend to estimate benefits from 2013 to 2040. Adoption is stable at 75% across the 2000 to 2040 period. ***CF*** - This is estimated as above using genetic trends at 61% imported (at US rate) and 39% Australian genetics (1994 to 2006 trend) to estimate benefits from 2000 to 2040, with adoption at 75%.

<u>Northern Beef:</u> ***Base*** - This has been estimated using the same periods as for Southern Beef. Adoption is stable at 20% for *Bos indicus* use and 50% for *Bos taurus* across the entire 2000 to 2040 period. The economic value of trait changes in North is half of that in the South. ***CF*** - This is estimated as above using trends at 65% imported (at their rate) and 35% Australian genetics. Adoption is stable at 10% for *Bos indicus* and 25% for *Bos taurus* across the period to 2040. The economic value of trait changes in North is half of that in the South.

Investment performance

The gains are most apparent in terminal and maternal rams and *Southern Beef* bulls. In contrast the gains have been small for Merino rams and *Northern (tropical) Beef* bulls. Table ES2 further documents the benefits, and Table ES3 provides an estimate of the attribution to MLA.

Table ES2. Performance of the RD&E as an investment (Real, 2014 present values)

		Gross benefits ($M)	Investment ($M)	Benefit to Cost ratio	Net Benefits ($M)	IRR
Sheep		$767	$132	5.8	$658	27%
Beef	Southern	$629	$143	4.4	$486	29%
	Northern	$49	$48	1.0	$1	8%
	Total beef	$678	$191	3.5	$487	24%
Total		**$1,445**	**$323**	**4.5**	**$1,122**	**26%**

Table ES3. Attribution of the benefits to investment by MLA (Real, 2014 present values)

	Investment		Benefits (CF)	Benefit to Cost ratio for MLA investment	IRR on MLA investment
	$ M	**MLA share of Total**	**MLA share of Total**		
Sheep	$60	46% (of $132M)	46% ($350 of $767 M)	5.8	27%
Beef	$31	16% (of $191 M)	16% ($108 of $678 M)	3.5	24%
Total	**$91**	**28% (of $323 M)**	**32% ($458 of $1,445)**	**5.1**	**26%**

Distribution of benefits

The net impact of the RD&E investment incorporating the second round (ie producer response and subsequent effects on market prices) significantly reduces the estimated first round gains to producers. On average over the period sheepmeat producers are estimated to retain 30% of the first round gain and beef producers, 50%. The rest of the gains are distributed to others beyond the farm gate, including consumers.

Overview of the investment

The focus of this analysis is on improvement in meat production from sheep and beef.

MLA and co-investor support for genetics RD&E has resulted in significant genetic gains in traits of commercial value in recorded flocks and herds. Realisation of these gains is dependent on uptake by commercial producers. Estimated industry benefits are conservative for the following reasons: parameter values used are generally conservative (e.g. feed costs of heavier mature animals are recognised, but such costs are dependent on the management system; a 75% realisation factor has been applied to reflect the likelihood that commercial producers will not realise the full gains of the sire-breeding businesses; adoption 2012 - 2040 is held at 2012 levels (sensitivity analysis undertaken); gains from the contribution of genetics to meat quality and wool are not included; the future value of more comprehensive and/or faster gains through genetics (options value to meet future challenges) has not been estimated.

Perspectives on future MLA investment

The case for future MLA involvement focuses on aspects of market failure, and in particular, the proposition that adoption of the new genomic-based technology may compromise the future success of genetic improvement programs. That is, it is a potentially-disruptive technology. The key factors considered are mainly those relating to the impact of genomic tools in the development and application of new breeding technologies. Practices that will facilitate uptake and encourage uptake of genetically-improved animals are fundamental - this issue highlights adoption as an area where more data are required. There is a case for a greater investment in generation of robust data to show the benefits of genetic improvement in commercial settings.

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Overview of the report

Terms of reference

The focus is on the benefits of investment by the red meat industry (via MLA), the Australian Government and others in the MLA Animal Genetics & Genomics RD&E 'program' from 2001/02 to 2011/12. This requires consideration of both past and future benefits. The terms of reference are summarised as:

1. Estimate the **economic value of benefits** realized (or expected) by seed-stock & meat producers from genetics RDE investment (investment, genetic gain, adoption)
2. Assess the **counter-factual** to MLA investment
3. **Analyse the investment** in terms of attribution of the value to investment by MLA, along with the estimated returns and the beneficiaries
4. Provide a perspective on future **MLA investment**
5. **Assess the methodology and findings** in terms of future MLA investment activities

Deliverables

The deliverables in response to the Terms of Reference are as below.

- Estimates of the **MLA investment in RDE** in genetics & genomics: both direct investment and co-investment
- **A methodology to assess the benefits of the investment** including methods to :
    - Generate genetic trends in recorded flocks/herds derived from EBVs (with the basic premise of a cumulative and permanent change from genetics)
    - Convert these trends to the genetic trend in productivity expressed as kilograms of carcase sold per female mated
    - Generate profit functions (including recognition of the additional cost of feed for heavier breeding females)
    - Estimate the impact for the producer/industry with the key factors being adoption and the potential impact of the environment on realisation of benefits
    - Assess some different systems to provide credibility checks
- Assessment of a **counter-factual position** in terms of what might have happened had MLA not invested in the period from 2001/02 to 2011/12?
- **Investment analysis** in terms of the value realised at the industry level
- **Perspectives on future MLA investment** – options, new technologies, market failure
- **Assessment of the methodology and findings** in terms of future MLA investment activities (i.e. it provides a perspective in terms of the lessons learned)

Part 1. Estimating costs and benefits

Part 1.1: The cost of investment

Background

This Review addresses the return on investment by the red meat industry (via MLA), the Australian Government and others in the MLA Animal Genetics & Genomics RD&E 'program' from 2001/02 to 2011/12.

Data have been sourced from MLA and include investments by MLA from producer levy funding, Australian Government matching, donor company investment, and others, together with co-investors in R&D programs. The analysis also includes assessment of the scale of investment by users of the technology especially seed-stock producers. Two specific questions are:

- What was, and is, the **rationale behind MLA involvement** in this investment?
- In what **specific areas** has MLA invested and who are the co-investors alongside MLA (and what is the scale of investment by those likely to benefit from investment)?

The rationale behind MLA involvement in this investment

Background

Genetic improvement is well-recognised as a means to improve productive traits in livestock. Hence it is one of the key factors allowing cattle and sheep producers to become more productive and efficient, maintain or improve product quality, and enhance sustainability of their enterprises. The factors that influence the success of genetic improvement include:

- the level of adoption, and
- the effectiveness of use of genetic evaluation and genetic improvement tools

by seed stock producers (the enterprises that breed and sell bulls and rams). Benefits (return on investment) from RD&E into beef and sheep genetics and genomics, are captured through:

- producers being able to make more informed decisions on which bulls or rams to buy (or which studs to buy from) than would otherwise be the case;
- commercial cattle and sheep producers realizing genetic gains in their herds and flocks through use of genetically superior sires; in this respect, the herds and flocks are improving steadily in terms of productivity, product quality and a lower cost of production over time;
- managers being able to target specific management to animals with specific genetic merit to meet a market demand (an example is knowing which animals to put into feedlots to produce marbled beef).

Realisation of these benefits ultimately depends on seed stock producers recording the performance of individual animals, and the conversion of those data into EBVs or ASBVs (estimates of the genetic merit of an individual) through the genetic evaluation schemes. For successful genetic improvement at the industry level, this must be combined with selection of genetically superior animals to be parents of future generations, together with the uptake of genetically-superior individuals by commercial producers.

MLA plans

The current MLA business plan for Investment in Beef and Sheep Genetics and Genomics

RD&E (2012/13 to 2014/15) identifies where MLA's investment should be prioritised. In the MLA plans, there are four key strategic platforms for this investment by industry:

- strategic research focused on scoping the use of genomic sequencing to reduce cost and increase accuracy in implementation of genomic technologies, plus development of breeding values for methane production and potentially key disease traits in sheep;
- applied R&D focused on the genetics of fertility in northern cattle, animal health and welfare traits in sheep and cattle, mechanisms for stimulating or incentivizing performance recording, particularly in hard-to-measure traits, and on development of breeding program and enterprise models to exploit genomic technologies;
- core infrastructure, including maintenance of underpinning analytical software for Sheep Genetics, BREEDPLAN and national databases, and ongoing genetic parameter estimation;
- evolution of the delivery and extension models to increase flexibility in information capture and delivery, continue building capability in breeders and advisors, and accelerate trialing and implementation of new tools and knowledge.

The program and investment

MLA's investment in genetics comprises support for a number of specific programs each of which address genetics to some degree. Within the period under review, the principal 'single line' areas of investment were the Sheep Genomics Program, the Sheep CRC, Sheep Genetics Australia and the Beef CRC, and within each of these areas there is a range of projects.

The MLA and co-investment data have been derived from MLA records. In addition there is extension and advisory support which might often not be recorded as part of these programs, and hence is an unknown. There are also the investment and operational costs of stud breeders in data collection for BREEDPLAN, LAMBPLAN and MERINO SELECT, along with on-farm implementation costs for stud and commercial breeders adopting the findings of R&D.

MLA investment

MLA investment in genetics R&D programs between 2001/02 and 2011/12 is estimated to total around $91 M in real, present value terms. The time series of investment (in nominal terms or current dollars or dollars of the day), by broad area of investment is shown in Tables 1 and 2.

Table 1. MLA investment in genetics: Current dollars ($M, 2001/02 to 2011/12)

	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
Beef CRC		0.34	0.18	0.45	0.01	0.40	0.32		0.12	0.24	
BIN	0.04	0.04	0.04	0.04					1.16	2.47	2.64
Beef other (a)	0.31	0.85	0.49	0.36	0.18	1.59	1.10	0.64	1.75	1.33	1.34
Total beef	**0.35**	**1.22**	**0.70**	**0.85**	**0.18**	**1.99**	**1.42**	**0.64**	**3.03**	**4.04**	**3.98**
Sheep CRC						0.01	0.83	0.70	1.45	1.01	0.58
Sheep Genetics	0.31	0.59	0.58	0.37	0.24	0.34	0.92	0.21	0.27	0.06	0.08
Sheep Genomics		0.14	3.00	3.00	3.00	3.00	3.00		0.79	0.00	
Sheep other (a)	0.03	0.36	0.04	0.17	0.08	1.13	0.60	0.29	1.47	0.75	1.95
Total sheep	**0.34**	**1.08**	**3.62**	**3.54**	**3.32**	**4.47**	**4.52**	**1.20**	**3.98**	**1.83**	**2.61**
Total	**0.69**	**2.30**	**4.32**	**4.39**	**3.50**	**6.46**	**5.94**	**1.84**	**7.01**	**5.87**	**6.59**
Beef % of Total	**51%**	**53%**	**16%**	**19%**	**5%**	**31%**	**24%**	**35%**	**43%**	**69%**	**60%**
Sheep % of Total	**49%**	**47%**	**84%**	**81%**	**95%**	**69%**	**76%**	**65%**	**57%**	**31%**	**40%**

(a) Includes share of "Beef and sheep" - apportioned value of the total "Beef and Sheep" MLA genetics programs/ projects - apportioned *pro rata* of identified Beef and Sheep genetics programs/projects

Table 2. MLA investment in genetics 2001/02 to 2011/12 ($M) by broad area in Real Present Values (7% discount rate)

Beef		**Sheep**	
Beef CRC	4.3	Sheep CRC	6.7
BIN	8.5	Sheep Genetics	8.7
Beef other	17.8	Sheep Genomics	33.8
		Sheep other	10.9
Total beef	**30.6**	**Total sheep**	**60.1**
Total		**$90.7 M**	

Co-investment

Most MLA programs involve co-investment by research organisations, producers and breeders and off-farm interests such as processors. Such investment may be as cash or in-kind. In addition there are commercial and other interests which play an important role in enabling genetic improvement through R&D, evaluation and facilitation of adoption.

An estimate of the co-investment in MLA genetic programs has been made for 2012/13 by Banks (Table 3). In relative terms, producer funding (via levies) contributed around 6% (Beef) and 18% (Sheep). Breeders contribute substantially more than producers but governments (via CRCs, universities, CSIRO and state departments), contribute the major share at around two-thirds of the total investment.

Table 3. Investment in beef and sheep genetics: Relative contributions in 2012/13 (source data MLA)

	Beef ($M)	Sheep ($M)	Total	Beef %	Sheep %	Overall
Breeders	8.0	8.4	16.4	31%	31%	31%
Producer levies	1.5	4.3	5.8	6%	16%	11%
Governments	16.7	14.6	31.3	64%	53%	59%
Total	**$26.2 M**	**$27.3 M**	**$53.5 M**	**100%**	**100%**	

Total investment

MLA investment is taken as twice the producer levy contribution, given $ for $ matching by the Commonwealth Government. In estimating total investment in genetics to achieve the benefits to producers outlined above, an issue is the investment made by breeders. While this investment has undeniably contributed to the overall genetic progress, much, if not all, would likely have been made even had the MLA funding been withdrawn. However the focus would likely have been different, with the focus on short-term R&D. It is also possible that breeders may have committed extra funding. The counter-factual analysis considers this area in detail.

The focus of this evaluation is the additional return to producers from MLA programs. Typically it is the MLA programs that have attracted co-investment. The total investment by and associated with the MLA programs has been estimated using the following basis:

- MLA investment is twice the producer levy contribution;
- total investment associated with MLA programs equals MLA program investment plus Government investment (less the matching dollar);
- investment by breeders is excluded as they realize direct return on their investment through sale of rams or bulls;
- the raising factor equals the ratio of total investment associated with MLA programs to the: MLA program investment; these ratios are 6.2:1 for beef and 2.2:1 for sheep (Table 4).

Table 4. MLA and Total investment in 2012/13

	Beef	Sheep	
MLA	2.9	8.7	Producer levy funding x 2
Others	15.2	10.3	Government less matched dollar
Total	18.1	19.0	Total associated with MLA programs
Raising factor on MLA investment	**6.2**	**2.2**	

These raising factors have then been applied to each year in the time series of MLA programs investment 2001/02 to 2011/12 to obtain a series for total investment.

The approach has its drawbacks but is likely to provide a reasonable estimate of the MLA and co-investor investment in beef and sheep genetics. The assumption is that the raising factor is the same in each year (which is unlikely given the substantial investment in CRCs – which has differed between years). Further, the basis of calculating the raising factors relies on the MLA (RJ Banks) analysis for 2012/13 and this estimate has the producer levy investment of $5.8 M which is more than half of the MLA program estimate of that year ($7.33 M). However, for present purposes (calculating total program area investment) the approach is considered satisfactory.

When the raising factors are applied the total MLA and co-investor investment 2001/02 to 2011/12 is estimated at $323 M (Real, present value).

Part 1.2: Benefits of investment

Background

The focus of the evaluation is with investment in genetics and genomics R&D in the Australian beef and sheep meat sectors between the investment years of 2001/02 and 2011/12 (11 years) However benefits being realized now are the consequence of investment as long as thirty years ago. There are also very significant lags in terms of research being converted into practical technologies and the impact of the uptake of those technologies in terms of realized benefits.

Therefore, while the analysis includes estimates of the benefits from recent research, the Report also looks at the benefits that are expected to be realized in the future as a result of genetic gains which have already been made in the seed-stock sector. Given the above, the focus in this section is on estimating the **economic value of benefits** realized (or expected to be realized – including the impact of adoption) through the sector. In particular, the focus is on benefits to seed-stock producers, and commercial cattle and sheep-meat producers from uptake of the outputs of genetic R&D investment.

Estimating the **economic value of the benefits** from the MLA programs requires valuing the net outcomes which can be attributed to the MLA programs. The broad areas of industry where the benefits are realized are through changes in profitability:

- for levy payers (seed-stock and commercial meat producers) through higher returns and lower costs including avoiding future possible costs (creating future options)[1];
- for other industry interests with investments in the genetics area (donor company investors);
- in other industries directly resulting from the MLA program outputs[2].

The **beneficiaries** of the investment are defined in terms of how the uptake has added value for the Australian red meat industry (specifically groups that have benefited or are likely to benefit) and the wider community where the benefits/value are realized amongst:

- **cattle and sheep producers** who use information provided by seed-stock producers through decision support tools (e.g. BREEDPLAN EBVs) to make more informed purchasing decisions, and the consequential impact of adoption of genetic investment outputs across the sector (note that the **seed-stock producers** who provide data into genetic evaluation systems - BREEDPLAN, LAMBPLAN & MERINOSELECT – may also benefit through improved prices and volumes of sales of breeding sires, elite females, and semen);
- **owners of land** when improvements in profitability become capitalized into land values, whether or not they themselves actually invest in improved genetics;
- **feedlot operators and meat processors** who process greater volumes of higher quality animals in a more timely way;

[1] For example, investment may be considered as creating options (future opportunities per potential solutions to deal with adverse environmental changes such as emission charges or is more robust cattle that are more resistant to diseases that are expected to increase as a result of greater environmental variation). In this respect, the potential for MLA programs, either specifically or more generally, to create future options for the industry to respond more quickly to adverse situations or to capitalise on opportunities is one aspect considered (see Part 4, *The notion of options*).

[2] This does not include benefits arising from the increased activity of the production sector as these are flow-on impacts or multiplier effects; note that outside of the meat industry, valuing the benefits is well-recognised as being difficult (see the Rural RDC Evaluation Guidelines revised version following Goucher and Alston)

- the **community** through mitigation of potentially adverse environmental impacts of animal production; and
- **consumers** though higher quality animal products consumed at same or lower prices.

Approaches and methodology

The impact of genetic improvement cannot be estimated directly in commercial flocks or herds. Here we apply a combination of approaches to estimate outcomes/benefits. These are summarised in Figure 1. The main focus has been on estimating the genetic contribution to the value of improvements in productivity which essentially reduce the costs per unit of meat (carcase) generated at the farm gate. While there are likely to have been benefits from improvement in product quality resulting in demand shifts in both international and export markets, we have focussed on direct benefits from MLA investment through productivity gains which are also expressed in economic terms. While there is evidence of value being realised through improvements in quality (e.g. Griffith & Thompson 2012), it can be argued strongly that the use of average prices for products in the benefit calculations in this report does take account for this change.

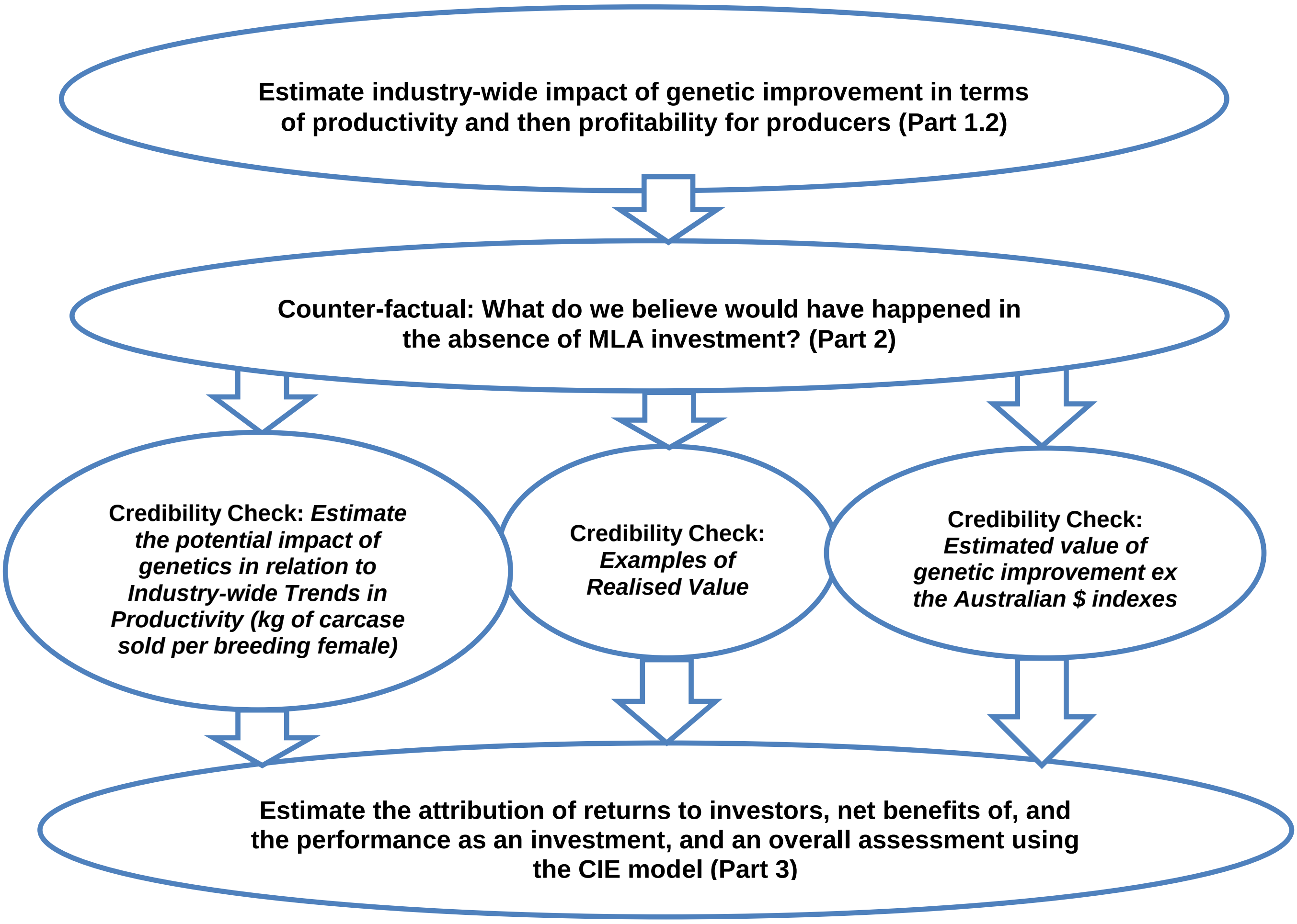


Figure 1. Methodology: estimating the value of the contribution of genetics

The approach taken involved:

1) estimation of **the rate of genetic gain** in the sire-breeding (recorded) sector expressed in terms of changes in the traits that contribute to the output of meat and the estimated costs of that production which were then expressed in terms of the change in profitability (gross margin per kilogram of meat sold) such that the **impact on profitability** to the **sector** could be derived using estimates of adoption (based on the estimated number of males with EBVs that were sold and the effective life of sires in flocks and herds), the realisation of the genetic gain in the commercial sector, and changes in industry structure over time (**base case**);
2) estimation of **a counter-factual** to provide an assessment of the likely position in the absence of investment by MLA (whether direct or via the MLA Donor Company);
3) **credibility checks** in terms of the impact of genetic change **through estimates of:**
    - the industry-wide trend in productivity using industry statistics to derive data for **industry-wide estimates of productivity per breeding female** (this defines the upper bound of the potential influence of genetics, which is in turn is influenced by adoption, industry structure and the relative level of expression of improved genetics in commercial farming situations);
    - the **value realised** through examples of the use of genetically-improved animals in **industry sector sub-groups**;

- the estimated **value derived from the Australian Breeding Indexes** (BREEDPLAN, Sheep Genetics, MERINOSELECT);

4) estimates of the **attribution** of outcomes to specific investment**,** and **the net benefits of investment** and the **performance of the MLA funding as an investment**

The ***base case*** is based on investment from 2001/02 to 2011/12, while the ***counter-factual*** provides an assessment of the impact that might have occurred should MLA have withdrawn investment from the area in 2001.

The **credibility checks** have been applied to help assess whether the scale of the overall estimate is credible in terms of the impact derived using different approaches, and to estimate the likely scale of the contribution of genetics to the change in productivity in terms of carcase sold per breeding female (we recognise that other changes such as pasture renewal, an increased throughput through feedlots, or structural changes such as lower proportion of Merino ewes in the sheep industry will also impact).

Industry-wide estimates of genetic trends in productivity

Estimates of the trend in terms of **the rate of genetic gain** in the recorded sector (herds and flocks who breed sires for sale using annual data from Sheep Genetics and BREEDPLAN) have been derived. The estimates have been integrated to generate estimates of the ***genetic trends in productivity*** for the sheep and beef sectors.

Hence these define the potential **impact of genetic improvement** programs on the rate of genetic change within **the sheep and beef sectors;** that is, they represent the upper bound of gain due to genetics. Although the data have been analysed across various time periods, for the *ex post* analyses, we have used trends for the period from 1997 to 2009 for sheep and 1994 to 2006 for beef.

A number of factors influence the realization of benefits of genetic improvement for the national flock or herd (as distinct from the ram or bull breeding sectors). These are:

1. **rates of genetic gain** (expressed in both trait and productivity terms) in ram- and bull-breeding flocks/herds;
2. the **level of adoption** of genetic improvement, assessed through the use of genetically improved males, in commercial flocks and herds;
3. the scale of the **benefits** of genetic improvement actually **realized in commercial environments** due to differences between the ‘stud’ and commercial environments**;**
4. the impact of **industry structure** on the realization of **genetic gain** within the commercial sheep and beef sectors.

1. Rates of genetic gain in traits and productivity

Sheep – ram breeding sector

The summary of estimates of genetic trends for EBVs of weight traits and numbers of lambs born, all of which contribute to the change in ***productivity*** (***weight of carcase sold per female mated per year***), are presented in two ways as the:

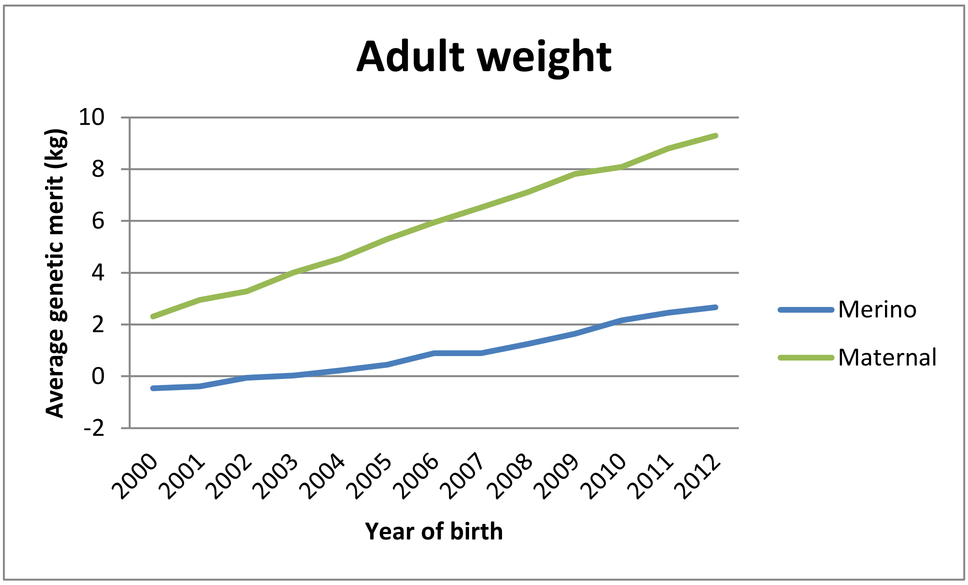
- genetic gain in seed-stock flocks over the period from 1997 to 2009 (Table 5, Figure 2); and
- genetic gain in the future projected from the estimates of genetic trends for the period from 2009 to 2012; this is important as there is good evidence that the rate of genetic improvement has increased markedly starting in about 2009.

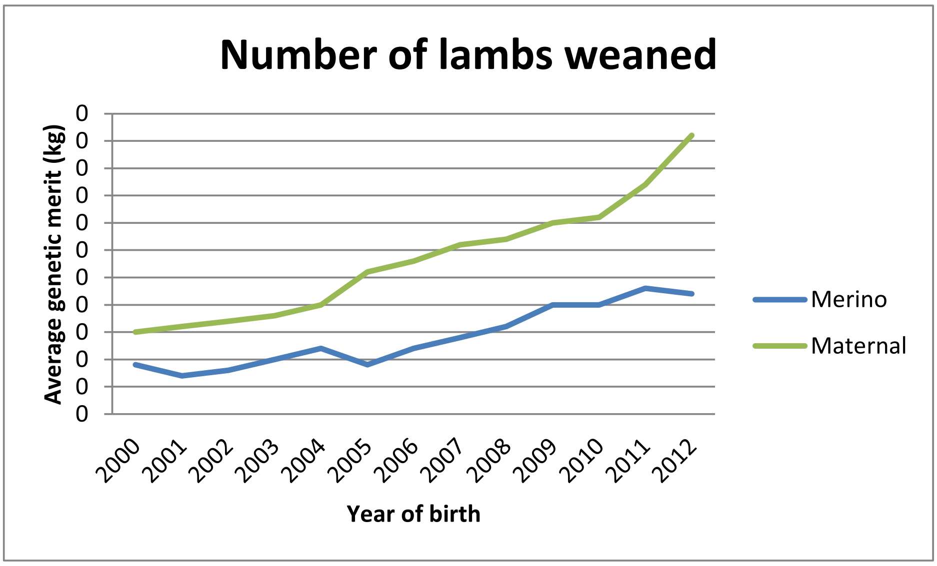
Table 5. Annual trends from 1997 to 2009 and 2009 to 2012 in EBVs for the traits and the derived integrated (composite) upper bound of the genetic trend in ewe productivity

Breed group	Post-weaning weight (PWT eBV (kg))		Adult weight (AWT eBV (kg))[1]		Numbers lambs weaned per 100 ewes mated (NLW eBV)[1]		Genetic trend translated to ewe productivity (kg carcase sold per ewe mated)[1]	
	97-09	**09-12**	**97-09**	**09-12**	**97-09**	**09-12**	**97-09**	**09-12**
Merino	0.113	0.305	0.170	0.334	0.08	0.09	0.052	0.155
Terminal	0.558	0.453	[0.704]	[0.502]	[0.129]	[0.210]	0.155	0.168
Maternal	0.474	0.436	0.631	0.514	0.176	0.540	0.278	0.326

[1] The BVs for Adult weight and NLW are not applied as progeny of terminal sires are not retained for breeding

Source: Appendix Tables 4.1 to 4.4





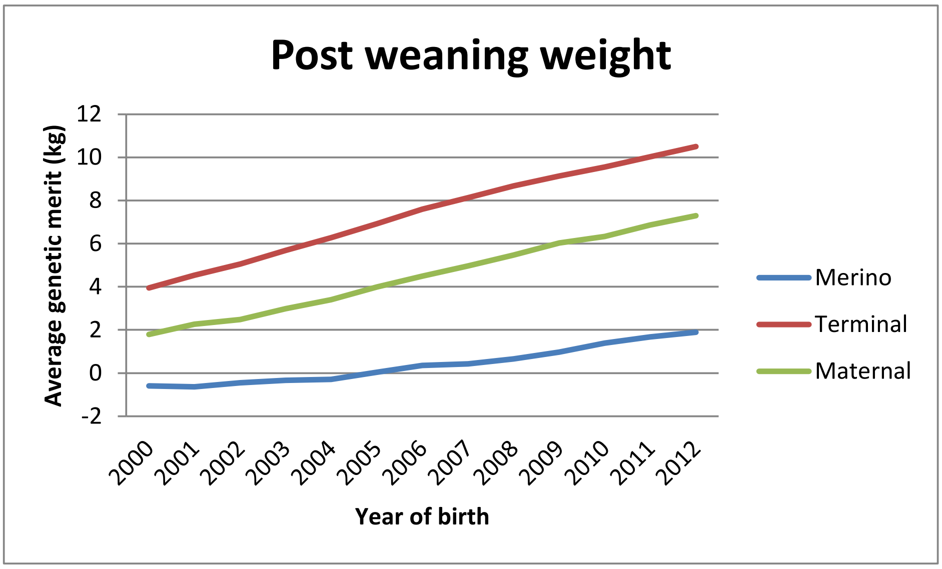


Figure 2. Genetic trends (for PWT, AWT, and NLW) in sheep over the period from 2000 to 2012

Recent (2009 to 2012) increases in genetic performance of the breeding flock are substantial. These gains reflect improvement in ASBV indexes in breeder flocks for the traits. It is important to note that any impact of different environments between seed-stock and commercial farms are not accounted for; also trends do not include adoption by commercial operators so do not reflect the level of genetic change in the commercial sheep-meat sector, as a whole.

Beef – bull breeding sector (Southern and Northern)

The summary of estimates of genetic trends (EBVs) for weight traits and fertility both of which contribute to ***productivity***, are in Table 6 and Figure 3.

Table 6. Annual trends from 1994 to 2006 (A) and 2009 to 2012 (B) in EBVs for traits

Breed group	Weight (600WT eBV)				Cow weight[2] (MWT eBV)	
	Direct		Per fertility[1]			
	A	B	A	B	A	B
Southern maternal (Angus and Hereford)	2.86	2.40	0.23	0.22	2.42	1.86
Terminal (Charolais, Simmental & Limousin)	0.91	1.12	0	0	0	0
Northern (Brahman, Santa Gertrudis & Droughtmaster)	1.00	0.75	0	0	1.23	1.11

[1] The estimated contribution of reduction in days to calving is based on the assumption that one day is equivalent to 1.60 kg in terms of 600 day (live) weight based on 1 day earlier being valued at $2.00 and carcase weight being valued at $2.32 per kg ($1.24 per kg of 600-day weight); there is no genetic trend in the Northern breeds.

[2] 82% of cows are mated to maternal bulls in the south and 83% to *Bos indicus* in the north

Source: Appendix Tables 4.7 to 4.9

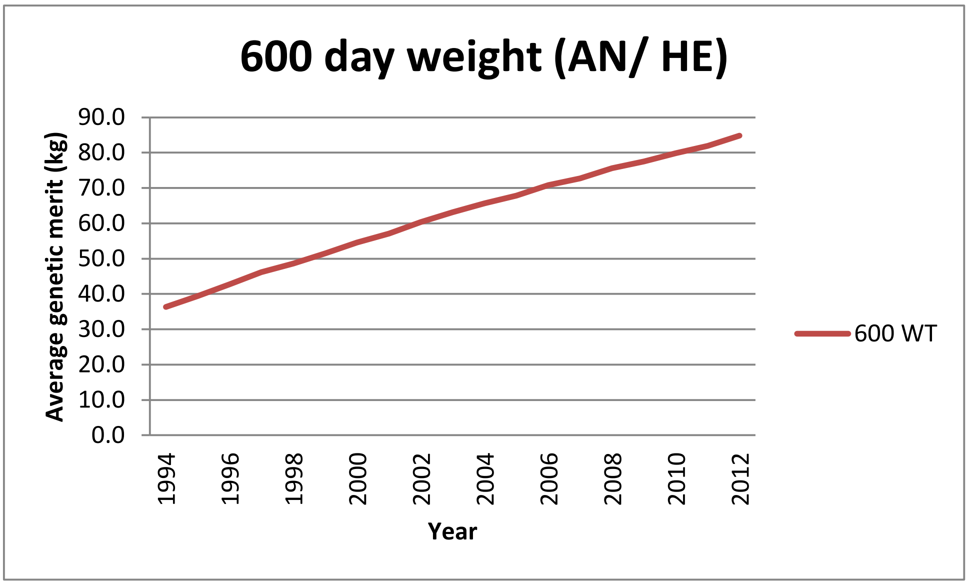


Figure 3a. Genetic trends for Angus and Hereford - 600 day weight

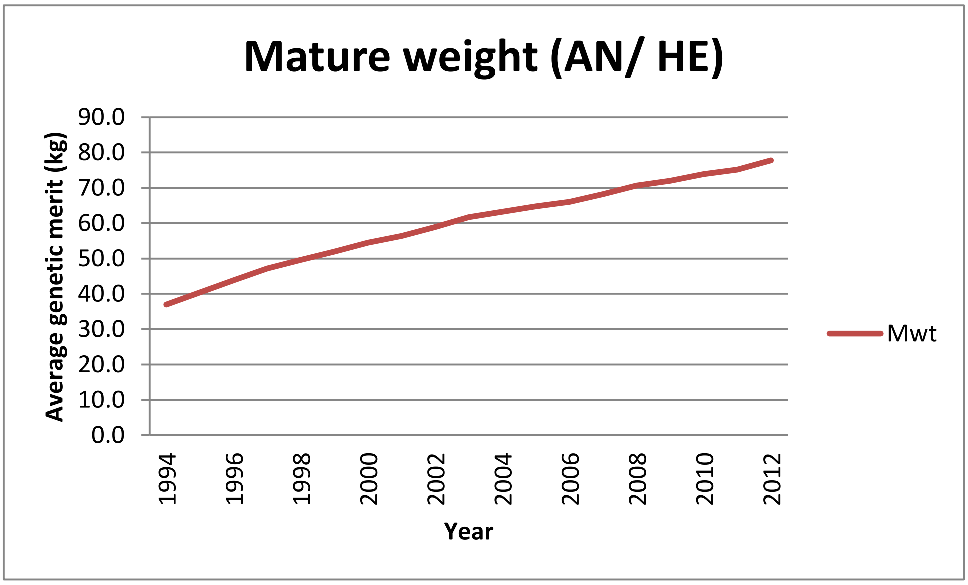


Figure 3b. Genetic trends for Angus and Hereford - Mature weight

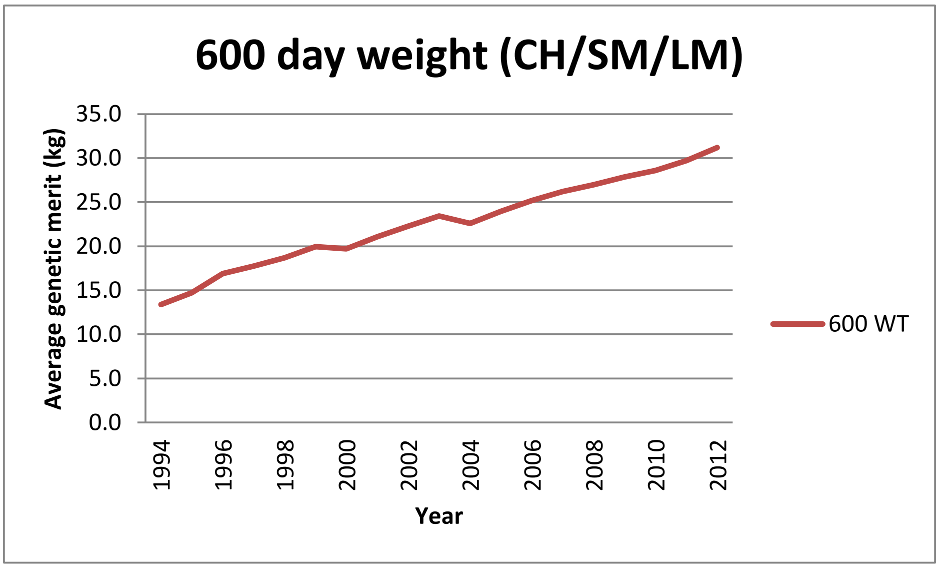


Figure 3c. Genetic trends for terminal sires (Charolais, Simmental, Limousin) - 600 day weight

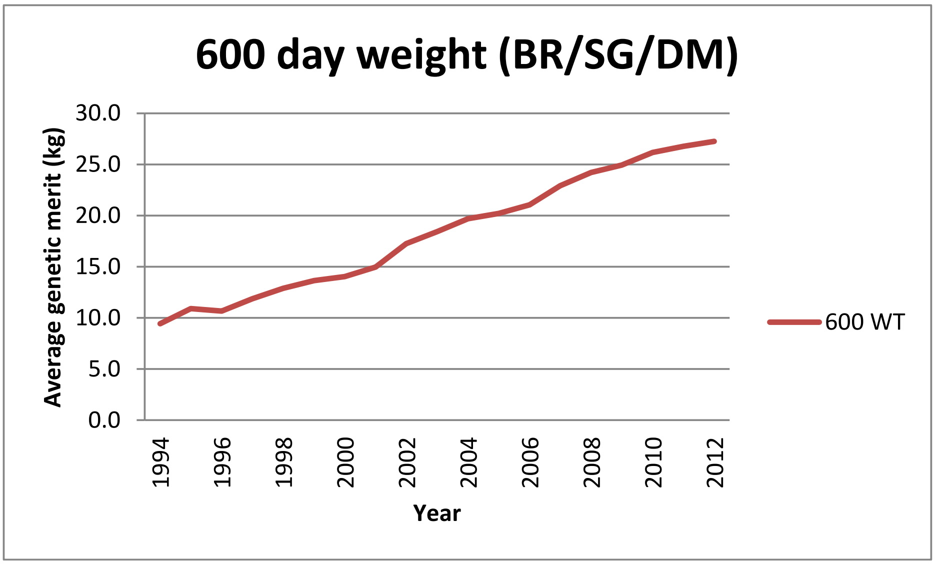


Figure 3d. Genetic trends for tropical breeds 600 day weight

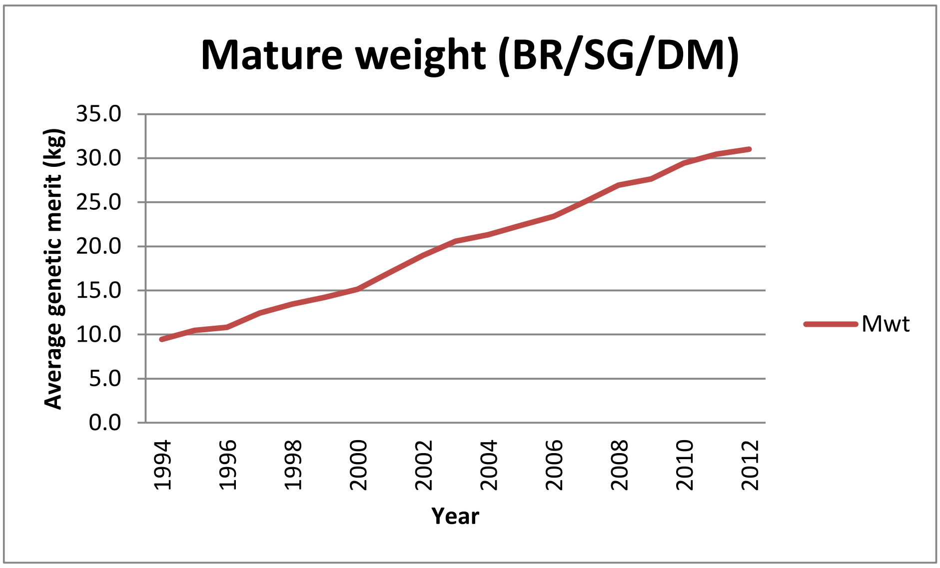


Figure 3e. Genetic trends for tropical breeds - Mature weight

2. Estimating adoption: Sire requirement and production capacity

The assessment of **adoption** is based on the **sire requirement** (which requires an estimate of the effective life of sires in commercial flocks and herds) and an estimate of **production capacity** (and estimated sales of sires) in the recorded sector.

The rate of uptake of improved genetics via sires used in the commercial sector has been estimated based on numbers of sires generated from recorded herds/flocks (proxy for adoption rate) from 2001/02 to 2011/12 together with estimates of lifetime coverage (females per male lifetime) – that is, the capacity of the recorded sector to directly supply the commercial sector needs for breeding sires. Table 7 presents an estimate of the number of sires required to service the various industry sectors in 2012. We ask the question '*how many sires would be required to be purchased each year to mate X million females to a defined sire type given typical joining rates*?'

Table 7. Estimates of sire requirement and the capacity to generate recorded sires in 2012

	Estimated requirement for sires in 2012[3]		Estimated capacity to generate sires		Estimated adoption rate
	Number of females mated	**Total sires required**	**Number of recorded females mated**	**Sire generation capacity**	
Sheep (38 M ewes to be mated, at 150 joinings per ram lifetime)[4]					
Merino rams	20.6 M	**137,500**	*102,000*	24,200	18%
Terminal rams	9.4 M	**63,000**	*131,000*	42,600	68%
Maternal rams	8.0 M	**53,600**	*74,000*	22,200	41%
Southern Beef (3.2 M cows to be mated at 95 joinings per bull lifetime)					
Terminal bulls	0.58 M	**6,100**	*21,000*	25,700 *(plus 3,900 to Northern)*[5]	75%
Maternal bulls	2.65 M	**27,900**	*90,000*		
Northern Beef (6.0 M cows to be mated at 115 joinings per bull lifetime)					
***Bos taurus* bulls**	1.0 M	**8,700**	*21,000*	3,900 ex Southern *(plus 500 local)*	50%
Maternal (*Bos indicus*) bulls	5.0 M	**43,300**	*23,000*	5,300 *(plus 3,300 local)*	20%

These data provide estimates of the impact of the use of genetically-improved sires in the national herd/flock in 2012 where for sheep (at 150 joinings per ram lifetime) 50% of all recorded rams weaned are sold as sires:

- LAMBPLAN flocks are supplying about 68% of terminal sires, and 41% of maternal sires; and
- MERINOSELECT flocks are supplying about 18% of Merino sires in use (including rams that are sold with EBVs and those sold with Rampower estimates);

whereas for cattle (at 95 joinings per bull lifetime for Southern Beef – bulls retained for 3.15 years and used at a rate of 1 per 30 cows, and 115 joinings per bull lifetime for Northern Beef, bulls are retained for 3.85 years and used at a rate of 1 per 30 cows):

- Bulls from BREEDPLAN recorded herds are meeting around 75% of demand for *Bos taurus* bulls (say 25,700 'sold' to meet Southern needs and Northern use of about 3,900[6]), while there is the capacity for BREEDPLAN recorded herd *Bos indicus* bulls to meet about 12% of demand. The northern use of *Bos taurus* bulls is taken as supplying about 50% of the need for bulls for non-*indicus* matings (1 million of a total of 6 million cows mated); in the case of Northern Beef, it is estimated that within-herd breeding (*'local'* in Table 7) provides the remainder of bulls to meet the estimated adoption rates.

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[3] Barnett (2006, SHGEN.114; LAMBPLAN: National system for describing the genetic worth of animals in the Australian sheep meat industry. Review of Adoption by the Australian Meat Sheep Breeding Industry) estimated the annual sale of 70,000 LAMBPLAN rams (terminal & maternal rams) would be responsible for production of around 10 million lambs at 110 joinings per lifetime per ram.

[4] Appendix Table 4.13 provides further details for sheep

[5] These estimates are based on weaning 47,700 *Bos taurus* weaned bull calves from recorded cows, of which 29,600 (62%) are sold for breeding; of these 25,700 are used in the south and 3,900 in the north; the *Bos indicus* estimates are based on 8,500 weaned bull calves, of which 5,300 (62%) are sold for breeding.

[6] Peter Parnell, Terence Farrell, Alex McDonald (pers comm); note that this would be around 4,000 bulls (2,000 Angus, 2,000 Charolais, 200 Limousin bulls); an estimated 5,000 cross-bred bulls are also bred in the north; for example, AACO and Consolidated use half and quarter-bred Charolais x *Bos indicus* bulls.

Figure 4 provides another perspective on adoption in the sheep industry and shows how adoption (based on actual number of commercial ewes mated to improved rams from the ram supply, measured by the number of recorded breeding ewes by breed type, and by the required number for mating as per Table 9) increased over the period from 2000 to 2012.

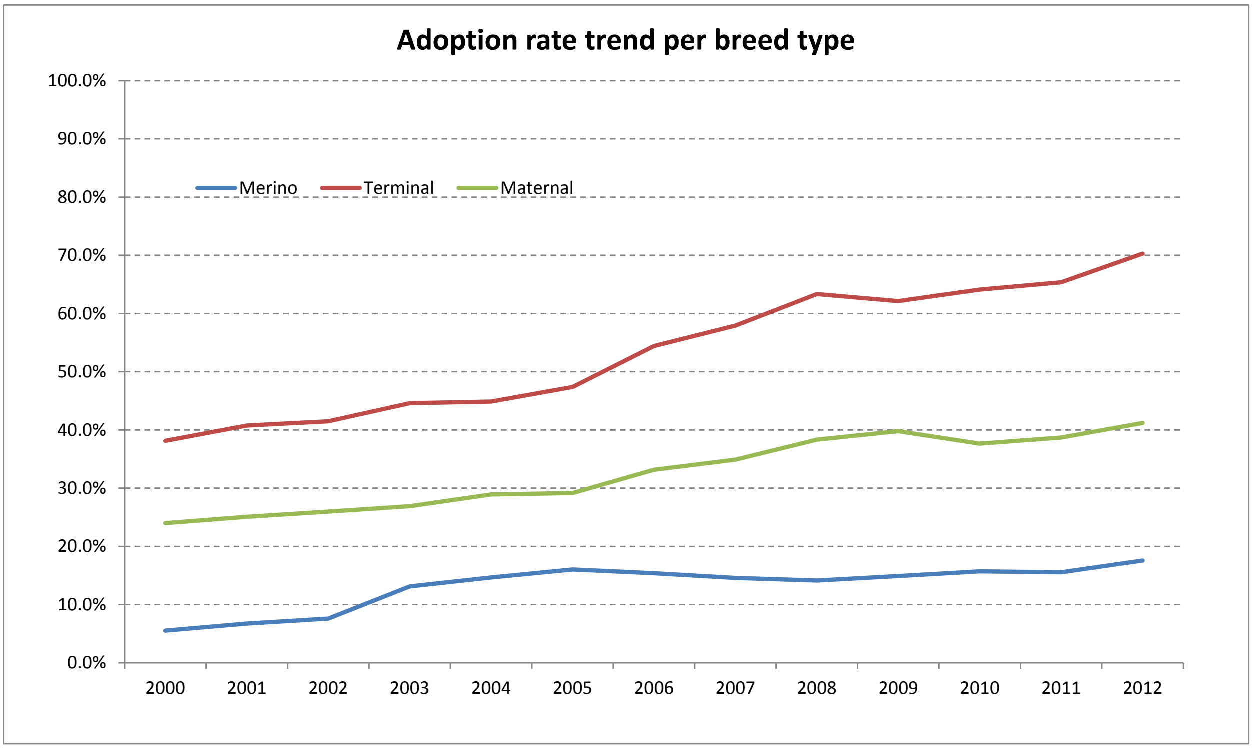

Figure 4. The number of commercial ewes mated to genetically improved rams over the period from 2000 to 2012, as an index of adoption

3. <u>The potential impact of environmental challenges</u>

This aspect is considered in detail under Credibility Check #2.

4. <u>Industry structure</u>

The industry structure has a considerable effect on the contribution of investment in genetic improvement to improvements in productivity. The main factors are the structure of the sire-breeding industry (the impact of major or nucleus studs and their own breeding programs), the adoption rate, and the relative use of terminal sires (especially in the sheep flock). These issues are addressed in Appendix 3.

Part 2: Analysis of the MLA investment

Background

There are four components to this analysis. They are:

1. define the **estimated benefits**
2. consider the impact of the **counter-factual** and the impact of these factors in the estimation of benefits
3. assess the **investment performance**

4. estimate the **attribution of benefits to MLA investment** – that is define the extent to which the MLA investment was responsible for the realized benefits, and identifying the beneficiaries of that investment
5. define the beneficiaries of the investment using GMI modelling (CIE).

Estimated benefits

Factors impacting the economic assessment

The cost of feed

A consequence of selection for early growth to increase weight at slaughter is that the weight of the mature reproducing cow or ewe also increases due to a genetically correlated response. Hence the feed intake of the mature animal also increases. The cost of this increase can be readily estimated. However the real cost of this in a livestock business is actually a function of the nature of the feed supply and the management of that feed supply. If producers reduce stocking rate because animals are larger, then the cost is real. This is likely to be the situation in intensive pasture-based enterprises (e.g. more intensive sheep enterprises and pasture-based dairying in Australia). On the other hand in more extensive operations it may require little or no change or perhaps a more intensive style of management to allocate the feed more efficiently at particular times of the year rather than a reduction in stocking rate. Paradoxically more productive animals may also facilitate better management of pasture.

Sheep

Economic values and economic weights for breeding objective traits are used to value genetic change. The annual rates of genetic gain multiplied by economic weights have been used to create an economic genetic trend to provide an estimate of the upper bound of contribution of genetic improvement via the mating type structure of the national flock. These rates of gain represent the combined trends in both male and females within each of the mating types. The economic impact (cost) of increases in adult size through increased feed costs associated with selection for faster growth in young animals has been explicitly taken into account. These annual trends for recorded sheep flocks have been applied at a sub-sector (breed or breed-type) level. The data used and analysis is presented in Appendix 4C.

Beef

Southern Beef: The economic values and economic weights for breeding objective traits to value genetic change have been estimated using the same methodology as for sheep. The analysis is presented in Appendix 4B.

Northern Beef:. The economic weights were assumed to be 50% of the Southern Beef values. The full analysis is presented in Appendix 4B.

Analysis of benefits: The base case

The estimated benefits of the RD&E investment are summarized in Table 10.

The estimated benefits reflect the following.

- The genetic trend realised from the investment is expected to be generated from about 2008 to 2017 and beyond (see below) and the genetic trends applied to the analysis were:
  - sheep: from 1997 to 2009 for the benefit period 2000 to 2012, and from 2009 to 2012 for the benefit period 2013 to 2040;
  - beef: from 1994 to 2006 for the benefit period 2000 to 2012, and from 2009 to 2012 for the benefit period 2013 to 2040; the economic value of trait changes in Northern Beef

estimated to be half of that of Southern Beef.

- The measured average (linearized) genetic gain in growth and most other trait EBVs in BREEDPLAN, LAMBPLAN and MERINOSELECT:
  - using the average is likely to be conservative since it does not reflect the overall tendency of breeders and producers to source/use sires with better than average EBVs for any given trait, or any tendency to change their sire purchasing preferences towards larger recorded herds and flocks who tend to have higher rates of genetic progress.
- The net derived $ value of these average genetic gains at the commercial level:
  - for example, in the case of growth traits, the savings in feed costs for maintenance brought about by the option to slaughter animals earlier provides producers with options; an option is to use the saved feed to grow these animals to a higher weight or alternatively run additional animals or, depending upon the situation, use the land for other purposes; these $ gains have been estimated - first at the individual trait level and then, as a combined overall level on a per ewe or per cow mated basis;
  - also as the values of changes in all traits have not been measured (e.g. improved meat quality), the benefits are likely underestimated; this is especially the case in beef where there has been a major focus on intramuscular fat in the Australian industry (Barwick *et al* 2009. AAABG 18: 484-487 and Credibility Check #3).
- The cumulative effect of improved genetics or herd/flock performance over time:
  - this is important given that there is significant benefit in retaining replacement breeding females that are progeny from those sires with EBVs.
- Past and current ‘actual’ levels of adoption by commercial producers:
  - adoption is measured, at the industry level, as the proportion of cows/ewes mated to sires with EBVs; however, this is conservative as much of the future genetic benefits are ‘certain’ in the sense that adoption of the improved genetic information has already taken place: it is within the gene pool of those breeders using sires with EBVs; also breeders who do not use bulls with EBVs often buy from breeders who have used such bulls; hence the effect of genetic improvement is lagged in these sub-set of breeders; in the analysis in this report, this aspect is covered through the increasing adoption scenario under the sensitivity analysis (Part 3).
- No change in real prices:
  - future real prices for sheep meat and beef are held at the real price level of the last decade; this may be conservative given projections of world food supply and demand;
  - on the other hand, no account is taken of the potential impacts of increased meat supply on real prices; however this facet is covered under the global model analysis.
- The total MLA and co-investment between 2001/02 and 2011/12 is estimated at $323 million (2014 Real, Present value).
- The lag between when R&D begins and when the genetic gains subsequently begin to be realized by commercial producers:
  - improved genetic information first impacts upon breeders before it is reflected in improved genetics in sires purchased by commercial producers and then in the resulting on farm revenue increases/cost savings;
  - MLA has invested in a range of RD&E: some is short-term which has relatively quick uptake while other research is very long-term (strategic); in the analysis, we have used an average lag of 7 years and 12 years for sheepmeat and beef respectively, between the investment in RD&E and the first impact in commercial flocks and herds.

- The net value of the genetic improvement from the RD&E investment in the period from 2001/02 to 2011/12:
  - the counterfactual recognises that some genetic improvement would continue given the previous investment by MLA and others (particularly in developing BREEDPLAN and LAMBPLAN), from imported genetics (especially beef), and continuing investment by breeders individually and collectively through breed societies;
  - there is no allowance for any further genetic gain from investment beyond ‘two generation intervals’ (7 and 12 years for sheep and cattle, respectively); that is, any genetic gain beyond that time would reflect additional MLA or other investment, but not investment in the 2001/02 to 2011/12 period. Thus there is a levelling out in the measured genetic gain.
- Estimated realization of genetic benefits by commercial producers:
  - commercial producers may not realize the full gains as predicted as producers are operating in a larger scale commercial environment than breeder; the magnitude of this difference is difficult to estimate but a realization factor of 75% has been used in the analysis (i.e. the impact in the commercial environment is taken as 75% of that expected from the EBVs of the sires used);
  - the genetic gains estimated by EBVs take account of environmental effects; however, in situations where the new production environment is quite different to that where progeny have been raised (and recorded), the EBVs could be less indicative of performance.
- The adoption costs for commercial producers:
  - these are minimal as the choice is sires with records (EBVs) or not; there is little or no price premium, and some breeders suggest that there is a discount for sires with EBVs;
  - in some instances, producers breed their own sires from sires with EBVs to further reduce the costs of adopting improved genetics.
- The estimated benefits do not take into account the consequential impacts on prices of the expected increase in aggregate supply of beef and sheep meat:
  - genetic gains will likely lead to additional meat production, through higher carcase weights and overall additional profitability (leading to expanded meat production); in turn, meat prices can be expected to be impacted adversely (these issues are addressed from a whole of market perspective using the CIE Global Meat Industry Model (Part 3)).

Analysis of benefits: The counter-factual to MLA investment

Background

An assessment of the counter-factual to the current MLA investment in animal genetics and genomics is an important component of the overall evaluation. Essentially the counter-factual provides an assessment of the likely position in the absence of investment by MLA (whether direct or via the MLA Donor Company mechanism). The key issue to explore is the role of the MLA programs (the relative importance of the MLA within the programs is addressed below in the context of attribution).

In considering the counter-factual, it is important to recognize that much of the realized progress in terms of genetic merit of animals in the commercial sector is an outcome of investment by MLA prior to 2000. That is the lags between research and adoption via the genetic evaluation schemes and then commercial impact through use of sires are long. However an important feature of the MLA investment in the period under evaluation to

2011/12 has been the investment in the ongoing development of BREEDPLAN, LAMBPLAN and MERINOSELECT and extension to breeders and the wider industry.

Perspectives

Therefore the counter-factual is addressed from three broad perspectives taking into account both historical and future perspectives.

First, what might have happened had MLA not made these investments in genetics since 2001?

Second, what is the opportunity cost then if MLA had not made this investment in genetics?

Third, what do we expect would have been the impact of MLA withdrawing investment ?

1. What might have happened had MLA not invested?

The potential scenarios to consider are different across the three sectors, although there are common factors across each. These are best considered at three levels: *structural or investment level, research contribution level* and *alternative source of genetics level* as below.

Structural or investment level

1. What is the likelihood that other organisations within Australia would have assumed the financial role filled by MLA - would these investments have expanded or taken a different focus in the absence of the MLA programs?

   Governments (federal, state) have been major co-investors within MLA programs (60 to 70%, Table 3). A question is whether government funds would have been so forthcoming had there not been co-investment from industry. The reality is that for many forms of government research investment, industry co-investment is a requirement. The CRCs are a particular example as is investment per the MLA Donor Company, both of which have been very significant contributors to the overall investment. In addition, many State government primary industry departments take industry co-investment (as per MLA) as a way to define priorities for investment. Without industry co-investment, any research that might have been undertaken would probably have been less focused on issues of direct relevance to industry.

   On the contrary, small groups of producers/breeders may have been able to leverage some government funding although experience has shown that this carries very high transaction costs to secure funds. In this respect, breeders make a significant contribution to the total investment within MLA programs. Since most breeder investment relates to their participation in BREEDPLAN and LAMBPLAN (and in the Information Nucleus flocks and herds) it is probable that much of their investment would have continued. However, some reduction in genetic gain would likely have occurred as there would have been fewer new traits, and progress would have been much slower, and thus there would be less incentive to undertake risky research and to undertake the required recording activities on farm.

2. How important is the role of MLA in terms of generating leverage such that others have chosen to invest alongside MLA but would not have invested otherwise?

   The key question is whether other interests would have expanded their role and activities? For example, would small groups of producers/breeders/breed societies have come together to fund the type of work that MLA programs have addressed. While such groups already invest directly (ABRI, Sheep Genetics) to obtain information for their own recorded animals, it is most unlikely that they would make the substantive investment necessary to maintain an R&D effort, especially in longer-term work such as genomics (see proposal for MLA future investment below). Even in a case where small groups may have functioned, the fragmented structure created would likely be inefficient and would be unlikely to generate sustainable genetic improvement.

In the case of sheep there is a question as to whether AWI would have expanded its investment. However this too is considered most unlikely given that it has recently withdrawn investment in genetics research activities such as the Sheep Information Nucleus.

The Sheep Information Nucleus is a direct investment by MLA, whereas the various Beef Information Nucleus herds represent a joint investment by MLA through the donor company alongside the breeders through their breed societies. The nucleus herds and flocks are at the heart of future-proofing the investment in genetics in that these investments represent investments in options. They are particularly important in two respects: first for '*hard-to-measure*' traits, being those traits which are either expensive (net feed intake) or can only be measured post-slaughter (meat quality), and second they enable the application of genomic selection (which provides much-improved knowledge of the genetic relationships between individuals and therefore improves the accuracy of estimates of genetic merit). Hence the MLA investment in this area can be considered in the category of creating options.

Research contribution level

3. What is the impact of spill-ins from the work of others and R&D prior to these MLA programs (MLA work prior to 2000)?

   The reality is that much of the gain during the period from 2000 to 2012 is a consequence of prior investment and the uptake of that work by breeders. It is also important to note that the gains from prior investments in genetics are 'long lived' as genetic gains are both permanent and cumulative so long as the breeding objective does not change markedly. This is important for both the counter-factual (longevity of pre-2000 investment) and post-2000 investment as the benefits of the latter continue well into the future. This is an inevitable consequence of prior investment and purchase of improved sires by commercial producers. In this respect we have modelled the impact of a decline in adoption (Figure 4A2 – sheep, and Figure 4A3 – beef). By the same token however, research undertaken during the 2000 to 2012 period can be expected to have enduring impact in terms of benefits post-2012.

4. What is the relevance of research carried out in other countries to breeding organisations in the absence of MLA-supported research?

   Research in livestock genetics is international and interaction among researchers is critical to progress. Perhaps surprisingly, there is a recognized shortage of practically-focused animal geneticists who can apply design solutions that are amenable to practical application. Thus these researchers are internationally-mobile and the lack of investment in Australia could be expected to result in loss of such individuals to the Australia industry.

Alternative source of genetics level

5. What is the impact of imported genetics?

   The contribution is well-recognised in cattle and a recent analysis[7] showed the contribution of overseas genetics to the Angus, Hereford and Brahman herd is around 74%, 48% and 65% respectively. At the national level, overseas genetics are much less important for sheep, although the recent expansion of meat sheep breeds (e.g. Dorper) is notable as they may have a much greater impact in the future (being less seasonal in terms of reproduction). In the absence of continuing MLA investment, it is probable that the level of imported genetics would have been at least as high if not higher although the

[7] Amer P, B Lindner, J van der Werf & R Woolaston (2011). Strategic questions related to RD&E genetics and genomics investment for the beef industry.

lack of any system to provide robust comparisons of genetic merit would have hindered genetic progress.

6. What would be the likely impact in the absence of on-going MLA investment?

   A significant component of the MLA investment in LAMBPLAN and MERINOSELECT has been support for the operational costs. That said, a significant proportion of the support from MLA has been recouped through charges on breeders. BREEDPLAN itself is fully-funded by breeders, although MLA is a major investor in delivering improvements in all schemes.

   In the absence of MLA financial support, user costs would have risen with the consequence that either costs to breeders would have risen or the programs would have been significantly reduced. It is probable that programs would have continued much as they are with breeders facing higher costs given that the programs offered the most innovative breeders significant economic benefit. Without doubt some breeders would have withdrawn from programs and over time this would have led to structural change within the breeding industries. The likely consequence would have been a greater concentration (fewer more dominant) of breeders.

   In terms of overall impact at the industry level, there are two over-riding aspects to consider: *adoption,* and the *rate of genetic gain.*

   Adoption is reflected in the increase in the total number of recorded ewes (around 5,000 per year since 2001, or about 30% over the period) despite a decline in numbers of commercial ewes mated. This is important given that the number of recorded ewes (as producers of rams for sale) is almost certainly an accurate proxy for the rate of adoption. There is no evidence of any significant change in the estimated annual rate of genetic gain until 2009, where in both the Merino and maternal breeds of sheep, there was acceleration in the gain (see Figure 2). At this point there was a change in the methodology and a consequent greater focus on the NLW (Number of Lambs Weaned) trait and a growing realization within the sheep industry of a strong need to shift from wool production to lamb production. Since this shift in selection emphasis and faster gain was a direct consequence of investment in Sheep Genetics, then it is appropriate to credit the increase to investment by MLA (and their associates especially breeders). On the beef side, there was no evidence of any change in the number of recorded cows over the period.

   Genetic gain is considered in the context of asking the question: *what would have occurred in the absence of a formal across-flock or across-herd evaluation system?* In the absence of BREEDPLAN, LAMBPLAN and MERINOSELECT there would have been some genetic gain. An alternative to genetic gain outside of these programs would have been a continuation of more traditional approaches with simple recording but lacking the adjustments for fixed effects (contemporary group, age, etc) and the across herd/flock BLUP comparative data.

   For some traits, there is evidence that breeders make genetic progress through selection within flocks/herds using phenotypes and simple records. For example selection for growth rate (a highly-heritable trait) based on records can lead to genetic progress; selection against structural defects with culling based on visual observation can be very effective although the recessive nature of some such defects can compromise progress. Similarly selection for stature and body shape, both of which may be associated with genetically-desirable traits (stature - height and leanness, compact body shape - muscling via myostatin mutations), can be quite effective. However, stature and compactness are highly antagonistic, so these gains are likely to be less than those realized through use of objective criteria of selection.

   It is difficult to measure what the level of genetic gain would have been from relying only on more traditional approaches to breeding. However, as noted above, traditional breeding would have continued to deliver some gains. In the merino industry for example, carcass weight gains have been achieved by traditional breeders (and subsequently commercial producers) in response to the changing relative prices of meat compared to wool and changes in the relative price of broader wools compared to fine wool. Anecdotally some traditional prime lamb breeders report that they have been able to respond to changing processor requirements and production challenges without using LAMBPLAN.[8]

Other aspects

The realization of the benefit of genetics RD&E depends in part on complementary development in other areas of technology. For example, realization of benefits of genetic improvement in growth potential may depend on improvements in feed supply and management of the health of animals. The non-genetics R&D investment is taken to be unchanged in the counter-factual.

2. What is the opportunity cost had MLA not invested?

Traditionally MLA evaluations have used the approach of using the discount rate (set at 7%, real) to reflect opportunity cost of both its investment and that of others (i.e. the total RD&E investment). An alternative credible approach is to ask what MLA might have otherwise done in the way of investment such as in pastures, or market development and so on.

The analysis above (*what might have happened had MLA not made these investments in genetics since 2001/02?*) considers a range of scenarios, but quantifying the impact is difficult. We have taken four approaches: a *consideration from the breeder investment perspective* (costs of adoption to breeder/benefits to industry), *the potential consequences in terms of technology development,* the *potential benefits of alternative investments,* and *previous studies*.

Breeder investment: Costs of adoption to the breeder and benefits to the industry

One way to ascertain the likelihood of breeders making the decision to continue to invest in R&D in genetic improvement is to define the value proposition to the breeder as an investor. Our perspective is that commercial producers will continue to purchase bulls and rams from specialist breeders although with increased corporate involvement in livestock farming, there is a strong case for individual corporates to breed their own bulls or rams (albeit often purchasing sires and/or semen from major breeding operations as their core source of genetics)[9].

The situations are quite different in cattle and sheep. Imported genetics play a major role in genetic improvement in the beef industry as noted previously. However BREEDPLAN through ABRI provides critical information on the performance of imported genetics in Australia and this improves the accuracy of the assessments of genetic merit.

In considering this opportunity in sheep, there is a need to recognize that on a global scale sheep genetics investment is largely focused in only three countries (Australia, New Zealand and the the United Kingdom) with a lesser investment in Ireland, USA, France and South Africa. In this respect, across-flock evaluation is regarded as integral to the value proposition for a genetic improvement system. Importantly Sheep Genetics provides the means to ensure that this system operates well in Australia by ensuring flock connectedness through young sire teams and the Sheep Information Nucleus. Hence for sheep, the perspective is that in the absence of MLA investment, there would be three options:

- breeders take over Sheep Genetics with a focus on maintaining the database but without

[8] See for example, “Sheep genetics headed in the wrong direction”, Cowra Guardian Aug. 30, 2013

[9] For example in Australia, AACO and NAPCO operate their own breeding programs

investment in new technology - although the across-flock component could be maintained, the rate of genetic progress in Australian sheep would fall behind competitors both in sheep and in other sources of animal protein; also costs to breeders would be expected to increase;

- breeders establish a local entity and transition genetic evaluation to an alternative system – the most appropriate would be the New Zealand genetic evaluation scheme (Sheep Improvement Limited, SIL) which is now operated by Beef & Lamb New Zealand Genetics (BLG); although the across-flock component could be maintained, the NZ approach is different and the direct relevance to the Australian industry would be compromised; it is arguable as to whether Australian breeders could have a significant influence on the direction of the BLG scheme unless they became a major commercial force;
- breeders revert to within-flock selection – this would mean that breeders would be essentially operating their own schemes, perhaps using a commercial software product to analyse their data or an outside provider who would likely offer such a simple service.

Therefore to assess the immediate value proposition for breeders to continue to invest, we have defined the overall costs to the breeders and benefits to the commercial user of these improved genetics at a single point in time (year). This gives an indication of the scope for commercial buyers to assess the value proposition to continue to invest in superior genetics in the absence of MLA investment in R&D. Table 8 shows this analysis for a single cohort of sires. Estimates of the rate of gain (2009 to 2012) have been applied and discounted gene expressions used to derive the forward benefit from rams or bulls purchased.

Table 8. Estimate of the costs to breeders for 2012-born males and the value realized from the use of these sires (compared with 2000-born males) within the national flock/herd as a result of the breeders' investment in genetic improvement

Ram or bull type		**Females to breed sires for sale**	**Breeders costs[1]**	**Estimate of the number of sires sold**	**Future value of sires ($M)**	
					Discounted Value	**Further Discounted[2]**
Sheep	Merino	102,000	$2.81 M	24,200	$43.0	$38.8
	Terminal	131,000	$3.60 M	42,600		
	Maternal	74,000	$2.03 M	22,200		
Total Sheep		**337,000**	**$8.44 M**	**89,000**		
Southern Beef[3]	*Bos taurus* Maternal	90,000	$5.40 M	25,700 (S) + 3,900 (N)	$48.9	$41.9
	Terminal	21,000	$1.26 M			
Northern beef	*Bos taurus*	Included above		3,900 ex S + 500 local		
	Bos indicus Maternal	23,000	$1.38 M	5,300 + 3,300 local	$4.5	$3.9
Total Beef		**134,000**	**$8.04 M**	**34,900 + local**	$53.4	$45.8
Total Breeder Costs (expected to be realized by breeders as a return on investment through sales of sires)					**$16.5 M**	
Total industry benefits					**$96 M**	**$85 M**

[1] These are based on a marginal cost of a recorded ewe of $27.50, and of a recorded cow of $60, and includes direct costs, recording costs and investment in R&D including breeder's share of BIN costs by way of example, but breeders' costs for generating local production bulls are not included. Note that the R&D costs in the same year amount to $37.1 M ($18.9 M for sheep and $18.2 M for beef).

[2] Discounted at 7% and further discounted in commercial flocks and herds by 1.5 years for rams and 2.3 years for bulls to allow for the lag from birth in the recorded flock to mating in the commercial flock or herd.

[3] The differences from previous numbers are due to estimates of the numbers of BREEDPLAN cows that are NZ-

based (approximately 25,000 of the total 115,000).

The fundamental issue is that the value proposition for genetic improvement is not self-evident to individuals or groups of commercial producers as the impact of genetic progress is lost in the noise of year-to-year environmental or seasonal variation. The value of BREEDPLAN, LAMBPLAN and MERINOSELECT lies in the fact that they enable breeders and commercial producers to define the underlying genetic trends. Further, breeders using the advanced genetic evaluation systems incur higher costs than breeders who do not use this more expensive approach of intensive recording and formal genetic evaluation and thus the former may be less competitive.

Taken together, these two aspects mean that in the absence of MLA investment, by far the most likely consequence is that there would have been a reduction in the rate of genetic gain at the national level and, a reduction in adoption/uptake by commercial producers.

The potential consequences in terms of technology development

In the absence of MLA investment it is reasonable to conclude that some genetic R&D would have continued, but it would have been limited. Potential external investors would have included Zoetis (previously Pfizer Animal Genetics). The extent of investment by Zoetis may have been very limited and there would have been difficulty obtaining independent assessment of the efficacy of their genetic improvement products. Their investment in sheep is secondary to their investment in cattle. Therefore it is very unlikely that Zoetis would have invested significantly in sheep for the Australian sector as the knowledge generated is not transferrable internationally, and it is reasonable to conclude that the majority, if not all, of any sheep products would have been derived from New Zealand research (carried out in association with Ovita Limited). In the case of cattle, it is most likely that Zoetis would have sought to rely on North American data, especially given the contribution of North American genetics to the most important cattle gene pool in Australia (Angus). While they would have invested in translational R&D to ensure commercial relevance to Australia, this would have been small and very focused.

In conclusion, the most important impacts of a reduction in MLA investment would likely be:

- reduction in co-investment by other parties, *and*
- consequent reduction in the development of new technology (*hard-to-measure* traits, genomics, Sheep Genetics development of LAMBPLAN and MERINOSELECT).

The outcome could be expected to be a decline in uptake of genetics by sire breeders (and the consequent downstream effects) and a reversion to the pre-2000 model of genetic improvement (within-flock or within-herd selection). The latter is particularly important as in contrast, the current model exploits the power of population genetics through genetic connectedness of stud flocks and herds to one another through the use of related sires. This greatly increases the rate of gain. A conservative estimate is that the use of BLUP (involving the use of flock genetic connectedness) has doubled the rate of genetic gain in the New Zealand sheep industry (Sise *et al* 2012[10]) and there is no reason to doubt that the same applies in Australia.

Potential benefits of alternative investments

An alternative credible approach is to ask what MLA might have otherwise done in the way of investment. Alternative R&D investments might have included expanded or new programs such as the development and application of improved on-farm practices (e.g. EverGraze),

[10] Sise JA, TJ Byrne, NB Jopson, MJ Young & PR Amer 2012. Comparative analysis of genetic trends within the New Zealand sheep industry. *Proc NZ Society of Animal Production 72*: 159-182; Amer P, T Byrne & J Sise 2012. Achieving Genetic Change: *A report prepared by AbacusBio in support of the Ovita Business Development Plan*

non-genetic investments in the Beef & Sheep CRCs, pasture agronomy, soil and environmentally-focused R&D and animal health R&D and/or market development research. However, this approach requires a good deal of information about the returns from additional R&D in these areas - a much more challenging task and beyond the scope of this evaluation.

The default position is to use the traditional MLA discount rate (set at 7%, real) to reflect the opportunity cost of both the MLA investment and that of others (i.e. the total RDE investment). That is, it is the return that producers (as levy payers) or governments might expect from an investment in any form of R&D.

In this analysis the counter-factual has focused on the contribution that ‘genetics’ would have made to productivity and other measures of performance in the absence of the MLA investment in genetics RD&E. Therefore it is reasonable to conclude the following:

- sourcing genetics from overseas would have continued and may have increased; this is important for beef but not for sheep; and
- adoption rates of BREEDPLAN, LAMBPLAN and MERINOSELECT would have been very likely to decline with the lack of active promotion and further development; in this respect, there is evidence that the adoption rates actually increased over the last decade and hence it is reasonable to conclude that this increase reflects the underlying profit gains from adoption, new traits, greater accuracy of estimated breeding values and investment in extension to encourage adoption.

As far as the future is concerned, the absence of the MLA investment would have seen fewer new traits and little investment in genomics. It is most unlikely that the Sheep Information Nucleus and the Beef Information Nucleus herds would have been established, thus reducing the potential gains in the future and inhibiting or compromising the development of options for the future (feed efficiency, methane production, etc). Further, there would be less capacity to adapt to future market, environmental or on-farm technological challenges through genetic improvement, thus slowing future productivity growth. Hence it can be expected that the gap in productivity growth between *the with MLA investment* and the *without MLA investment* would have widened over time.

Previous studies in beef and sheep

Griffith *et al* (2004) drew on a number of past studies of productivity growth in the Australian beef industry and estimates of adoption levels to determine that the underlying potential rate of productivity growth available was about 5% per annum; they estimated a similar rate in sheep.

ABARES[11] estimated TFP growth for the beef sector over the years 1977/78 to 2007/08 at 1.5% per annum, and for sheep at 0.3% per annum (ABARES 2010). The potential CRC contributions were estimated at 4% and 2.5% respectively. In another analysis, Banks (2012) estimated the impact of CRC investment on the rate of genetic gain in BREEDPLAN as $0.61 per cow per year in 1988 to 2003, $0.75 from 1993 to 1998, $1.03 from 2003 to 2008 and $1.65 from 2003 to 2009.

The counter-factual: estimating the impact of MLA investment

The counter-factual in terms of the estimated impact assuming MLA had withdrawn investment in the area in 2001 is presented in Tables 9 and 10. These estimates (Table 9) provide for a range of impacts that then are used to estimate the potential economic impact (Table 10).

[11] ABARES. (2010). Australian Commodities, Vol 17 No. 1. ABARES

Table 9. Rationale underlying the counter-factual in terms of the impact of MLA withdrawing investment in RD&E in beef and sheep genetics and genomics in the period from 2000 and the impact through to 2040 (2014 real Present values, $M)

<table>
<tr><td colspan="5">Estimated percentage of current genetic gain realized in a post-MLA investment world (assumes that the selection component, the evaluation component and the adoption component are equal contributors to overall progress in terms of genetic improvement at the commercial level)</td></tr>
<tr><td colspan="2"></td><td>Sheep-meat[1]</td><td>Southern Beef[1 & 2]</td><td>Northern Beef[3]</td></tr>
<tr><td><u>Selection component:</u> Traditional breeding & imported genetics will continue</td><td>What a continuation of the genetic trend, and traditional breeding in Australia would have been expected to deliver along with greater reliance on imported genetics in beef</td><td rowspan="2">Genetic trend 1993 to 1997 for period 2000 to 2040</td><td colspan="2" rowspan="2">Genetic trend for the period from 1994 to 2006 but with reduced accuracy</td></tr>
<tr><td><u>Evaluation component:</u> Alternative providers of genetic evaluation services will take-over services over time</td><td>Requires that breeders continue to purchase genetic evaluation services probably from off-shore providers</td></tr>
<tr><td><u>Adoption component:</u> Decline in promotion of the value of genetic improvement will reduce adoption or uptake of improved genetics</td><td>Currently extension services for cattle are provided by TBTS & STBS with funds from breeders & from the MLA Donor Company (it is assumed that the MLA component would reduce to zero); Sheep Genetics provides services to the sheep sector and it is assumed that breeder groups would partly fill the role</td><td>Adoption as at present[4]</td><td>75% as at present</td><td>Adoption stable at 10% for Bos indicus and 25% for Bos taurus</td></tr>
</table>

[1] Sheep: this compares with the standard case which had genetic trends from 1997 to 2009 for the benefit period 2000 to 2012, and trends from 2009 to 2012 for the benefit period 2013 to 2040; beef: this compares with the standard case which had genetic trends from 1994 to 2006 for the benefit period 2000 to 2012, and from 2009 to 2012 for the benefit period 2013 to 2040.

[2] This is based on 61% of the trend being from imported genetics (at their rate) and 39% from Australian genetics; the counter-factual has the benefits realized in the absence of any RD&E investment with an allowance for a reduced accuracy of prediction of merit of imported US beef genetics in Australia (the accuracy is reduced to 70%)

[3] This is based on 65% imported genetics (at their rate) and 35% from Australian genetics at the observed genetic trend from 1994 to 2006 to estimate benefits between 2000 and 2040 with the appropriate lags

[4] Adoption is at 2000 level (5.5% Merino, 38% Terminal, 24% Maternal)

Table 10. Counter-factual: Summary of the estimated benefits from MLA and co-investor investment in RD&E in sheepmeat and beef genetics: estimated benefits and costs with stable adoption (2014 real present values, $M)

	Sheepmeat	Southern Beef	Northern Beef	Total
Estimation of gross benefits assuming that MLA investment was maintained from 2001/02 to 2011/12				
Benefits	$1,051	$1,023	$79	**$2,153**
Estimation of gross benefits in the absence of RD&E investment from 2001/02 to 2011/12				
Benefits	$284	$394	$30	**$708**
Difference represents the estimated net benefit realized due to RD&E investment				
	Sheepmeat	**Southern Beef**	**Northern Beef**	**Total**
Costs	$132	$143	$48	**$323**
Benefits due to MLA	$767	$629	$49	**$1,445**
Benefit to Cost ratio	5.8	4.4	1.0	**4.5**
Internal Rate of Return	27%	29%	8%	26%

The conclusion is that MLA investment will add net benefits of $767 M for sheepmeat and $678M for beef to the gross margins of producers over the period from 2000 to 2040.

Investment performance

The benefits to commercial sheepmeat and beef producers (2000 to 2040) from the MLA and co-investor investment in genetics (2001/02 to 2011/12) are estimated to total around $2,153 M (2014 real Present Value) without any change in adoption from 2000 levels. Given the counter-factual as being the relevant basis on which to estimate the return from the MLA investment, the benefits are estimated at $1,445 M. The net return allowing for RD&E costs is estimated at $1,122 M. Thus the overall investment:

- has returned $4.5 dollars for each $1 invested,
- with an estimated internal rate of return of 26%.

The major contribution comes from the investment in sheepmeat genetics (B/C of 5.8). The sheepmeat return is around 70% higher than that for beef genetics (B/C of 3.5).

The underlying drivers in sheepmeat are faster genetic gain especially due to the impact of genetic improvement on fertility and fecundity reflected in the number of lambs weaned, whereas this focus is not possible in cattle. In cattle, the higher return in Southern Beef due to a high rate of adoption is offset by the situation of low gain and low adoption in the Northern Beef sector. Consequently the sheepmeat investment offers a higher benefit to cost return and a higher internal rate of return.

As noted earlier, the returns from the beef investment are driven by Southern Beef. Although there has been significant genetic gain for growth rate (an important trait of economic importance) in Northern Beef, the fact that there has been no progress in fertility coupled with the low rate of adoption in the *Bos indicus* sub-sector (estimated at 20%), together with the significant benefits under the counterfactual scenario mean that the Northern beef investment has not delivered any return although this ignores longer-term benefits from strategic research.

Attribution

Attribution of benefits from investment by MLA (levy money plus the government matching contribution) is an important component of the analysis.

MLA direct investment represents some 28% of the total investment. However, the leverage of co-investor funds and overall strategic effect from MLA is likely equivalent to about double the cost-based attribution.

On the basis of a cost share attribution only for the respective industry level investments, the net return attributable to the MLA investment is around $ 458 M. The greater dollar contribution and higher returns from the sheep investment are also reflected in the overall higher return attributable to the MLA.

Table 11. Attribution of the benefits to investment by MLA

	Investment		Benefits (CF)	Benefit to Cost ratio for MLA investment	IRR on MLA investment
	$ M	**MLA share of Total**	**MLA share of Total**		
Sheep	$60	46% (of $132M)	46% ($350 of $767 M)	5.8	27%
Southern Beef	$23	16% (of $143M)	16% ($101M of $629M)	4.4	29%
Northern Beef	$8	16% (of $48M)	16% ($8M of $49M)	1.0	8%
Total Beef	$31	16% (of $191 M)	16% ($108 of $678 M)	3.5	24%
Total	**$91**	**28% (of $323 M)**	**32% ($458 of $1,445)**	**5.1**	**26%**

Part 3. Credibility checks

Credibility check 1: Industry-wide estimates of trends in productivity

Rate of change

The rate of change in productivity reflects the upper bound of any change due to genetics. Therefore estimates of the rate of change in productivity over time using industry productivity data have been derived. ***Productivity*** is expressed as the ***weight of carcase sold per female mated per year*** (trends from 1991 to 2012 are in Figure 5).

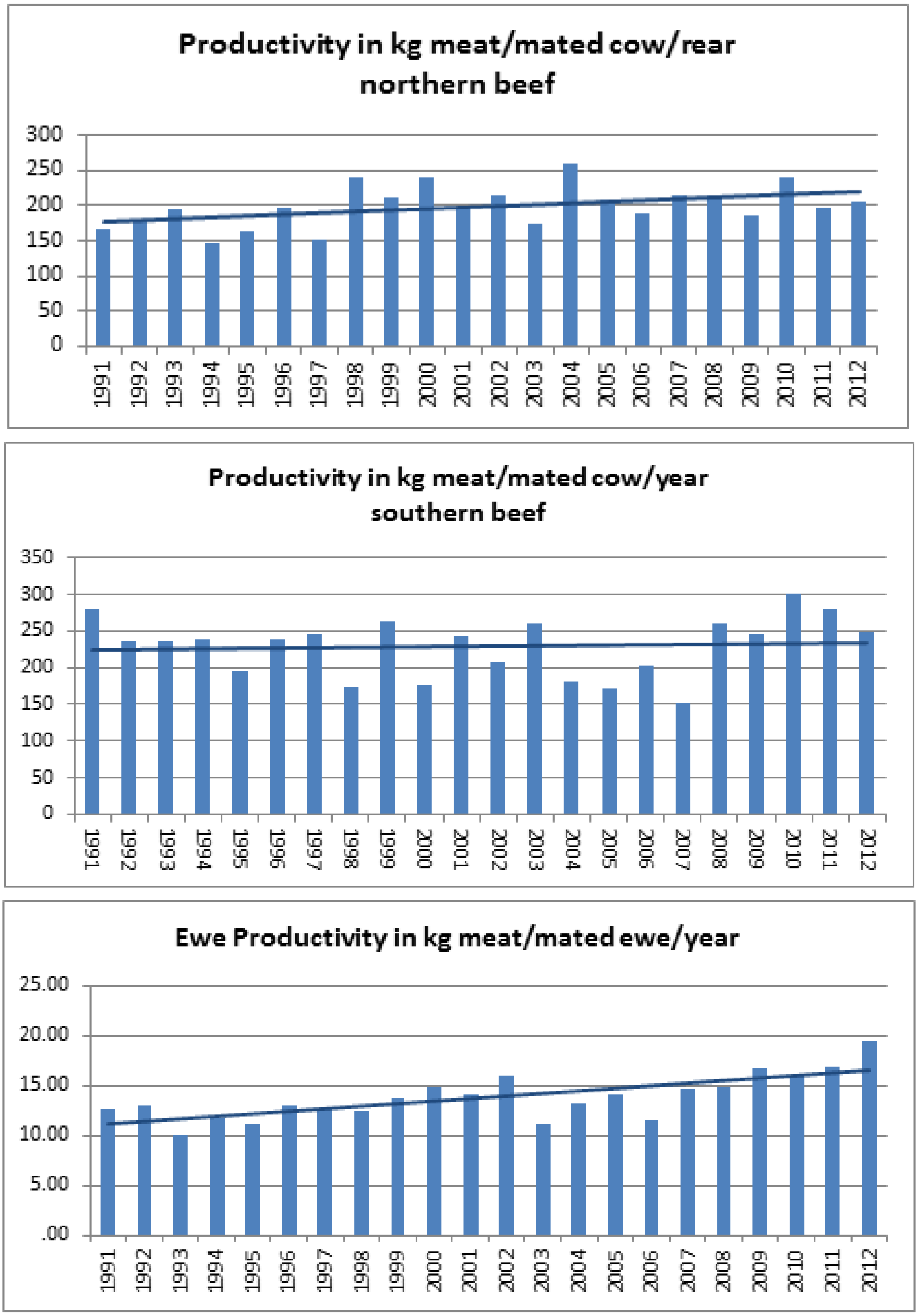

Figure 5. Industry-wide trends in productivity (kg of carcase sold per female mated) for Northern Beef, Southern Beef and Sheep-meat from 1991 to 2012.
Source: Appendix 2.

Observations on productivity

Productivity can be measured in a variety of ways depending upon the purpose. Irrespective of how it is measured, an understanding of the underlying drivers in trends and differences between producers is important. Recent analysis funded by MLA, focussing on economic performance, has identified the key performance drivers in the respective red meat industry sectors.

Specifically, that in the better farming operations, profitability was a function of higher animal productivity (performance) and lower costs per head, and possibly higher product price. While genetics is likely to be a contributor to some of these factors, overall managerial ability, differences in farming systems, and differences in enterprise scale are also likely to be significant contributors.

Trends in productivity

Table 12 presents the summary across sheep and beef.

Table 12. Estimate of trends in industry-wide productivity expressed as the weight of carcase sold per female mated per year for defined periods.

	Rate of gain (kg per mated female per year)		Estimated Upper bound Productivity (kg per year)	Compound Annual Growth Rate (% per year)
	1991 to 2012	Other estimates		
Sheep meat	0.254	0.343 (2000-12)	0.284[1] (0.340)	1.9% (2.5%)
Northern Beef	2.032		2.0 kg per year[4]	1.0%
Southern Beef	0.394	1.75[2] 1.58[3]	1.6 kg per year[5]	0.7%

[1] It is necessary to correct the sheep productivity estimates for a change in the structure of the industry from 2000 to 2012 in that the proportion of Merinos in the mated ewe flock declined from 82% (44.5 of 54.2 M) to 69% (26.4 of 38.0 M). This resulted in a reduction from 0.340 to 0.284 kg carcase sold per ewe mated per year – Appendix 6. The estimates for beef are from 1991 to 2012, as the stability of the trends over the shorter periods is affected by drought.

[2] Drought years (2004 to 2007 inclusive) excluded

[3] Drought and wet years (2004 to 2007 inclusive plus 2010 & 2011) excluded

[4] Estimate used in further analysis, based on regression analysis

[5] Estimate used in further analysis, based on regression analysis, with drought and wet years excluded

Source: Appendix Table 2.9

Given the analyses summarised above, the upper bounds for trends in terms of the annual gain in productivity that have been applied within this report are

- 0.284 kg per year for Sheepmeat,
- 1.6 kg per year for Southern Beef, and
- 2.0 kg per year for Northern Beef.

Contribution of genetic gains to the increase in productivity

The linearized genetic trends from 2000 to 2012 have been compared with the trends in ***productivity*** as these are the basis of the derivation of the upper bound for the impact of genetics (this allows for some part of the lag between the gain in the ram breeding flocks/bull breeding herds that are realized in the commercial flocks/herds that purchase sires).

1. Sheep

Table 13 presents estimates of the upper bound of the contribution that genetics could make to the observed change in productivity. The estimated upper bound due to the contribution of genetics over the period from 2002 to 2012 for sheep is 0.145 kg per carcase per ewe per year (based on the genetic trend from 1997 to 2009). The analysis indicates that about 50% of the increase could be explained by genetics.

Table 13. Estimate of upper bound of the contribution of genetics from 2002 to 2012 for sheep.

Gain in productivity (kg meat sold per breeding female per year) and the estimated contribution of specific components to the overall gain in productivity[1]		**Upper bound of contribution to Productivity (kg meat sold per breeding female per year) from genetic improvement after accounting for adoption over the 11-year period**			
		Components of genetic gain			**Estimated genetic gain in productivity**
		Direct effect of genetics of rams & ewes used	**Effect of future genetic expression**	**Indirect genetic effect of LW on NLW[2]**	
Lamb CW	0.122	0.034	0.005	0	0.039
Ewe CW	0.036	0.010	0.007	0	0.017
NLW	0.126	0.011	0.014	0.066	0.090
Productivity trend adjusted for change in breed structure[3]	**0.284**	**0.055**	**0.025**	**0.066**	**0.145**
Percentage of productivity trend accounted for by the upper bound of the estimated genetic change					
Contribution to cumulative change		19%	28%	51%	51%

[1] Gains presented at the component (lamb and ewe carcase weight, and NLW) level to enable an estimate of indirect genetic effect of LW on NLW

[2] Estimated that 43% of the observed change in ewe LW is genetic with an consequential impact of 1.8% increase in NLW per kg LW

[3] See Appendix 3 for explanation of industry structure changes between 2000 and 2012; the estimates for adoption applied were 14%, 55% and 33% respectively, whereas the values for 2010-born rams were 18%, 68% and 41% for Merinos, Terminals and Maternals as per Figure 4; if the estimates for rams bred in 2010 are used, the rate of genetic gain increases by 13% to 0.165 kg per ewe mated per year.

Source: Appendix Table 2.9

The estimate (51%) may represent either an over- or under-estimate of the true contribution. For example, there is no allowance for any dampening effect of a poorer environment on commercial farms compared with those of seedstock producers; also a proportion of breeders who do not use LAMBPLAN or MERINOSELECT buy rams from breeders who do use these systems. Such breeders are effectively multipliers of the gain achieved by recording breeders, albeit with a lag equal to two generation intervals. Also genetic improvements have produced a larger, more productive animal that is likely to better utilise feed in times of surplus (e.g. spring).

2. Beef

The estimates for beef are presented in Table 14. The estimated upper bound of change due to the contribution of genetics over the period from 2001/02 to 2011/12 for Southern Beef is about 1.0 kg carcase per cow per year (adoption rate of 75%), while that for Northern Beef is 0.12 kg (adoption rate of 20% for matings of *Bos indicus* bulls and 50% for terminal sire matings). These are based on the genetic trends from 1994 to 2006.

Table 14. Estimate of upper bound of the contribution of genetics from 2001/02 to 2011/12 for beef

<table>
<tr><th colspan="2" rowspan="4">Gain in productivity (kg meat sold per breeding female per year) and the estimated contribution of specific components to the overall gain in productivity[1]</th><th colspan="3">Upper bound of contribution to Productivity from genetic improvement after accounting for adoption</th></tr>
<tr><th colspan="2">Components of genetic gain</th><th rowspan="2">Estimated genetic gain in productivity</th></tr>
<tr><th>Direct effect of genetics on cows & bulls used</th><th>Effect of future genetic expression</th></tr>
<tr><th colspan="3">Southern beef (75% adoption)</th></tr>
<tr><td colspan="2">Slaughter weight of cattle</td><td>0.62</td><td>0.12</td><td>0.74</td></tr>
<tr><td colspan="2">Cow CW</td><td>0.13</td><td>0.03</td><td>0.16</td></tr>
<tr><td colspan="2">Cow fertility</td><td>0.09</td><td>0.02</td><td>0.11</td></tr>
<tr><td>Productivity trend</td><td>1.6 kg</td><td>0.85</td><td>0.16</td><td>1.01</td></tr>
<tr><td colspan="5">Percentage of productivity trend accounted for by the upper bound of the estimated genetic change</td></tr>
<tr><td colspan="2">Contribution to cumulative change</td><td>53%</td><td>63%</td><td>63%</td></tr>
<tr><td colspan="2">Component[1]</td><td colspan="3">Northern beef (20% maternal adoption & 50% terminal adoption)[2]</td></tr>
<tr><td colspan="2">Slaughter weight of cattle</td><td>0.08</td><td>0.01</td><td>0.10</td></tr>
<tr><td colspan="2">Cow CW</td><td>0.03</td><td>0.00</td><td>0.03</td></tr>
<tr><td colspan="2">Cow fertility</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Productivity trend</td><td>2.0 kg</td><td>0.11</td><td>0.01</td><td>0.12</td></tr>
<tr><td colspan="5">Percentage of productivity trend accounted for by the upper bound of the estimated genetic change</td></tr>
<tr><td colspan="2">Contribution to cumulative change</td><td>6%</td><td>6%</td><td>6%</td></tr>
</table>

[1] Gains presented at the component (slaughter and cow carcase weight) level

[2] Based on 1.0 M cows mated to terminal sires and 5.0 M mated to maternal (*Bos indicus*) sires

3. Overview of the contribution of genetic improvement to productivity changes

Table 15 provides a summary of the estimates of the upper bound of the contribution of genetic improvement to the change in productivity for the period from 2001/02 to 2011/12.

Table 15. Estimates of the upper bound of the contribution of genetic improvement for the period from 2001/02 to 2011/12

	Gain in Productivity (kg meat sold per breeding female per year)	Upper bound of contribution to productivity from genetic improvement after accounting for adoption	
		Estimated genetic contribution to productivity	Estimated proportional contribution
Sheep	0.284	0.145	51%
Southern beef	1.6	1.01	63%
Northern beef	2.0	0.12	6%

It is important to note that these estimates of the potential contribution of genetic improvement expressed as changes in carcase production cannot be readily translated into financial benefits. There are three reasons in that there is no accounting for: the additional feed costs of the heavier animal in the flock or herd with its higher feed requirements, the future genetic expressions are discounted in financial terms but not in product terms, and the value of the carcase from younger growing animals is higher than that of mature or cull animals. However an expression in terms of the output of the product per breeding female does provide a very useful credibility check.

Credibility check 2: Economic value of genetic improvement in commercial beef and sheep enterprises

The estimates of the value realized from genetic improvement initiatives in the meat sheep and beef sectors have been calculated and converted into estimates of the **economic benefits** of genetic improvement for different enterprises:

1. the value proposition for the use of **improved (genetically-superior) bulls** to the purchaser of those bulls;
2. the potential impact of the **environment** on the realization of gains through genetic improvement;
3. associated benefits realised by producers of Meat Standards Australia (MSA) cattle who utilise **improved bulls;** and
4. associated benefits realised by producers of Victorian lamb who utilise **improved rams**.

These are considered in turn below.

Value proposition for improved (genetically-superior) bulls

The value proposition for the use of improved (genetically-superior) bulls to the purchaser of those bulls is one way to assess the value of genetic improvement. Hence the estimates below provide the means to enable a commercial producer to make an informed decision re the price margin they would be prepared to pay for a genetically-superior bull from within a recorded herd and between recorded herds (so long as they are genetically connected); they also offer the opportunity to make comparisons with buying bulls from an unrecorded herd.

The value proposition for a better bull from a recorded herd - differences in index

The value proposition behind the purchase of a superior bull from a BREEDPLAN-recorded herd is derived by comparing the genetic merits of candidate bulls. For example, if bull A has an economic index $20 greater than bull B for 600 days weight, then the average offspring of bull A are predicted to differ in profitability realized through growth rate, relative to bull B, by $10. Assuming bulls are mated to 150 cows on over their lifetime, bull A is expected to generate a $1,500 higher gross margin over his lifetime for the commercial farmer, compared to bull B. This captures the value generated through direct descendants (slaughtered) and retained descendants who contribute via growth rate in progeny.

The value proposition for buying bulls (with EBVs) from a recorded herd

The value proposition is derived by consideration of the genetic merit of the herd from which the bull is bought. This is compared with a previous point in time which includes the progressive genetic improvement in the bull-breeding herd.

In the example above, the focus is on the value of a superior bull from within a BREEDPLAN herd. Here, we focus on the value of purchasing bulls from a BREEDPLAN-recorded herd over time, and the flow of genetic merit through the commercial herd based on the value proposition for the annual purchase of 13 new bulls from a recorded herd to service a 2,000 cow herd. The purchaser of new bulls from a BREEDPLAN herd will acquire the genetic improvement of that herd. The cumulative value to that producer after 20 years is estimated to be $276K discounted at a rate of 7% per annum (Appendix 5).

Accuracy of estimated genetic merit improves when buying a team of bulls

The accuracy of estimation of the genetic merit of a group of bulls is higher than the accuracy of the estimate of a single bull; although individual bulls may perform better or worse than predicted from the EBV, the greater the number of bulls selected, the more accurate is the estimated genetic merit of the group. For example the accuracy of selection for one bull is 45% for a trait with a heritability of 20%, but the accuracy for a group of 13 bulls is 93% (Appendix 5).

The potential impact of environment on the realization of expected genetic gains

There are two issues with respect to the impact of environment on performance of the progeny of improved sires. They are genotype x environment interaction and a dampening effect of the commercial environment.

- Genotype x environment interaction – the interaction of the genotype of an animal with its environment is a complex issue as this reflects the phenomenon where animals change their relative rankings between environments; a good example at the breed level is where *Bos indicus* cattle perform much better than *Bos taurus* animals in hot, tick-challenged environments in northern Australia but the situation is reversed in southern Australia where the *Bos taurus* animals are superior.
- Dampening effect of the commercial environment – there is a common belief that the genetic trends realized in the sire breeding sector are not fully realized in the commercial sector (in other words the proportion of the estimated genetic gain realized in the commercial sector is less than that in the recorded sector). This could be due to differences in management input or in environments between the two sectors (such as different levels of nutrition and different levels of animal health management. A recent meta-analysis (Banks *et al*)[12] and a review of several evaluations (Ramsay) provided evidence that the relationship between the sire index and the progeny value realized (expected to be 50% of the sire deviation) are reasonable but probably less than expected. However there is a concern with respect to the relationship with carcase weight as highlighted by Banks *et al*; this was much less than expected but it may be an artefact of the range of animals in the meta-analysis. In general it is important to note that the fact that the potential rate of growth is much greater than the actual rate of growth does not mean that the proportional impact of genetic improvement is not being realized. The impact of dampening has been incorporated in the analysis of benefits in Part 1 through the application of a '*realisation factor*' which was taken as 75% of that expected from the EBVs.

However even with an allowance for a substantial interaction so that only a third of the value is realized, benefits are still considerable. For example in the analysis above, the discounted gross margin to the commercial producer after 20 years was $276K; thus even with a two-thirds penalty allowance for dampening, the realized value would still provide a substantial margin of $92K over the period (Appendix Table 5.4). This provides a major opportunity for a commercial producer to pay a margin for bulls such that the break-even position in year 20 would be $550 per bull ($7,300 added value in that year with13 bulls purchased in that year). It would be surprising if the extent of dampening was as great as this, and in this context it is also important to consider the accuracy of selection of a group of bulls compared with buying the odd bull.

[12]Banks RJ, DJ Brown, SR Field 2009. Meta-analysis of cross-bred progeny data for Australian terminal sire sheep. Proceedings AAABG *18*: 480-487; Ramsay 2012. Using ASBVs – What's in it for me? Sheep CRC

Associated benefits: using improved bulls to produce MSA-graded cattle

The additional value realized by a producer who purchases bulls from a genetically-superior (recorded) herd is estimated here in terms of associated benefits realised through an increase in the quantity of beef from the herd that meets MSA-grading standards – it is not due to the impact of MSA grading but rather due to higher growth rates meaning that a higher proportion of animals (and weight of animal) meet the standards within the time/age categories.

The benefits were modelled using the 2,000 cow herd referred to earlier applying the genetic trend for 600-Day Weight[13]. The increase in weight resulted in an increase in the number of animals meeting the MSA threshold and this benefit was estimated. Thus it is the benefit of the increased weight and not that of MSA grading that is assessed.[14] The amount of additional carcase weight accumulated between 2000 and 2012 is 71 tonnes for the reference herd cows representing a cumulative additional gain through genetic improvement of $9,300 (the analysis is retrospective and applies the premium every year with no discounting).

To estimate the value of using genetically-improved bulls at an industry sector level, the model was extrapolated to the Southern Beef sector. The additional carcase weight accumulated due to the introduction of genetically-improved bulls (26% per year) into the sire team annually at 75% adoption amounts to 115,500 tonnes with a value of $15 M (77,000 tonnes and $10 M for 50% adoption) (Appendix 5 Tables 5.8 and 5.9).

Associated benefits: using improved rams for lamb production in Victoria

The Victorian prime lamb (breeding/finishing) sector (crossbred sheep for lamb production) provides an example of technology uptake where the use of rams from LAMBPLAN-recorded flocks provides the basis for some assessments of impact.

The average carcase weight increased by approximately 9% over 10 years to 2012 (19.4 to 21.2 kg), but the distribution of lambs slaughtered within the course of a year did not change. Hence the increase in CW is a result of improvement in growth rate (and not older age at slaughter), and so CW can be used to derive an estimate of the value of genetic improvement to prime lamb producers.[15] The estimated increase in production was 12,600 tonnes (based on 2000 slaughterings of 7.14M) with a cumulative gross margin value of $188 M (2012 PV is calculated based on a net interest rate of 3% per annum) to producers over the period (after fully accounting for the extra feed required) (Appendix 5).

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[13] The trend in 600-day weight (live weight trait) in the *Bos taurus* breeds was 2.86 kg/year (Table 6) and this was used to define the genetic merit of the herd and the value to the producer over the period from 2000 to 2012.

[14] There are two components: 1) the additional CW of the number of animals that already made the cut in previous years; 2) the CW of the additional animals that pass the live weight threshold at 600 days of age each year. A second threshold was established to allow for a more realistic assessment; animals that reached 538 kg LW at 16 mths were assumed to have a higher killing-out of 52%; MSA beef is worth $0.13 per kg over the whole carcase to the producer.

[15] A proportion of the apparent gain in 'productivity' between 2000 and 2012 can be attributed to the 'increase' in ewe productivity (Appendix Figure 5.4) where lambs slaughtered per ewe mated ewe rose from 0.8 to 1.2. This is due to three factors - genetic improvement in maternal traits (number of lambs weaned per ewe), changes in ewe management, and the confounding effect of moving sheep interstate for slaughter.

This estimated gain it does not include any value generated further up the supply chain. Box 1 and Box 2 highlight some aspects of the responses and value generated within the Victorian lamb industry.

BOX 1: Increase in Carcase Weight due to a shift in market demand for heavier, leaner lambs

Initial response
- Lambs were finished to heavier weights, but they were then too fat for the market

Short term
- Immediate changes in animal management. e.g. feed, turn-off age
- Strategic changes in farm management, e.g. in crop usage, sheep breed, implementation of genetics

Long term
- Genetic improvement and availability of information on genetically improved animals to the farmer, e.g. LAMBPLAN

BOX 2: Value of increased carcase weight to the meat processor/marketer

- *Higher CW reduces processing cost per kg as many costs of operating a plant are related to carcase throughput*
- *The consistent availability of larger carcases that meet market requirements provides a processor with more flexibility (further processing of carcases to consumer-ready cuts)*
- *Consistent carcase quality justifies the investment in accreditation processes that are necessary to participate in high-end marketing schemes*
- *A processor that can rely on the availability of a good supply of high quality carcases can also implement technology for higher plant throughput without worrying about profitability*
- *Thus higher carcase weights and consistent quality enable a processor to add value to the final product*

Credibility check 3: Comparison of benefits with LAMBPLAN, MERINOSELECT, and BREEDPLAN $Indexes

The estimates of the value derived using this methodology have been compared with those index responses predicted using the current models in BREEDPLAN, LAMBPLAN and MERINOSELECT.

<u>LAMBPLAN and MERINOSELECT</u>

Trends in dollar indexes generated by Sheep Genetics have been compared with those generated in this report. Specifically, the MERINOSELECT FP+ and the LAMBPLAN Maternal $Index trends are presented in Table 16.

This analysis enables a comparison of the value of genetic improvement defined outside the value obtained through genetic change in meat production as reported here (through growth, adult size and fertility); in particular, this incorporates any value obtained through genetic change in wool traits, worm resistance, meat yield and ewe longevity. The differences for both types of matings, but in particular for Merino x Merino, are substantial. It should be noted that the benefits calculated using Sheep Genetics $ Indexes are likely to be over-estimates due to the fact that feed costs are not fully accounted for in current models (Sam Gill *pers. comm*.).

Table 16. Comparison of estimated rates of genetic change in this report compared with all traits derived from Sheep Genetics genetic trends

Mating type (male x female)	Fate of progeny	Annual rate of genetic gain ($) per ewe mated			
		This Report (Carcase only)		Sheep Genetics (All traits)	
		1997 to 2009	2009 to 2012	1997 to 2009	2009 to 2012
Merino x Merino	Replacements retained	0.07	0.20	0.92	0.53
Maternal x Maternal	Replacements retained	0.46	0.65	1.26	1.30

BREEDOBJECT

Trends in dollar indexes generated by BREEDOBJECT have been compared with those generated in this report. Specifically, the average trends in HGF and SFD for Angus; SUP, Grass FS, and Grain FS for Hereford; DOM for Charolais; DOM T for Limousin; and DOM for Simmental have been combined as appropriate and are presented in Table 17.

This analysis enables a comparison of the value of genetic improvement defined outside the value obtained through genetic change in meat production as reported (through growth, adult size, and fertility) here. In particular the additional value incorporates genetic change in meat quality (through the Intramuscular Fat, IMF%), meat yield, calving ease, gestation length, and residual feed intake. Again the differences are material for maternal matings but less so for terminal x maternal matings. However further analysis is beyond the scope of this report.

Table 17. Comparison of estimated rates of genetic change in this report compared with all traits derived from BREEDOBJECT genetic trends ($)

Mating type (male x female)	Fate of progeny	Annual rate of genetic gain ($) per cow mated			
		This Report (Carcase value only)		BREEDOBJECT (All traits)	
		1994 to 2006	2009 to 2012	1994 to 2006	2009 to 2012
Maternal x Maternal	Replacements retained	1.78	1.66	2.35	2.74
Terminal x Maternal	All progeny slaughtered	1.95	1.78	1.45	2.03

Differences between the performance of animals in the seedstock herd/ flock (for the selected trait) and that in the commercial herd/ flock are accounted for in BREEDOBJECT and SHEEPOBJECT, respectively. The difference varies from trait to trait (and with what is actually measured in the seedstock herd/flock). The realisation factors used in this report are essentially equivalent to those incorporated in BREEDOBJECT and SHEEPOBJECT. Thus, broadly, the scale of differences in estimated benefits realised from genetic change in meat production (calculated in this report) and meat production plus additional value through genetic change in other traits (wool, worm resistance, meat yield and ewe longevity in sheep and meat quality, meat yield, calving ease, gestation length, and residual feed intake in beef) are comparable.

Attribution of realised benefits to MLA investment

Perspectives

An assessment of the **attribution of benefits** from investment by MLA and the associated government investment is an important component of the analysis.

The preceding analysis and estimation of the net benefits from the MLA and other investment has been thoroughly considered the counterfactual. In particular the important factors are:

- prior research and extension (funded by MLA and others, and modelled as the continuation of earlier trends)
- the likely investment in other research and extension by breeders (individually and collectively, both traditional and more quantitatively-focused)
- the potential investment by other industry interests
- access to overseas genetics (important for beef)
- the value proposition for commercial producers in terms of adoption.

Thus the net benefits as measured reflect the **additional** genetic gain that can be attributed to MLA and broadly-termed co-investor funding and direction. Three aspects of investment by MLA and associates are identified as important in terms of attribution **between** these groups:

- funding levels - relative funding between each
- leverage - capacity to attract external funding
- strategic issues - leadership and direction.

MLA (levy plus matching) has contributed around 28% of the total investment by MLA and governments (Sheepmeat 46% and Beef 16%). However, without MLA investment, investment by governments (particularly Commonwealth) would have been less. The MLA investment was essential to securing other funding. The following points summarise the evidence.

- In the case of the CRCs, industry co-investment is a fundamental necessary requirement. MLA brought that industry component to the table.
- The same scenario can be argued with respect to CSIRO given the external funding requirements in place during the last decade and earlier. MLA, as a 'marginal funder' on CSIRO base level funding has exerted leverage. CSIRO funds have been drawn to animal genetics compared to other areas of agriculture or industry.
- In universities, the same marginal funding claim can be made.
- Individual state governments have been significant investors in their own right, but have been guided by where MLA has invested as this also leverages their own investment.

As well as leveraging funding, MLA can be credited with having provided (alongside individual and collective industry interests) strategic direction in genetics RD&E (alongside state governments). This has been important in the past and will likely become more evident in the medium term. Around one-third of the total investment in genetics has been in strategic R&D. Benefits of such past investments are yet to be realized by breeders or commercial producers.

Taken together these factors suggest that the MLA contribution is significantly above the 28% implied by the direct proportional funding (Table 2, 28% of $323 M). However, on the basis of the share of the relative investment, the net benefit that can be attributed to the MLA totals around $468 M (Table 18), indicating a B/C of 6.

Table 18. Estimated attribution of benefits to MLA investment (2014 Real Present Values, $M)

	Investment		Benefits (CF)	Benefit to Cost ratio for MLA investment	IRR on MLA investment
	$ M	**MLA share of Total**	**MLA share of Total**		
Sheep	$60	46% (of $132M)	46% ($350 of $767 M)	5.8	27%
Southern Beef	$23	16% (of $143M)	16% ($101M of $629M)	4.4	29%
Northern Beef	$8	16% (of $48M)	16% ($8M of $49M)	1.0	8%
Total Beef	$31	16% (of $191 M)	16% ($108 of $678 M)	3.5	24%
Total	**$91**	**28% (of $323 M)**	**32% ($458 of $1,445)**	**5.1**	**26%**

Sensitivity

The sensitivity of the returns to a number of factors also requires consideration. The most important in terms of their impact on the expected realization of benefits of genetic improvement in the commercial sector are:

- any dampening effect of environmental challenges (this has been dealt with in the estimation of value by assuming that 75% of the expected gain is realized), and
- the rate of adoption by the commercial producer sector.

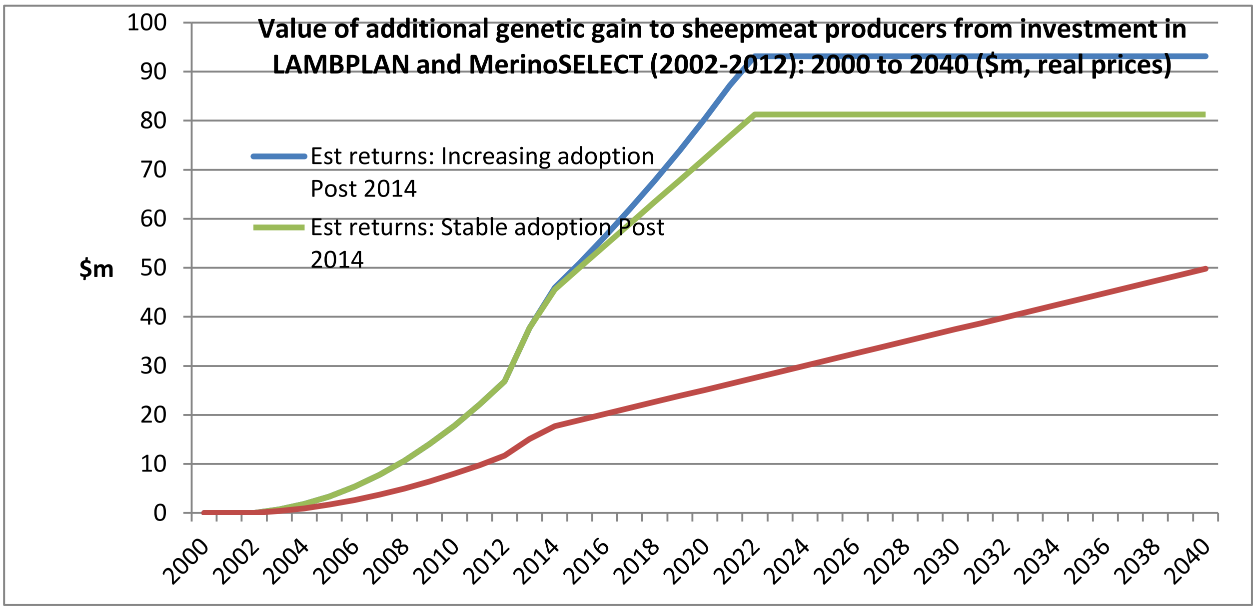
Table 19. Sensitivity: Estimated impact of the rate of adoption on the net benefit benefits (2014 real Present values, $M)

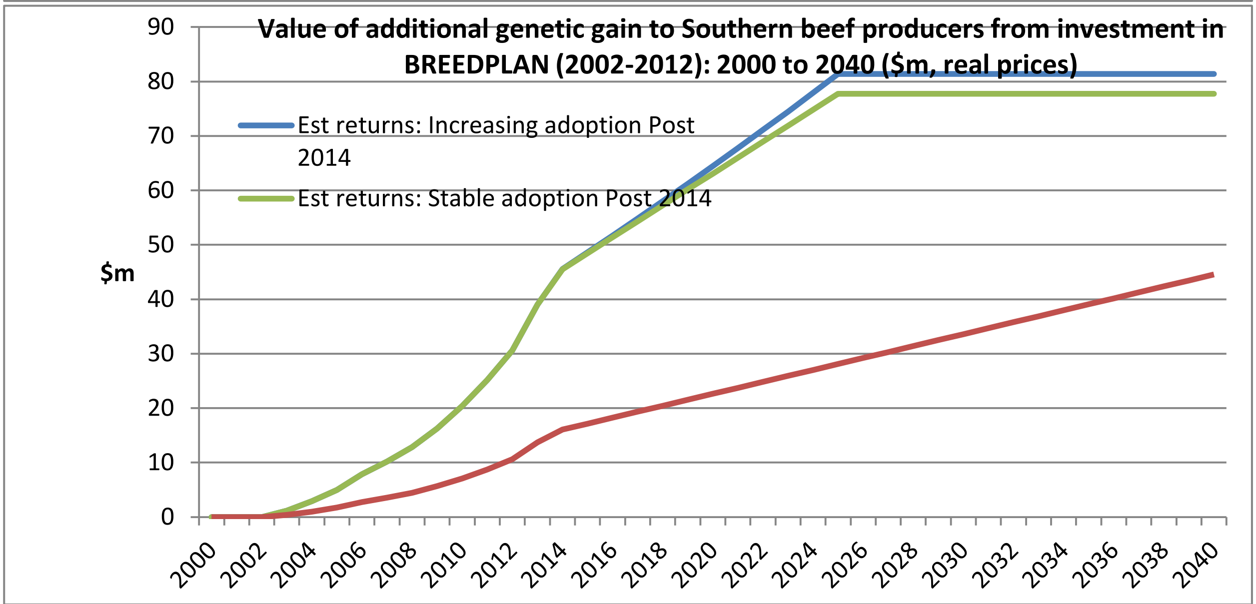
Scenario 1: Stable adoption post-2014				
	Sheepmeat	**Southern Beef**	**Northern Beef**	**Total**
Benefits	$1,051	$1,023	$79	$2,153
Estimated benefits from CF	$284	$394	$30	$424
Net benefits due to MLA investment	$767	$629	$49	$1,445
Costs	$132	$143	$48	$323
Net benefits	$636	$486	$1	$1,122
Benefit to Cost ratio	**5.8**	**4.4**	**1.0**	**4.5**
IRR	27%	29%	8%	26%
Scenario 2: Increasing adoption post-2014				
	Sheepmeat[1]	**Southern Beef**[2]	**Northern Beef**	**Total**
Benefits	$1,146	$1,047	$82	$2,275
Estimated benefits from CF	$284	$394	$30	$424
Net benefits due to MLA investment	$863	$653	$52	$1,568
Costs	$132	$143	$48	$323
Net benefits	$732	$521	$4	$1,245 (+11%)
Benefit to Cost ratio	**6.5**	**4.6**	**1.1**	**4.9**
IRR	29%	30%	8%	27%

[1]Adoption as per the data (steady rate increasing from 2000 levels of 5.5% Merino, 38% Terminal, 24% Maternal to 2012 levels of 18% Merino, 70% Terminal, 41% Maternal), and with the appropriate lags — results in an increase in benefits of around 9%.

[2] Southern Beef with 90% adoption; Northern Beef with adoption increasing to 20% for *Bos indicus* and 50% for *Bos taurus* in 2011/12 with the appropriate lags — results in an increase in beef benefits of around 3.5%.

The time profiles of the estimated benefits including the counterfactual are shown in Figure 6.





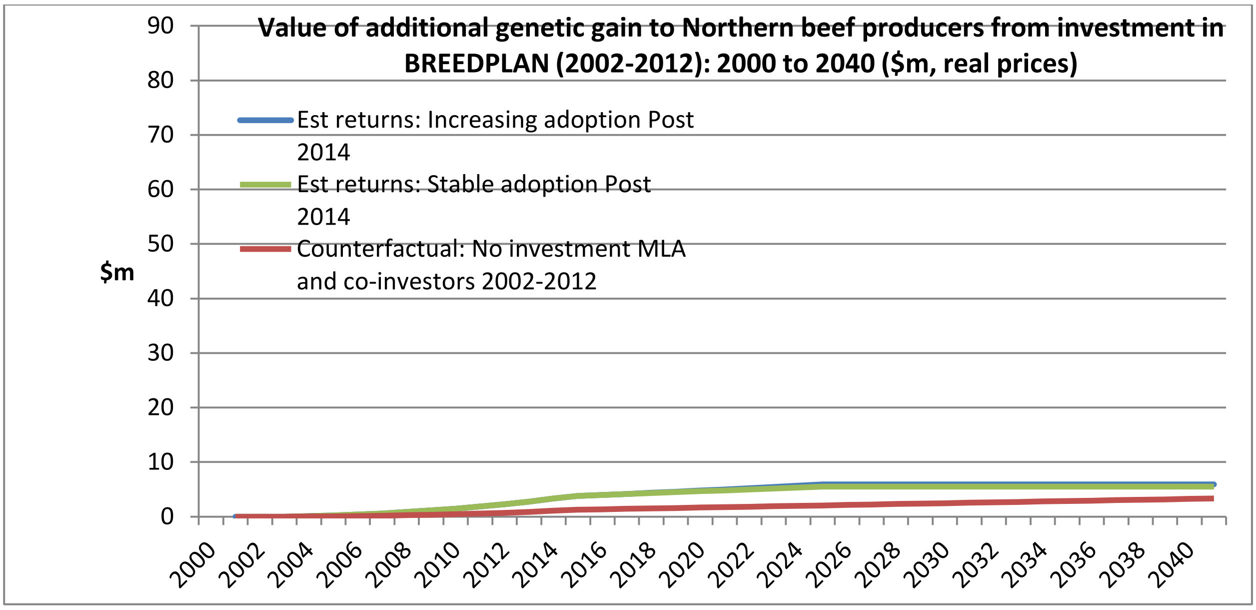


Figure 6. Time profile of benefits: Sheepmeat and beef 2000 to 2040 ($M, real)

Distribution of the benefits from the RD&E: GMI modelling

The issue

The preceding analysis has focused estimated the 'first round' benefit to beef and lamb producers of the RD&E investment in genetics. That is, the benefits as an increase in profits as a result of having adopted the improved genetics arising from the RD&E investment.

However, this increase in profits can be expected to lead to producers increasing beef and sheep production at the expense of other enterprises such as cropping, and/or increase production through applying additional inputs such as pasture improvement or supplementary feeding. Alternatively, producers might be able to maintain production, whereas without the gains from genetic improvement they might have contracted production — either way production is higher than otherwise.

In turn this additional production will impact upon average prices received for sheep and cattle, pushing them lower, compared to the 'otherwise'.

The combination of the initial increase in profitability, increased production, lower prices and an expansion in meat demand at these lower prices are termed 'second round effects'. The second round analysis does not change the overall gain from the R&D but rather enables an assessment of the distribution of the benefits along the livestock/meat value chain.

Approach

Quantitatively, these second round effects can be measured within a standard demand and supply partial equilibrium framework or using more detailed models which incorporate underlying demand and supply trends in livestock and meat production. In both frameworks the distribution of benefits between producers and consumers depend on the relative elasticities of supply and demand. The extent to which producers respond to lower costs or high profitability is determined by the elasticity of supply (and the initial profit increase) and the extent of the prices fall need to enable the sale of the additional production is determined by the elasticity of demand.

The MLA's Global Meat Industry (GMI) Model has been used to examine the second round effects since it permits analysis recognising underling industry trends. The GMI model provides a global representation of production, consumption, trade and prices at the bilateral level for meat and live animals (cattle and sheep). The model identifies 26 regions and ten meat types The GMI model measures payoffs to Australian beef and sheepmeat producers in terms of changes in prices, production and gross value of production at an aggregate industry level.

While the GMI model can evaluate how productivity improvements are passed between producers and consumers in both domestic and export markets, it lacks sufficient detail to be specific about how benefits are shared at each stage along the respective value chains. In the case of productivity improvements in the cattle industry, and ideal analysis would quantify how benefits move between northern and southern cattle producers, feedlots, processors and then with consumers. This type of analysis shows not only the size of the productivity improvement is critical but also where productivity improvements occur along the value chain.

Given the focus of the analysis is the return to producers, the first round net effect of the RD&E has been estimated as annual profit gain to producers (2002-2030), less the industry levy contribution (2002-2012). The levy contribution has been included (as a cost) since in the same way that RD&E delivers potential profit gains to producers, a levy reduces profits.

Industry trends

In both the sheepmeat and beef industries the analysis using the GMI modelling points to continuing growth in industry output and the (farm) gross value of production (Figure 7).

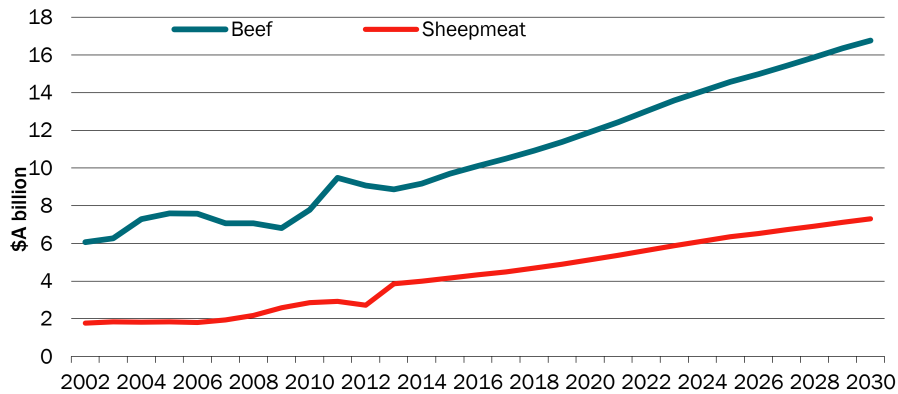


Figure 7: Sheepmeat and beef: Projected industry GVP (Nominal $m**)**

Source: GMI model

Second round effects

Against these trends (2002-2030) the net impact of the RD&E investment incorporating the second round significantly reduces the estimated first round gains to producers. On average over the period:

- Sheepmeat producers are estimated to retain 30% of the first round gain, and
- Beef producers, 50%.

The normal competitive dynamics within the red meat value chain means that the rest of these gains to producers are distributed to beneficiaries beyond the farm gate, including consumers.

Across the period of analysis the producer share changes, reflecting the size of the initial, first round, gain as well as small changes in the demand elasticities (Table 20).

Table 20: Supply shift, production and prices changes: Second round effects: Selected years

	2014	2020	2030
Sheep			
Supply shift (farm income gain)	0.85%	1.33%	1.24%
Production change	0.9%	1.3%	1.2%
Farm gate price change	-0.6%	-0.9%	-0.8%
Producer Retained gain	29%	28%	31%
Beef			
Supply shift (farm income gain)	0.21%	0.26%	0.20%
Production change	0.2%	0.2%	0.2%
Farm gate price change	-0.1%	-0.1%	-0.1%
Producer Retained gain	55%	48%	46%

Source: Centre for International Economics, GMI modelling

The small share retained by producers at the industry level, and the differences between the sheepmeat and beef industries, reflects several factors.

- In most situations a positive supply response by producers will mean that producers will not retain all of the gain from the R&D. The additional volumes produced will push farm gate prices down.
- The extent to which prices are pushed down will depend upon the nature of demand. The demand for both sheepmeat and beef is responsive to price (elastic) but far from perfectly elastic (which would imply that prices would not fall if supply increased). Thus additional volumes have significant effect on saleyard prices.
- Taken together – a positive supply response by producers and less than perfectly elastic demand —mean that producers, as group, will not retain all and not necessarily much of the gain from R&D.
- For sheepmeat the lower supply elasticity is outweighed by the lower demand elasticity meaning that, as it turns out, sheepmeat producers retain a smaller share of the first round gains compared to beef producers.
- The key elasticity estimates (derived within the GMI model, and which change to a small degree through time) for an example year (2020) are:
  - Elasticity of supply: sheepmeat (0.6) and beef (0.3)
  - Elasticity of demand across domestic and export markets: sheepmeat (-1.4) and beef (-3.7).

Significantly, the estimated share of the R&D gain retained by producers applies to sheep and cattle meat production research in general, not only genetics.

The estimated share of the first round gain retained by producers, using the GMI modelling, suggests that the share of R&D gains retained by beef producers in now higher than a decade ago. Farquharson, et al, in their 2003 study of the returns to beef genetics estimated that beef producers retained about 33% of the overall benefits.[16]

Mounter et al estimated the distribution of returns from a range of beef related R&D and promotion. In the scenarios examined, the producer share was under 30%, except in the case of weaner R&D where it was 33% (Table 21).

Table 21: Beef producer share of benefits from R&D and promotion: 2006-10 industry data

Weaner production R&D	Grass finishing R&D	Processing R&D	Domestic marketing R&D	Domestic grainfed promotion	Domestic grassfed promotion
33%	27%	26%	20%	23%	22%

Source: Mounter et.al.[17]

Such an outcome using the GMI model is consistent with world trade developments, in particular greater access to a wider number of very price sensitive markets, such as China and the re-emergence of the US beef market have meant that additional sales volumes place less pressure on saleyard prices than previously.

The investment performance of the MLA investment given the second round effects is presented in Table 22. In the second round the MLA cost has been estimated as the Government contribution plus the second round producer contribution.

Table 22: Attribution to MLA investment: First and second round investment performance (Real, 2014 present value)

Benefits	First round	Second round (a)
	B/C	B/C
Sheepmeat	5.8	2.7
Beef	3.5	2.2
Total	5.1	2.5
(a) Producer shares post 2030 held constant at 2030 levels		

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16 Farquharson, Robert, Garry Griffith, Steve Barwick, Rob Banks and Bill Holmes, *Estimating the Returns from Past Investment into Beef Cattle Genetic Technologies in Australia*, NSW Agriculture Economics Research Report No. 15, October 2003.

17 Mounter, Stuart, Kara Tighe, Kirrily Pollock and Garry Griffith, *Updating and Recalibrating an Equilibrium Displacement Model of the Australian Beef Market*, MLA project B COM 0335, June 2012.

Other issues

As well as the distribution of benefits between producers, others in the value chain and consumers, there are issues of the distribution of benefits within the production sector.

- Those producers adopting the technologies benefit directly, although as noted the second round effects mean that some of the gains are lost through subsequent lower farm gate prices.
- Those not adopting the technology are at a double disadvantage. First, there is no cost saving/productivity gain on farm. Second, livestock prices are lower because those who do adopt the technology increase production.
- Across the industry Southern beef producers will gain at the expense of the Northern producers. Northern producers have low adoption rates and they will face lower prices as a result of Southern adoption and resulting additional beef supply.
- That said, non-adopters may gain to some extent through capital gains on their land. As the genetics RD&E has improved the potential profitability of sheepmeat and beef production, those holding land capable of sheepmeat and beef production will gain to some extent. However, this gain is likely small given the relatively small percentage increase in annual farm income (on average 0.83% for sheepmeat and 0.17% for beef), the opportunities to substitute for land (for example, pasture improvement and supplementary feeding) and, the overall supply of land available for additional sheep and beef production from cropping.

Part 4. Perspective on future investment by MLA

Background

Part 4 provides recommendations regarding possible *ex ante* measures of success and considers the case for future investment. These recommendations are designed to be applicable to animal genetics and genomics investments over the next 3 years to 2015-16, and thereafter should MLA continue to invest.

In developing these recommendations it is important to recognize that a key factor that allows cattle and sheep producers to sustain their business is their uptake of genetically-improved seed-stock. While in the longer term, this depends on programs that ensure on-going genetic progress, the focus here is on:

a) **the on-going assessment of benefits** (over the next 3 years) that result from historical investment, and

b) **ensuring a focused R&D investment** during this period (and beyond if appropriate) can be expected to make a substantial contribution to future genetic progress.

Given the above, the assessment covers:

1) **Methodology for future assessments, findings/learnings and definition of additional data** that MLA may need to obtain to enable more robust estimates of benefit in the future

2) **The proposition for the involvement of MLA over the next 3 years (and potentially beyond)**

3) Assessment of the **sensitivity of the analysis** of the future trends to key assumptions

Methodology and findings

An important aspect of the review is an assessment of the methodology and the findings or learnings in terms of their relevance to assisting in future decision-making by MLA.

Evaluation and the estimation of benefits

There is a need to define an appropriate methodology for future assessments of the benefits of investment by MLA in RD&E. In this respect, the basic methodology employed in this review does provide a sound basis for future evaluation especially when supported by the credibility checks.

Defining productivity trends over time

The definition of trends in productivity (kg of carcase sold per female mated per year) provides a sound basis for comparisons over time and hence provides the basis of a credibility check against which genetic changes (and any other changes) can be assessed. In one way they have an advantage over Total Factor Productivity as they can be readily interpreted in physical productivity terms. Similarly genetic trends can be analysed in the same way so that comparisons can be made as in this report. The productivity trend can also be converted to an economic trend by including data on costs and prices.

It is recommended that MLA commissions an analysis to fully decompose the trends in productivity over time.

Changes in industry structure

An understanding of changes in industry structure is critical to interpretation of the impact of genetic improvement and the productivity data.

Impact of genetic improvement

Analysis of the impact of genetic improvement requires access to information that was not readily available.

It is recommended that MLA ensures that the methodology including details of the profit functions and their derivation underlying economic weights (EVs, DGEs, etc) is fully documented (including documentation for BreedObject and sheep breeding objectives) and that they are readily accessible.

Estimation of benefits

There is a need to establish a clearer value proposition for commercial producers and define the value of recorded genetics in comparative commercial situations. The information on sheep (Ramsay, What's in it for me?) represents a conundrum as highlighted in the meta-analysis by Banks *et al* (2009). A more comprehensive analysis of the data behind the meta-analysis may provide clarification. There is a lack of robust data for beef although the BINS may deliver very useful information.

Therefore it is recommended that MLA commissions a significant trial to quantify potential scale effects ('dampening') whereby genetic trends in better fed recorded animals result in proportionally smaller trait improvements in lower input commercial farming systems. This would involve taking high and low index sires from recorded herds, and testing their progeny performance in low input and high input commercial settings.

There are two other areas where there is a strong case for desk-top analysis prior to any decisions for additional investment. They are:

- defining the relative value of genomics (overall genetic gain in hard-to-measure/later life traits) as a guide to investment priorities; the importance of possible changes in industry structure are especially important to consider;
- value of lifetime productivity in commercial situations.

Additional data requirements

This section outlines some of the additional data that MLA may need to obtain to enable more robust estimates of benefit in the future. In this respect, a number of questions/issues have been raised in the development of this report that could not be addressed in a satisfactory way. For example, some of the following had to and have been evaluated in the best way possible such as through extrapolation from small datasets. Nevertheless, having access to a full dataset (or generating such) would create a better foundation to work with in future assessments. Therefore it is recommended that the following data sources are created.

Industry structure

Surveys are an effective way of generating these data so long as the questions are consistent such that the data can be readily interpreted. In this respect the only data available to estimate the change in the structure of the sheep flock were (fortuitously) two data sets in 2000 and 2012. Refinement of the Northern and Southern Australia split is important especially in terms of the contribution of beef from the Southern region to slaughter in the north (including feedlots).

Adoption

Soundly-based data on adoption are essential to estimate the impact of genetic improvement. Therefore the following are required:

- data on commercial **mating types** for cattle (*Southern* – Maternal/Terminal, *Northern* – tropical maternal/*Bos taurus* Maternal/Terminal, crossbred)
- consistency of questions in the **lamb survey** to enable generation of a timeline to show changes in industry structure
- two **virtual categories** within BREEDPLAN: *SOLD to breeder*, *SOLD to commercial* (as can be found in LAMBPLAN)

Productivity

In order to generate the productivity data, consistent data sources are required. This was a major issue with the sources of data available for this project. Therefore the following are required:

- **live export** data (sheep and cattle) split into breeder (merino/meat sheep and dairy or beef for slaughter)
- data on **breed types** in feedlots (to estimate numbers of animals transferred in) OR
- data on **animal movements between states** (especially into feedlots/grazing operations/ for slaughter) to construct more accurate split into Northern and Southern beef
- data on **Merino numbers** (lambs slaughtered and/or retention rates)
- better **definition** of data on hand (e.g. age of animals by category)

The proposition for on-going MLA involvement

Background

The proposition for the involvement of MLA over the next 3 years (and potentially beyond) focuses on aspects of market failure, and in particular, the proposition that adoption of the new genomic-based technology may actually compromise the future success of genetic improvement programs. Therefore key factors to be considered are mainly those relating to the impact of genomic tools in the development and application of new breeding technologies.

MLA plans for investment to 2014/15

The MLA Business Plan *"Investment into Beef and Sheep Genetics and Genomics RD&E 2012/13 to 2014/15"* specifies the aforementioned responsibilities that MLA has with regards to investment in genetics and genomics. The stated target for 2014/15 is to double the value of annual genetic gain while covering a number of specific targets; examples include improved eating quality in Northern Beef, the development of Breeding Values for methane production, improved models for generating and delivering genetic information or the increased utilization of genomic information.

Due to the end of the Beef CRC and the impending end of the current Sheep CRC (although a new CRC is currently commencing), the investment into genetic improvement by MLA will become a larger share of overall investment, thus increasing the responsibility of MLA in the entire genetic improvement system and the need for the development of a sustainable funding system in these matters. Crucial steps in the realization of the targets outlined include:

1. **Strategic research** – genomics for cost reduction at high accuracies and for hard to measure traits including methane production, marbling and eating quality and (sheep) disease traits
2. **Core applied R&D** – Northern reproduction, Animal Health/Welfare, incentivisation
3. **Core infrastructure** – up-to-date BREEDPLAN and Sheep Genetics software
4. **Delivery, implementation and capability building** – evolution of delivery/extension

In order to reach these goals, the business plan allocated *c.* $5 M annually between 2012 and 2015 for beef and sheep combined. The proposed distribution of this in the year 2014/15 is in Table 20. It is important to note that this allocation of funds is based on distribution of past funding so that it needs to be treated with caution. It also does not include investment in the cattle information nucleus herds (BINs) and in the Tropical Beef and Southern Beef Technical Services (TBTS & STBS), all of which receive investment via the MLA Donor Company (c. $1.6 M annually which is matched by breeder investment).

Table 20. Proposed distribution of funds in 2014/15 ex Business Plan Genetics/Genomics

Action	Beef	Sheep
1. Development of new traits and genomic technologies	0.3 Mill	0.5 Mill
2. Core applied R&D	0.2 Mill	0.26 Mill
3. Core infrastructure	0.2 Mill	1.1 Mill
4. Delivery, implementation and capability-building	0.18 Mill	0.35 Mill
5. Co-ordination	0.07 Mill	0.07 Mill
Available for new projects	1.93 Mill	0.72 Mill

Proposal for MLA future investment

The plan for future investment by MLA must take into account the paradigm shift that is occurring in genetic evaluation and genetic improvement internationally – that is the rise of genomic approaches that promise faster rates of genetic gain and a much more effective way to deal with and make improvement in the so-called *hard-to-measure* traits. Therefore we address the case for future investment in three specific areas: the *implications of genomic approaches, the notion of investment in options,* with *delivery and implementation.*

Implications of genomic approaches

The issues include:

a) the critical importance of phenotypes and recognition of population structures in the development of genomic tools and in the application of genomic selection

b) the value propositions for seed-stock and commercial producers, and downstream users (e.g. processors) to capture data (tools for incentivisation)

c) the potential, and the value positions, for novel phenotypes (e.g. methane intensity, product quality and disease resistance traits)

d) the core infrastructure to support the tools for genetic evaluation (including underpinning analytical software) and the management of data

e) the potential value for commercial producers and downstream users (e.g. processors) of genomic predictors of phenotypic performance.

The situation

Bull and ram breeders are in the business of breeding and rearing sound fertile sires to sale with those investing in performance recording seeking a premium over the base product of a sound unimproved breeding sire. The new technologies of genomic selection represent both a threat and an opportunity to breeders and to their industry. The threat comes through an ability of breeders to substitute their investment in recording with an investment in DNA testing (potentially at a lower cost).

It is a threat because, paradoxically, the development of genomic selection is dependent on the on-going collection of phenotypic data to support the development of new traits and to provide data to continually assess the accuracy of such genomic technologies. Thus if breeders using DNA-based methods only, are able to capture a significant share of the market for bulls and rams marketed as "genetically-improved", there will be a disincentive for other breeders to continue recording at higher costs.

The opportunity arises through the potential for breeders to differentiate themselves as "performance recorders" and extract extra value. The balance between threat and opportunity depends on how breeding structures within the industry change to accommodate new opportunities and the way in which structural/pricing mechanisms operate.

Genomic selection offers opportunities to generate value from incorporation of non-traditional traits in genetic selection. Good examples include meat quality and health traits. Pre-genomic methods such as BLUP are limited by the need to generate data through the recording of phenotypes and/or progeny testing on a relatively large scale. Consequently collection of such data can be prohibitively expensive and is often limited to industries that are either vertically-integrated (pigs and poultry) or where there are well-developed artificial breeding (AB) systems that enable the widespread utilisation of elite males through AB such as with dairy.

Genomics offers a paradigm shift in that a breeding program can be structured such that data can be collected on a smaller number of animals within well-structured nucleus population(s). These populations must be designed so that they incorporate the key sources of genetics from within the wider (e.g. breed) population so that the data and information generated are relevant to the wider population. As there is a need to sample a much smaller number of animals than in pre-genomic systems, the cost of individual assessments is much less of an issue. A good example is the use of CT (computed tomography) approaches in sheep breeding schemes, and feed intake in cattle (as in Australia).

In addition there is the opportunity to collect progeny test data through commercial ventures as accuracy of pedigree is no longer an issue as pedigree can effectively be re-constructed using genomic approaches through gBLUP[18]. Good examples are health traits for animals in feedlots, meat quality traits at slaughter, and maternal traits such as lifetime productivity (especially in sheep), and longevity and health in cows.

One potential advantage of genomic selection will be a reduction in generation interval that is achievable given the availability of good quality phenotypic (and genetic relationship) data both in the nucleus and in downstream related herds. While this is the case with beef, it is much less important with sheep. However the Sheep Information Nucleus[19] provides an example of the operation of the nucleus, although the utilisation of the outputs downstream through the industry is a work in progress.

New opportunities in evaluation through genomics

While there is considerable potential to capture new value from genomic selection this will be limited without a change in structure of data collection and evaluation practices and further development of the technology. Without a change in the way that data are collected, the result could well be an increase in cost without a parallel increase in value.

Therefore there is a major opportunity to develop a new framework for the development and application of genomic tools in systems to accelerate genetic gain. These include:

- improved processes for the collection and analysis of phenotypic data,
- improved statistical and analytical processes for efficiently and appropriately incorporating genomic information into routine genetic evaluations and selection list reports used by breeders,
- utilisation of males to provide genetic connectedness between herds,
- utilising the inherent structure and genetic relationships within breeds within the beef and sheep populations,
- the genotyping of influential individuals.

Given these factors, the value of the Information Nucleus herds[20] is immediately evident. The next stage is the co-ordinated collection of downstream (effectively progeny-test) data that are integrated through DNA-based relationship analysis. In both sheep and cattle, the need for, and the value proposition to, increase the rate of genetic gain in maternal traits represents both a particular challenge and an opportunity for breeding schemes with a focus on investment in genetic progress and who are prepared to undertake detailed recording.

Role for genomic technologies through the value chain

There is potential for the application of **genomic technologies** to generate additional data through the value chain. This could range from data collection such as that around meat quality and the consumer eating experience through to detailed feedlot performance in cattle. As noted above, this is effectively a DNA-enabled progeny testing approach (See Appendix 10, How does genomic selection work?).

Arguably the greatest value will come from integrating data ex the supply chain back into breeding and production systems, especially as DNA systems provide the opportunity to identify problems that are relatively uncommon but important. These include 'symptoms' of

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[18] See Appendix 68 *How does genomic selection work?*

[19] See Clark, SA *et al* 2012. Genetics Selection Evolution, 44:4-9

[20] The value of the training set is a function of the relatedness of that set of animals to the population under evaluation. Hence it is essential that they are closely-related (see Saatchi, Mahdi *et al* 2013. Genomic breeding values in Hereford cattle: Accuracies of direct genomic breeding values in Hereford cattle using national or international training populations. *Journal of Animal Science (online. 23 Jan 2013))*

problems such as diseases of animals in feedlots or a high incidence of poor quality meat products from a suspected common source, where a genetic link might now be suspected but undetectable. DNA-based systems will enable such analysis.

Facilitating uptake

Practices that will **facilitate uptake** and encourage industry-wide adoption of genomic technologies within the sheep and beef cattle industries are critical. The realisation of the importance of genetic relationships to successful implementation of genomic technologies is fundamental to this process. However this reality also puts a premium on the on-going generation and collection of high-quality data for performance traits such as fertility and survival that are especially important in the commercial sector. While collection of data for some difficult to measure traits such as feed intake and new traits such as methane production are well-suited to evaluation through centralized facilities (albeit problematic in pregnant and lactating animals), other traits will require much more data. In particular, recording of breeding cow fertility, survival and performance will be critical to avoid costly unfavourable outcomes from selection on growth rate and residual feed intake in young growing animals. Hence this highlights the critical importance of downstream progeny testing.

The notion of investment in options

The potential opportunities are very broad and the future is very uncertain. Therefore it is important to recognize the potential for MLA programs to create future options for the industry.

The outcomes of the research would enable a much quicker response to adverse situations and/or the means to help capitalise on opportunities. Some examples include aspects such as changes in the market (such as a geographical shift which is reflected currently in the increasing demand from China, greater competition from other countries in export markets, increased demand for ground beef in some markets[21]), changes in the production environment (e.g. due to new disease challenges or to a more variable climate, farming within regulatory limits such as nutrient loading of water catchments), changes in technologies (automated systems for data collection based on individual electronic identification, and applications of genomics especially in terms of the options around capturing data from commercial flocks and herds).

There are some traits which are always likely to be important because they are fundamental to the productivity of the female and hence to the profitability of the enterprise (gain in carcase weight and weaning percentage are examples) and hence they are important for all breeds. However there are other traits which are likely to become more important in the future; these include feed efficiency, and a reduced output of methane (per unit of product), while there are other traits that are relatively more important for particular breeds such as meat quality. The central concept is that genetic improvement provides options; in other words, it is a form of insurance that enables producers to better manage forward risks and better exploit forward opportunities[22]. While the rate of change within a breed may be limited (by the extent of variation within that breed), there is a considerable opportunity to exploit differences between breeds. In this respect the power of genomic methodologies can be utilized to help define the value proposition for cross-breeding using real on-farm data, or defining the response of individuals within a herd to disease challenges can both be considered as applications of options thinking in that they help provide a broader range of possibilities for the future.

[21] Rabobank AgFocus (January 2014), Ground beef nation: The effect of changing consumer tastes and preferences on the US cattle industry

[22] ACIL Tasman (October 2012) Assessing MLA genetics research

Delivery and implementation

There are three central features to delivery: systems to provide support to breeders, making the case for objectively-based genetic improvement, and providing the evidence for uptake.

Support for breeders

Support for breeders is fundamental to the success of genetic improvement systems. In this respect Australian breeders are very well-served through Southern (SBTS) and Tropical Beef Technology Services (TBTS)[23]. This role is a critical one and is well-appreciated by breeders[24].

Showing the benefits of genetic improvement

There are numerous sceptics with respect to the value of objective recording and genetic evaluation in the improvement of animals – as a group they cannot be ignored. However the reality is that while some are unlikely to be convinced, others have legitimate concerns. These include the impact of selection for growth on meat quality and on the replacement rate (the implication of a less robust animal), and the impact of genotype by environment interactions (animals perform very differently in different environments). There is a case to address these concerns and simple progeny tests in relevant environments run under commercial conditions under MLA-contracted supervision can make a real difference. Transparency is a critical issue in such evaluations. They also need to be well designed in order to ensure sufficient statistical power to support conclusions.

Measuring uptake or adoption

The uptake and (rate of) adoption of improved genetics are major drivers in terms of realizing the impact of genetic improvement. Estimating adoption is fraught with uncertainties and while we have estimated adoption based on the production of sires from recorded herds/flocks and estimated usage, we have also assessed the sensitivity of the estimated impact as a function of adoption (Section Ex-post sensitivity). The estimates are summarized in Table 5. However there is an important proviso to the interpretation of these estimates. In the case of Merino sheep and northern cattle there are well-established systems where producers will purchase genetics from recorded herds (semen or sires) and then use these to generate their own sires – that is they are multipliers. In the case of Merinos there is also an analogous process operated by MERINOSELECT through Rampower. Here sons of improved sires are sold direct to producers – essentially Rampower flocks operate as multipliers. Hence as multipliers, they can be regarded as being ‘improved’ but lagging the parent ‘stud’ in terms of genetic merit.

The foregoing discussion highlights the importance of measures of uptake which are critical to understanding and defining the impact of genetic improvement at a national level. There are two key aspects: first the sales of animals from recorded herds and flocks, and second, their use commercially. Such data could be collected through some soundly-based surveys; these would cover bulls/rams purchased, type (terminal, maternal), usage (mating ratios, years of usage) in the flock/herd. Another source of such data may be some of the farm business consultancy practices although how representative they may be is a potential issue in terms of relevance.

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[23] Both are joint initiatives of MLA, ABRI and Breed Societies that run the majority of their cattle in Southern Australia, and Northern Australia respectively. SBTS and TBTS provide the members of participating breed societies with technical support that enables them to maximise their understanding and use of the different genetic technologies that are available (including BREEDPLAN, BreedObject Selection Indexes, Internet Solutions, TakeStock and DNA based technologies).

[24] MLA Pipeline Consultation Working Party 2011

There is a case to believe that the Northern Beef sector is poised to realize the value of genetic improvement. This is based on outputs from the Beef CRC which has shown the value of improvement in reproduction, and the evidence of uptake by major beef operations in the north. Albeit at this point, much of this is based on management approaches rather than on genetic approaches.

Appendices

Appendix 1. Context and Previous Reports

A number of reports are on hand concerning red meat industry investments on different levels. Remarkably, these reports ore often related be it by using the same methodology (including tools like models) or by building on the same base assumptions coming out of expert consultation.

One example of the repeated use of the same resource is the use of the Zhao *et al*[25] Equilibrium Displacement Model[26] of the Australian beef industry. The model was used by Zhao and by Farquharson *et al*[27] in an investigation of the returns from beef industry R&D in 2003. The basic parameters in this industry model were defined and verified by Zhao. Since it includes different horizontal pathways (different finishing strategies, such as grain-fed and grass-fed) as well as vertical ones (producer, feedlotter, processor, retailer, etc.), it provides a comprehensive overview of the industry as a whole.

Nevertheless, in the investigation of the impact of research and development, the model requires active definition of parameters in every scenario investigated. Zhao developed a number of different scenarios to estimate attribution of returns from positive 1% shifts within the EDM (such as might be triggered by R&D investments). Even though this is a standardized system with every scenario operating at its respective profit maximum, these evaluations allow for different conclusions regarding specific programs by looking at different scenarios.

Farquharson used the same EDM to estimate returns from investments in genetic improvement in the beef industry in 2003. In their approach, three different scenarios were constructed based on shifts in the production system. These were within-breed genetic improvement and cross-breeding in the south, infusion of *Bos indicus* genetics into northern beef population and a shift within the southern beef herd towards a higher percentage of high-marbling Angus cattle. The latter two scenarios were modeled based on expert opinions on the value of a *Bos indicus* over a *Bos taurus* animal in tropical climate and a carcase with a higher marbling score over a carcase with a lower marbling score[28].

While these case studies provide valuable assessments of the value of certain aspects of genetic improvement, no attempt was made to assess the impact of genetics within the context of improvements in overall industry productivity. In fact Farquharson did not attempt attribution of benefits due to uncertainties around the distribution of returns. The different timeframes for the three scenarios (e.g. the infusion of *Bos indicus* in the north started in the 1970s) further hindered the attribution of benefits.

A broader evaluation of MLA on-farm beef programs was carried out by the CIE in 2009[29]

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[25] Zhao X, Mullen J, Griffith GR, Griffiths WE, Piggott RR (2000) *An Equilibrium Displacement Model of the Australian Beef Industry*; Economic Research Report No.4, NSW Agriculture, Orange

[26] The EDM is a system of relationships between supply and demand that is widely used in economic evaluations; the model can be adjusted to analyse the impact of different scenarios on shifts in supply and demand and subsequent changes in value gathered by the industry as a whole.

[27] Farquharson B, Griffith GR, Barwick S, Banks R, Homes B (2003) *Estimating the Returns from Past Investment into Beef Cattle Genetic Technologies in Australia;* Economic Research Report No.15, NSW Agriculture, Orange

[28] No specifics were given on what "high marbling" entailed or how the applied premium was generated.

[29] *An evaluation of MLA beef on-farm programs*; prepared for MLA by the CIE,

using Total Factor Productivity[30] where they estimated that 70% of southern bulls entering the market came from herds using BREEDPLAN and had EBVs. The industry was split into three different systems being Northern Beef, Southern Beef and Feedlots (the analysis included marketing, animal health, animal welfare (especially in feedlots), reproduction and genetics although only a small portion concerned genetic improvement). Moreover, while TFP is a useful tool for evaluating changes in overall farm profitability as a result of improvements in productivity, the attribution of the changes in productivity is particularly difficult.

The industry was split into three different systems being Northern Beef, Southern Beef and Feedlots (the analysis included marketing, animal health, animal welfare (especially in feedlots), reproduction and genetics, only a small portion concerned genetic improvement). Moreover, while TFP is a useful tool for evaluating changes in overall farm profitability as a result of improvements in productivity, the attribution of the changes in productivity is particularly difficult.

Attribution of benefits was assumed to be proportional to inputs. Since MLA and the State Departments were identified as the most reliable source of investments and other investors, such as breed societies or processors had not been taken into consideration, a comparatively high share of benefits was attributed to MLA. The different timeframes for the three scenarios (e.g. the infusion of *Bos indicus* in the north started in the 1970s) further hindered the attribution of benefits.

The Zhao EDM was modified by Mounter *et al*[31] to model the sheep industry. A number of different scenarios were evaluated where emphasis was on different traits (lamb production vs wool) as well as different industry levels (producer, domestic market and export market, etc). As with the beef industry scenarios, this allowed for different estimates of the attribution of benefits across the industry, depending on the choice of scenario(s).

The CIE (2008)[32,33] applied their Global Meat Industry model, expanding it to capture the different levels of the national lamb industry. The major emphasis was on marketing, as this program tends to consume more resources than on-farm research and development. The estimated rate of genetic gain assumed in this report was based on work by Banks (2003) and Howard *et al*. (2007) and on expert opinion. Attribution of benefits was also based on a share-of-cost basis.

Banks (2003)[34] used the Gross Value of Production (GVP) instead of TFP to attempt to overcome the confounding problems associated with TFP analyses. GVP combines on-farm productivity with actual prices, thus reflecting the value generated without taking changes in cost of production into consideration. Banks compared the GVP of the lamb industry with the genetic merit of the sire team used in LAMBPLAN. While this represents a nominal value, it is an useful tool to visualize how the genetic merit of animals in the production system does not only impact on simple parameters such as carcase weight, but also on the more complex

[30] Estimates produced by Agtrans Research (*Economic Evaluation of MLA Feedlot Investment 2001-2006*, Peter Chudleigh and Sarah Simpson, MLA 2006; *Economic Evaluation of MLA Northern Beef RD&E Investment for 2000/2001 to 2007/08,* Peter Chudleigh, MLA August 2008; *Economic Evaluation of MLA Southern Beef RD&E Investment for 2000/2001 to 2007/08,* Peter Chudleigh, MLA August 2008, Table 2.8)

[31] Mounter S, Griffith GR, Piggot R, Fleming E, Zhao X (2008) *Potential Returns to the Australian Sheep and Wool Industries from Effective R&D and Promotion Investments and their Sensitivities to Assumed Elasticity Value*s. Australas. Agribus. Rev.(16) 1-25

[32] *An evaluation of lamb on-farm programs*; prepared by the CIE for MLA, December 2008

[33] Chudleigh (Agtrans Research) also presented a report to MLA in tandem with this one that investigated the economic implications of lamb production R&D investment between 1990/91 and 2007/08. However the issues with attribution, as described for the CIE report, are also inherent in this report.

[34] Robert Banks (2003) *The Australian Prime Lamb Industry Development Program 1985-2003*; unpublished

factor of product quality (large, lean lambs). However, while he notes that genetic improvement has played a major role in the development of the Australian lamb industry, he also notes that marketing, management and genetics need to be developed side by side to reap the benefits in terms of profitability and so does not attempt to value genetic improvement as such.

Ramsay (2012)[35] produced an extensive literature review on use and/or validation of ASBVs/EBVs (some projects were undertaken before the switch to ASBVs) to improve lamb production as well as wool traits. However this report did not attempt to put a value on any of the reported projects.

A key factor in genetic improvement on a commercial level (vs. a stud level) is adoption of genetic technologies throughout the industry. In this respect Barnett (2006)[36] reviewed the adoption of LAMBPLAN in the Australian sheep meat and lamb industry and identified strong connections between adoption rate and genetic improvement as well as between marketing programs and adoption rate. This once again underlines the need for a simultaneous development of marketing strategies and genetic improvement (as noted by Banks), since higher consumer acceptance and subsequently higher prices provide strong signals for higher adoption by commercial farmers.

The ACIL Tasman Report (2012)[37] poses another example of the relationships between reports. While trying to assess the impact of research funded by MLA in the entire red meat sector, it relies heavily of Farquharson *et al* for the beef sector and does not provide a general estimate for the sheep sector, but evaluates single projects (Beef and Sheep CRCs). While providing an in-depth analysis of the different levels of adoption, this report does not come to any definitive conclusion around the case for future MLA investment in genetics research.

The ACIL Allen Report (2013)[38] considers the significance of MLA genetics research and its implications both for the industry and for MLA. While attempting to address all factors that contribute to the success of genetic improvement programs, including adoption and the realization of benefits from genetic improvement along the supply chain, this review stops short of an actual evaluation of these factors. Hence, while attribution is recognised as an important part of an economic evaluation, it is not attempted. Although the goal of the report was to assess genetics R&D, the investigation focusses on case studies in the beef sector (covering a small part of the industry) and omits consideration of the sheep meat and lamb sector.

The counter-factual to MLA investment in genetics R, D & E is an important factor to be considered. While some reports include a baseline against which development made possible by investments in R&D is compared, these are more general, including productivity changes due to marketing or management changes as well as genetic improvement.

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[35] Ramsay A (2012) *Using ASBVs – What's in it for me?*; literature review prepared for the Sheep CRC

[36] Barnett R (2006) *LAMBPLAN – Review of Adoption by the Australian Meat Sheep Breeding Industry*; MLA Project Reference SHGEN.114

[37] Assessing MLA Genetics Research – The Future of MLA genetics research

[38] MLA Genetics Research – Review & Assessment of MLA's Genetics Portfolio

Appendix 2. Analysis of Industry Productivity

Methodological details

Industry-wide estimates of productivity

This analysis uses industry output data to estimate **productivity per breeding female** in the sheep and beef industries and then uses these outputs to estimate the change over time.

In order to allow for a realistic assessment of different industry sectors, the cattle population was split into Northern and Southern beef. Thus, the three sectors were Northern and Southern Beef and Sheep meat, while the two other sectors (Dairy and Wool) that impact on them were also taken into consideration where appropriate.

While an effort was made to correct for any kind of outside influence on a production system (e.g. drought, beef sourced from dairy cows), it is outside the scope of this part of the review to differentiate between gains in productivity achieved by implementing management changes (e.g. more intensive management, increased feedlot finishing) or other means (e.g. hormonal growth promoters in feedlot cattle), but to provide an overall estimation to enable further definition of the contribution of genetic improvement to productivity.

Data sources

The data used to generate the productivity trends were gathered from several different sources.

The foundation data were sourced from MLA[39]; these included data for both cattle and sheep: Animals' slaughtered, annual production (tonnes) of beef, veal, mutton and lamb and number of animals exported. Some numbers were given by states (animals slaughtered, meat production, live cattle exports), or by destination for live sheep exports. Dairy cattle numbers were included so that the data enabled an overview of beef production while factoring out cull dairy cows. Further data were sourced from the Farm Financial and Physical database[40] (also includes details on flock and herd structure - numbers of wethers, ewes, cows, heifers, steers, bulls, and performance - lambing/ calving weaning, and death rates). This was found to be the only consistent source for this type of information, since other sources either did not go back far enough or did not include the most recent years. These datasets essentially provide survey data and therefore, numbers could not be used directly, but were extrapolated and converted to proportions. These proportions were then utilized to create a flock or herd structure over time.

Other production and export data were sourced from ABARES (including more detailed data such as red meat consumption, exports, value) in order to 'validate' or supplement the foundation MLA data, and from various other sources[41]. A proportion of live cattle exports were dairy cattle; therefore a split of cattle exports into classes (beef for slaughter, beef breeders, dairy breeders) was obtained from the LiveCorp reports on the Australian Livestock Export Industry.

Modelling of productivity trends

There were considerable gaps in data in some years leading up to 1989; therefore years

[39] Per Ben Thomas, Beef Market Analyst with MLA

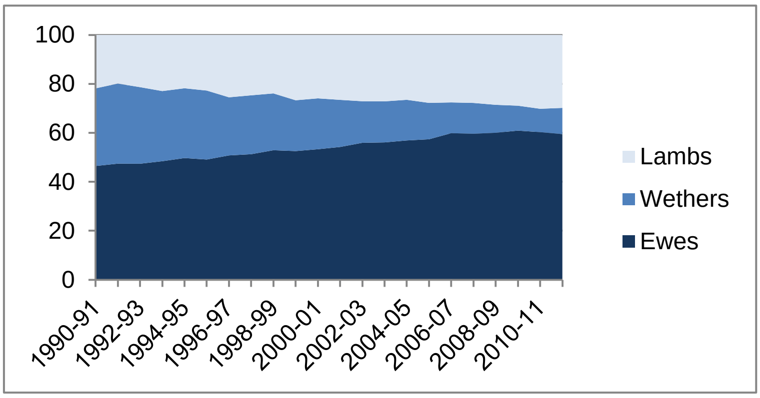
[40] MLA, available through the DAFF >> ABARES website

[41] (Australian/ Agricultural Commodity Statistics); Live export data (weight) were obtained from the Australian Bureau of Statistics Time Series 7215.0 (Livestock Products, Australia) and the distribution of dairy cattle across states from series 7121.0 (Livestock – Dairy, Australia)

before 1990 were excluded for both beef and sheep. Although the project is concerned with benefits of investment in the by MLA between 2001-02 and 2011-12, the analyses reported here cover the period from 1991 to 2012. This was to enable stable productivity estimates to be established.

Sheep

Analysis over time (Appendix Figure 2.1) shows a significant change in flock structure due to the shift from a system focused on wool production to one where prime lamb production is a major factor. This is evident in a decline in the proportion of wethers (32% in 1991 to 11% in 2012) along with a rise in ewes (47% in 1991 to 60% in 2012). This impacts on productivity per ewe as more wethers would have been culled, seemingly adding to production; therefore the flock restructuring effect was taken into account with the decline in ewes *vis a vis* other sheep.

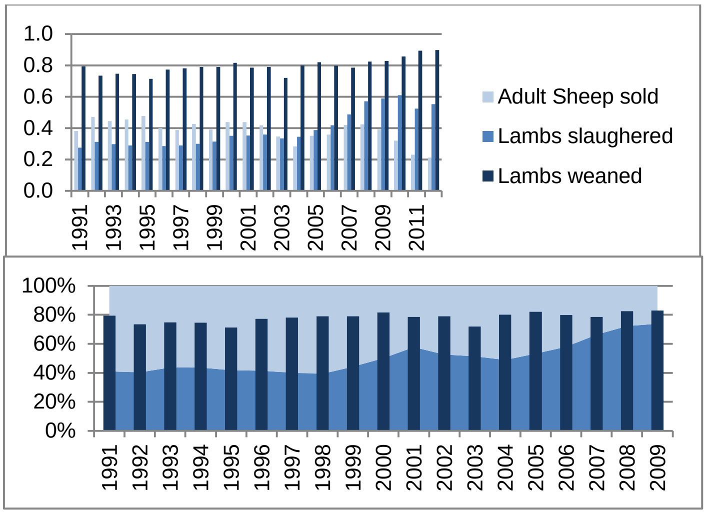


Appendix Figure 2.1. Structure of the Australian sheep flock

Estimation of ewe productivity requires a base in terms of the number of ewes mated; the available data (total number of ewes) includes non-breeding females (unmated wool-producing ewes and hoggets/yearlings). As with the calculations of the proportions of wethers, lambs and ewes in the flock, the percentage of ewes mated and lambs born were derived from the ABARE website and applied to the MLA dataset. Even though the estimated number of lambs marked per year using this approach was slightly higher than the one from the MLA dataset, this was used due to a higher level of rigor[42].

Further analysis of the production data split into lambs weaned per ewe and adult sheep/lambs sold per ewe showed that the number of animals sold per ewe and the number of lambs weaned were not in synchrony; therefore a lag of three years was applied to the number of adult sheep sold and this then brought the number of animals sold per ewe and per year more into synchrony with the number of lambs weaned. Although the general application of a three-year lag does not reflect reality, it does show that the changes in the production system become apparent in the changes in the proportion of lambs to adult sheep sold per mated ewe.

[42] Information on number of ewes joined and different mating types could be taken from the MLA AWI Wool and Sheepmeat Survey (Lamb Survey) 2009-2012, but unfortunately, it proved difficult to consolidate these data with other data on hand. Because of these difficulties and the fact that there were no data on the years prior to 2009, information from this survey was used to 'validate' lamb numbers and to generate a proportional split of mating types, but not to account for the number of ewes mated (see Appendix 3).



Appendix Figure 2.2. Production per mated ewe across years (2A, without 3 year-lag; 2B, with 3-year lag)

Appendix Table 2.1. Flock structure and production parameters from 1991 to 2012

Year	Numbers in millions of heads						Percentage of lambs weaned/ Total ewes	Percentage of lambs weaned/ Ewes mated
	Total sheep	**Wethers**	**Ewes**	**Live exports**	**Wethers & live exports**	**Lambs weaned**		
1991	162.774	53.843	74.876	4.45	58.293	48.178	64.30%	79.30%
1992	148.203	57.542	69.655	5.118	62.66	38.407	55.10%	73.50%
1993	138.102	46.887	66.289	5.441	52.327	39.033	58.90%	74.80%
1994	132.57	38.507	64.959	5.7	44.206	40.159	61.80%	74.50%
1995	120.86	32.623	61.639	5.881	38.503	36.757	59.60%	71.40%
1996	121.116	31.896	59.347	5.299	37.195	38.899	65.50%	77.30%
1997	120.228	29.843	61.316	5.109	34.952	39.607	64.60%	78.00%
1998	117.491	25.171	61.095	5.033	30.204	40.744	66.70%	79.00%
1999	115.456	23.74	61.192	4.948	28.688	40.478	66.10%	79.00%
2000	118.551	20.094	64.018	6.033	26.127	44.211	69.10%	81.50%
2001	110.927	16.174	59.901	6.533	22.707	41.67	69.60%	78.50%
2002	106.165	20.697	57.329	5.856	26.553	37.694	65.80%	78.90%
2003	99.252	12.457	57.008	3.845	16.302	36.333	63.70%	72.00%
2004	101.287	14.753	58.366	3.236	17.989	38.46	65.90%	80.00%
2005	101.125	14.504	56.63	4.251	18.755	39.053	69.00%	82.10%
2006	91.027	7.393	52.796	4.14	11.533	37.145	70.40%	79.90%
2007	85.711	3.153	51.427	4.07	7.223	36.333	70.70%	78.60%
2008	76.938	1.317	46.932	4.067	5.385	34.185	72.80%	82.50%
2009	72.74	1.107	43.644	3.06	4.167	32.468	74.40%	82.90%
2010	68.085	1.446	42.213	2.916	4.363	30.754	72.90%	85.70%
2011	73.099	2.493	43.859	2.562	5.055	33.327	76.00%	89.40%
2012	74.722	2.495	44.833	2.058	4.553	34.133	76.10%	89.60%

Year	Carcase production (tonnes)		Live Exports	
	Lamb production	Mutton production	Millions of heads	Carcase Weight Equivalent in tonnes
1991	287,440	381,444	4.45	109,029
1992	274,671	392,219	5.118	125,383
1993	273,423	369,955	5.441	133,296
1994	266,799	380,720	5.7	139,648
1995	267,968	353,588	5.881	144,076
1996	264,721	309,576	5.299	129,824
1997	270,279	296,151	5.109	125,174
1998	283,621	332,568	5.033	123,303
1999	312,069	316,307	4.948	121,231
2000	347,322	333,212	6.033	147,796
2001	367,432	347,525	6.533	160,068
2002	347,947	296,309	5.856	143,469
2003	329,407	268,218	3.845	94,192
2004	341,449	219,714	3.236	79,292
2005	354,291	237,356	4.251	104,154
2006	381,838	243,791	4.14	101,432
2007	412,585	270,988	4.07	99,714
2008	428,388	243,119	4.067	99,645
2009	415,867	219,820	3.06	74,962
2010	412,536	161,774	2.916	71,452
2011	391,340	123,246	2.562	62,774
2012	419,329	259,585	2.058	50,413

Total production per ewe was determined by combining mutton and lamb production with a CW equivalent for live exports[43]. To account for flock restructuring, standardized parameters[44] were applied to the observed changes in sheep numbers and used to generate productivity per ewe corrected for the decline in numbers[45]. The adjusted estimate (Appendix Table 2.2) provides a realistic perspective on ewe productivity without confusing it with changes in flock size.

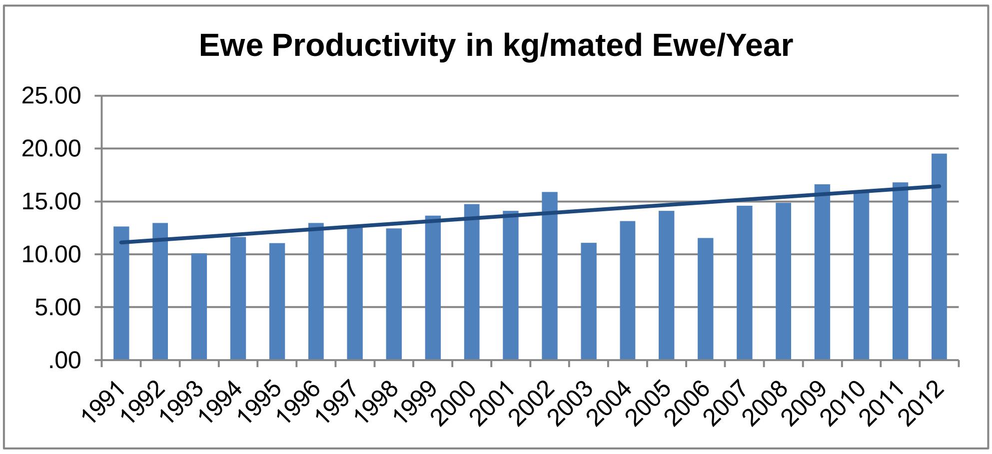
[43] These data were generated using standardized numbers for live weight and killing-out (KO) percentage, with KO% of males (44%) and females (45%) (MLA Live Assessment Yard Book – Sheep and Lamb); an average live weight for exported sheep of 50kg was calculated based on ABS Live Export data.

[44] Since no data could be found on average sheep live weight, a live weight of 50kg (range from 35 to 70kg) was assumed and combined with killing-out percentages above.

[45] An estimated average live weight for adult sheep slaughtered of approximately 42kg was derived from MLA data; however when taken with other data, a value of 50kg was considered more appropriate. There were some apparent deviations within the ABARES survey data, which led to the view that there may have been some confusion about the recording of “lamb” and “prime lamb”; this may have led to some lambs being recorded as mutton as they did not fit criteria for “prime lamb” (lambs produced explicitly for lamb production and not as a by-product of the wool industry).

Appendix Table 2.2. Changes in flock structure and adjusted productivity per ewe mated from 1991 to 2012

Year	Change in numbers in '000 head			Effect on carcase weight produced ('000 tonnes)		Productivity (kg carcase sold per ewe mated per year)	
	Overall	Ewes	Wethers	Of ewe decline	Of wether decline	Adjusted for decline in population	Lamb meat
1991	-263	-6,866	6,603	-151.04	148.56	12.64	4.73
1992	-4,800	-5,221	420	-114.85	9.46	12.86	5.26
1993	-10,727	-3,366	-7,360	-74.6	-165.61	9.82	5.24
1994	-6,658	-1,330	-5,329	-29.25	-119.89	11.56	4.95
1995	-8,308	-3,321	-4,987	-73.06	-112.22	10.89	5.21
1996	-1,886	-2,292	406	-50.42	9.14	13.05	5.26
1997	-1,596	1,969	-3,566	43.33	-80.23	12.87	5.32
1998	-3,874	-221	-3,653	-4.86	-82.2	12.50	5.50
1999	-1,769	96	-1,865	2.12	-41.96	13.79	6.09
2000	-638	2,826	-3,463	62.17	-77.93	15.01	6.40
2001	-5,083	-4,117	-966	-90.57	-21.75	14.10	6.92
2002	-786	-2,571	1,786	-56.57	40.18	16.06	7.28
2003	-5,552	-322	-5,230	-7.07	-117.68	11.01	6.53
2004	-92	1,358	-1,450	29.88	-32.63	13.29	7.10
2005	-755	-1,736	980	-38.18	22.06	14.22	7.45
2006	-8,190	-3,834	-4,355	-84.36	-97.99	11.28	8.21
2007	-4,504	-1,369	-3,135	-30.12	-70.54	14.54	8.93
2008	-6,625	-4,494	-2,130	-98.88	-47.93	14.64	10.34
2009	-2,481	-3,288	807	-72.34	18.15	16.55	10.62
2010	-2,941	-1,431	-1,509	-31.49	-33.96	15.97	11.50
2011	2,440	1,647	793	36.23	17.85	17.11	10.50
2012	818	974	-156	21.42	-3.51	19.68	11.01



Appendix Figure 2.3. Productivity per ewe (kg carcase sold per ewe mated per year, y) adjusted for changes in flock size against year (x) from 1991 to 2012.

Even though there are some fluctuations apparent within the study period, the trend amounts to a gain in productivity of 0.254 kg carcase produced per ewe mated per year. While productivity is higher in New Zealand (about 23.5 kg in 2012) compared to about 17 kg in Australia (17.6 kg being the actual 3-year average from 2010 to 2012, and 15.9 kg being the value for 2012 from the regression equation), the NZ trend represents a compound annual growth rate of 2.5% (from a higher base), compared with 1.6 to 2.1% in Australia. Considering the different sheep systems in Australia and New Zealand, with the greater Australian focus on wool (albeit there is an increase in its emphasis on lamb), this situation is not unexpected. As no distinction between Merino and non-Merino sheep could be made, the trend represents the overall trend within the Australian flock. There will be breed-related differences in the trend due to different rates of uptake of technology or its impact in different breeds or different environments.

Confounding the overall picture is drought. By 2003, the drought was recognised as the worst on record (reliable records since 1900). The productivity low from 2003 to 2006 (Appendix Figure 2.3) is attributed to the very low rainfall, especially in the southeast (Australian Bureau of Meteorology). As low air and ground humidity inhibits the natural buffering system of daytime evaporation/ night-time condensation, the drought contributed to high temperatures and wide daily temperature ranges. An adjustment for drought in sheep productivity by excluding the 4 worst years (2004-07) from the analysis increased the estimated productivity from 0.254 to 0.294 per year (albeit with a lower r^2). The results are summarized in Appendix Table 2.9.

Beef cattle

The split between Northern and Southern Beef was based on two groups: *Northern* - Western Australia, the Northern Territory and Queensland; *Southern* - South Australia, Victoria, Tasmania, New South Wales (including the ACT). Slaughter data were available on a state by state basis (MLA) and the distribution of animal numbers between states was derived from the Farm Financial and Physical database (ABARE). As there are animal movements between states (to feedlots and to slaughter, especially in Queensland[46]), this split is not entirely accurate[47]; however there are distinct differences in management, in the environment (including incidence of drought) and in the genetic background of beef cattle in the northern and the southern regions of Australia (very strong influence of *Bos indicus* in the north).

As with sheep, adjustments were necessary, particularly to estimates of the contribution of the dairy herd. There is no distinction between dairy and beef in slaughter statistics but changes in the numbers in the dairy herd allowed for an estimation of cull cows and bobby calves. Most of the Australian dairy herd is in the southeast (Victoria, Tasmania and southern NSW), so that corrections for beef and veal sourced from the dairy herd and exports of dairy were split proportionately before being applied to the *Northern* and *Southern* datasets[48]. To

[46] While the issue of cattle being transported between states certainly presents an issue, further analysis of the proportions of cattle slaughtered to calves born showed that only a very small percentage of the north Australian kill could not be explained by animals produced in the northern states. This is probably due to movements flowing in both directions (see Appendix Table 1.7).

[47] “Australian beef - Financial performance of beef cattle producing farms”, a yearly report prepared and issued by ABARES, provides a comprehensive review of the economic situation of beef farmers in different geographic and marketing situations, and uses a slightly different definition of “Northern” and “Southern”, with Western Australia split into a primarily *Bos indicus* influenced northern region focused on live export and a southern region with a higher percentage of Bos *taurus* and virtually no live exports. Such a split was not possible without deviating from the foundation dataset (Thomas, MLA) and falling back to the survey data these evaluations are based on. While these reports for the years 2009/10 to 2012/13 show positive trends in production, they also detail the cost to the farmer and show that not every rise in production is automatically reflected in a rise in farm business profit.

[48] Series 7121.0 of the Agricultural Commodities statistics indicates that 89.5% of the dairy herd are in the south.

factor out cull dairy cows, culling rates in dairy cows were calculated for each year using changes in dairy cattle numbers from the MLA dataset and applying an annual retention rate of heifers of 26% and an annual death rate of 3%. The average adult cattle slaughter weight for each year from the MLA dataset was applied (from 236 kg in 1990 to 288 kg in 2012); the same approach was applied to 5% of the dairy calves born (standard live weight of 70 kg and a killing-out of 50%). The animals that were neither killed as vealers nor retained as replacements were assumed to be slaughtered for beef as finished cattle. The resulting outputs of beef and veal ex the dairy herd were then split across the Northern and Southern subsets accordingly.

Northern Beef

The northern beef cattle population is characterised by *Bos indicus* x *Bos taurus* crosses to take advantage of the superior adaptation of *Bos indic*us breeds. Slightly lower live weights and higher killing-out percentages were applied compared with those used for Southern beef[49]. The data for herd structure are summarised in Appendix Table 2.3.

[49] KO% for Northern cattle - "Carcass and meat quality of cattle in northern Australia" (Wythes *et al*).

Appendix Table 2.3. Herd structure and production parameters for the Northern beef herd from 1991 to 2012

Year	Numbers in millions of head				Carcase weight (CW) produced (thousand tonnes)		
	Total beef cattle	Calves under 1 yr	Number of cows mated	Cattle live exports	Veal	Beef	Live exports (CW Equiv)
1991	11.767	2.653	5.234	0.098	16.8	782.8	18.4
1992	11.950	2.632	5.117	0.130	17.8	813.4	24.7
1993	12.458	2.900	5.028	0.158	18.0	847.8	29.8
1994	11.458	2.588	4.862	0.242	17.7	833.6	45.8
1995	11.695	2.764	5.270	0.391	16.8	778.8	74.0
1996	12.359	2.854	5.231	0.591	14.8	734.9	111.7
1997	11.611	2.885	4.858	0.828	16.1	764.8	156.4
1998	12.960	3.172	5.386	0.603	20.5	888.4	114.0
1999	12.848	3.056	5.339	0.626	18.9	991.9	118.3
2000	13.882	3.188	5.836	0.774	18.6	1004.4	146.2
2001	13.858	3.311	6.158	0.780	18.3	1107.4	147.5
2002	14.188	3.151	6.193	0.747	16.3	1031.7	141.1
2003	13.076	3.038	5.514	0.877	19.3	1024.2	165.8
2004	14.557	2.984	6.161	0.593	18.3	1062.8	112.1
2005	14.252	2.989	5.747	0.535	15.5	1146.7	101.1
2006	14.278	3.037	6.443	0.533	15.3	1138.9	100.8
2007	13.265	2.380	5.867	0.620	16.6	1193.9	117.2
2008	13.845	2.477	6.409	0.701	13.9	1124.5	132.4
2009	13.251	2.579	5.928	0.839	14.1	1096.6	158.5
2010	13.889	2.817	5.806	0.835	27.3	1091.3	157.8
2011	14.091	3.165	6.173	0.686	23.8	1127.1	129.6
2012	14.668	3.169	6.693	0.546	22.4	1124.0	103.2

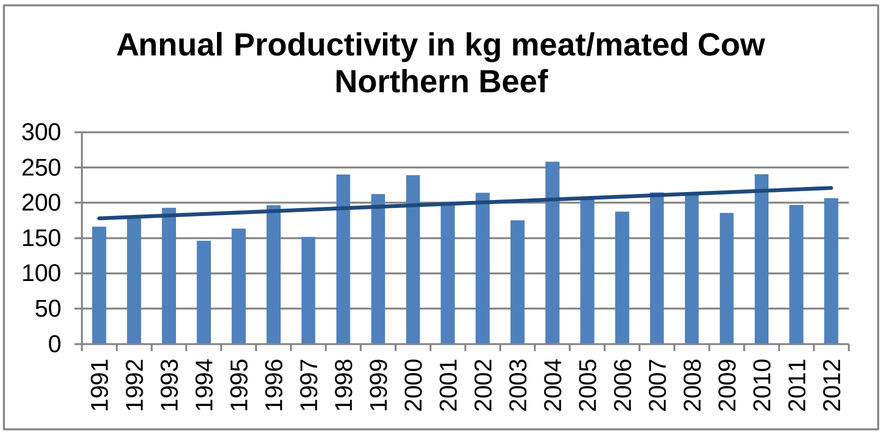
Productivity was calculated by combining domestic beef and veal production with live exports[50]. Although the overall numbers of northern cattle were relatively steady at around 14 million, there is a restructuring effect similar to that in the sheep flock. Apart from cull animals, it also includes a false negative effect on productivity due to heifers retained above the standard replacement rate, as these lead to a rise in numbers, but do not appear in beef sold. The changes in numbers were converted into carcase weight by assigning standard factors for carcase weight and killing-out percentages[51]. The analyses are presented in Appendix Table 2. 4 and Appendix Figure 2.4.

[50] An estimated carcase weight for live exports based on 350kg live weight and a killing-out (KO) of 54% was used.

[51] Live weight of 450kg & 500 kg, KO of 50% & 57% for females and males respectively; data on live weights in were provided by Jessira Perovic, MSA Research & Development Data Analyst (per Alex Ball, MLA), and Wythes *et al*. Hot carcase weight of Northern cattle slaughtered domestically increased about 8kg/ year from 2004 to 2013. Although there are no prior data, it is appropriate to assume that gain would have been lower in the years prior to 2004.

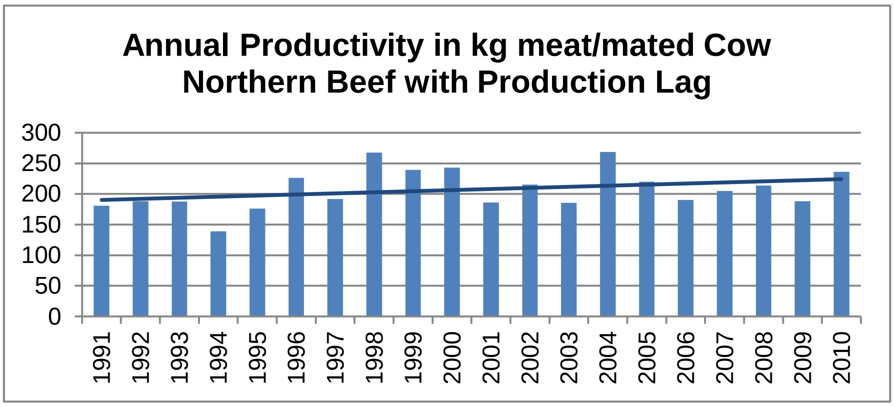
Appendix Table 2.4 Northern beef**.** Herd structure and adjusted productivity from 1991 to 2012

Year	Numbers in '000 head			Effects of herd restructuring on CW produced (thousand tonnes)		Productivity (kg carcase per cow per yr)	
	Overall change	Change in cows	Changes in other cattle	Of cows	Of other herd members	Adjusted for changes in population	Veal
1991	201.088	87.218	113.870	19.6	32.5	166.2	3.2
1992	203.837	-117.038	320.875	-26.3	91.4	180.0	3.5
1993	240.860	-88.855	329.715	-20.0	94.0	192.8	3.6
1994	-688.715	-166.078	-522.637	-37.4	-149.0	146.2	3.6
1995	60.914	407.655	-346.741	91.7	-98.8	163.7	3.2
1996	574.725	-39.410	614.135	-8.9	175.0	196.4	2.8
1997	-779.828	-373.101	-406.727	-83.9	-115.9	151.8	3.3
1998	1061.832	528.284	533.548	118.9	152.1	240.2	3.8
1999	4.425	-46.967	51.392	-10.6	14.6	212.2	3.5
2000	901.924	496.810	405.114	111.8	115.5	239.3	3.2
2001	-147.258	322.598	-469.856	72.6	-133.9	196.8	3.0
2002	490.625	34.664	455.961	7.8	129.9	214.3	2.6
2003	-999.138	-679.178	-319.959	-152.8	-91.2	175.1	3.5
2004	1535.403	647.630	887.773	145.7	253.0	258.4	3.0
2005	-310.252	-414.652	104.400	-93.3	29.8	208.8	2.7
2006	-21.834	696.381	-718.215	156.7	-204.7	187.3	2.4
2007	-356.225	-576.017	219.792	-129.6	62.6	214.9	2.8
2008	482.668	541.571	-58.903	121.9	-16.8	214.7	2.2
2009	-696.066	-480.925	-215.141	-108.2	-61.3	185.5	2.4
2010	399.862	-121.668	521.530	-27.4	148.6	240.7	4.7
2011	-146.035	367.282	-513.317	82.6	-146.3	197.1	3.9
2012	574.221	519.839	54.382	117.0	15.5	206.5	3.4



Appendix Figure 2.4. Northern cattle: Productivity per cow (kg carcase sold per cow mated per year, y) adjusted for changes in the herd size against year (x) from 1991 to 2012 (r^2 of 20%).

The trend in productivity over 22 years was a gain of 2.03 kg carcase sold per mated cow per year. This is based on a within-year production system where an animal is born and sold within the year. Clearly this is not the case with cattle so that the effect of allowing for these lags was estimated (cow mated for the first time in year 0 will not produce any meat harvested from her offspring until year 1 in the case of veal production or year 2/3 in the case of beef). The adjusted trend was 1.79 kg carcase produced per mated cow per year (Appendix Figure 2.5).



Appendix Figure 2.5. Northern cattle: Productivity per cow (kg carcase sold per cow mated per year, y) adjusted for changes in the herd size against year (x) from 1991 to 2012 with lags of 1 year for veal and 3 years for beef (r^2 of 11%).

Southern Beef

As noted above Southern beef includes herds in South Australia, Victoria, New South Wales (including the ACT) and Tasmania. The data for herd structure are in Appendix Table 2.5.

Appendix Table 2.5 Southern beef. Herd structure and production from 1991 to 2012

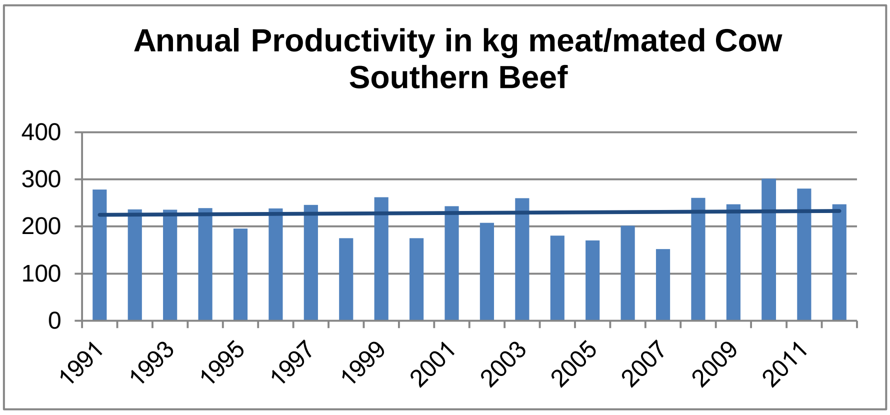
Year	Numbers in millions of head				Carcase weight (CW) produced (thousand tonnes)		
	Total beef cattle	Calves under 1 yr	Number of cows mated	Cattle live exports	Veal	Beef	Live exports (CW Equiv)
1991	7.403	1.858	3.152	0.014	17.7	733.0	2.5
1992	7.518	1.961	3.201	0.007	18.1	736.8	1.2
1993	8.013	2.211	3.398	0.009	17.4	723.2	1.7
1994	8.162	2.212	3.291	0.008	17.6	720.6	1.5
1995	8.121	2.391	3.552	0.009	18.5	749.3	1.6
1996	7.840	2.173	3.159	0.059	16.7	723.2	10.5
1997	8.375	2.418	3.438	0.068	18.2	747.5	12.1
1998	7.273	2.226	3.214	0.117	20.5	764.6	20.9
1999	7.512	2.042	3.211	0.104	15.4	687.5	18.6
2000	7.452	2.243	3.331	0.080	14.1	635.2	14.3
2001	7.656	1.986	3.352	0.079	12.8	658.8	14.0
2002	7.847	2.070	3.389	0.070	12.0	652.3	12.4
2003	8.005	1.780	3.419	0.104	15.9	729.7	18.5
2004	7.975	1.793	3.562	0.021	13.0	645.4	3.8
2005	7.408	1.748	3.251	0.018	10.1	672.4	3.2
2006	7.819	1.845	3.518	0.007	9.4	623.9	1.2
2007	6.419	1.581	3.003	0.024	11.3	733.7	4.3
2008	6.246	1.498	2.800	0.005	9.7	735.1	0.9
2009	5.999	1.573	2.732	0.008	10.4	749.4	1.5
2010	6.294	1.677	2.660	0.037	22.1	745.4	6.6
2011	6.644	1.853	2.842	0.044	18.1	727.8	7.9
2012	6.938	1.934	3.092	0.072	16.4	688.0	12.8

The assumptions for live exports are 350kg live weight and a killing-out of 51%. The slaughter parameters are: females 480kg live weight, killing-out percentage of 48%; males 550kg live weight and a 51% killing-out. The higher live weight of southern beef cattle was made based on the fact that southern beef cattle herd consists of British breeds (Hereford or Angus), along with some component of Continental European breeds. (Note: Due to the differences in carcase conformation in *Bos indicus* and *Bos taurus* breeds, this still amounts to very similar slaughter weights.) The analysis is presented in Appendix Table 2.6 and Appendix Figure 2.6.

Appendix Table 2.6 Southern beef. Herd structure and adjusted productivity per cow mated from 1991 to 2012

Year	Numbers in '000 head			Effects of herd restructuring on CW produced (thousand tonnes)		Productivity (kg carcase per cow per yr)	
	Overall change	Change in cows	Changes in other cattle	Of cows	Of other herd members	Adjusted for changes in population	Veal
1991	438.416	-35.500	473.916	-8.2	132.9	278.5	5.6
1992	12.333	48.665	-36.332	11.2	-10.2	236.5	5.6
1993	245.430	197.152	48.278	45.4	13.5	235.8	5.1
1994	147.206	-107.352	254.558	-24.7	71.4	239.0	5.3
1995	-219.668	260.939	-480.607	60.1	-134.8	195.6	5.2
1996	-63.590	-392.685	329.095	-90.5	92.3	238.1	5.3
1997	290.409	279.252	11.157	64.3	3.1	245.8	5.3
1998	-909.843	-224.576	-685.267	-51.7	-192.2	174.9	6.4
1999	423.282	-2.574	425.856	-0.6	119.5	261.7	4.8
2000	-260.933	120.294	-381.227	27.7	-106.9	175.4	4.2
2001	460.980	20.823	440.157	4.8	123.5	242.8	3.8
2002	107.203	37.148	70.055	8.6	19.7	208.0	3.5
2003	447.610	29.400	418.209	6.8	117.3	259.8	4.7
2004	-43.000	143.001	-186.001	32.9	-52.2	180.5	3.7
2005	-522.551	-310.436	-212.115	-71.5	-59.5	170.6	3.1
2006	314.701	266.328	48.373	61.4	13.6	201.7	2.7
2007	-1135.895	-514.177	-621.718	-118.5	-174.4	152.0	3.8
2008	-89.938	-203.205	113.267	-46.8	31.8	260.9	3.5
2009	-322.300	-67.995	-254.305	-15.7	-71.3	246.8	3.8
2010	191.397	13.862	177.535	3.2	49.8	301.2	8.1
2011	173.062	96.028	77.034	22.1	21.6	280.6	6.4
2012	213.162	249.430	-36.268	57.5	-10.2	247.3	5.3

The trend was an increase of 0.394 kg of carcase per cow mated per year from 1991 to 2012 (Appendix Figure 2.6). However, there were major changes in numbers between 2003 and 2006, which can be attributed to the effects of the drought.



Appendix Figure 2.6. Southern cattle: Productivity per cow (kg carcase sold per cow mated per year, y) adjusted for changes in the herd size against year (x) from 1991 to 2012.

Given these extreme environmental conditions and the fact that these had a stronger impact in the southern Australia, the data were subsequently analysed with four years (2004 to 2007) removed; the trend (slope) was 1.75 kg carcase sold per cow mated per year.

Appendix Table 2.7. Snapshot of the contribution of cows mated in 2010 to the north Australian beef industry (incl. beef sourced from the Dairy industry)

Year	Numbers in millions of Head									
	Beef Cows Mated	Beef Calves Branded	Beef Calf Slaughter	Dairy Calf Slaughter	Beef Cattle Slaughter	Cull Dairy Cow Slaughter	Finished Dairy Cattle Slaughter	Beef Cattle live Exports	Dairy Cattle live Exports	Beef Herd Change
2010	5.81	-	-	-	-	-	-	-	-	-
2011	-	4.14	0.11	0.01	-	-	-	-	-	-
2012	-	-	-	-	3.72	0.04	0.08	0.55	0.06	-
2013	-	-	-	-	-	-	-	-	-	-0.11

Cows mated in 2010 produced calves in 2011; some of these were slaughtered immediately as calves, while the bulk were slaughtered for beef or exported in 2012. The totals for cattle slaughtered or exported reported by the Australia Bureau of Statistics does not discriminate between dairy and beef cattle or calves. For this reason, numbers of dairy cows culled (taking into account the slight changes in overall dairy cow numbers over the years) and the number of dairy cattle finished and slaughtered were calculated (based on the assumption that 5% of dairy calves are killed as calves, a dairy cow death rate of 3% and a restocking rate of 26%).

Factoring out dairy as well as the decline in beef cattle numbers from 2012 and 2013 led to a higher culling than replacement within the beef herd; the number of beef animals sold (calves in 2011, slaughter and live exports in 2012) exceeds the number of calves born in 2010 by 3%. This is probably due to the fact that cattle are shifted from the south into the north for slaughter.

Appendix Table 2.8. Snapshot of the contribution of cows mated in 2010 to the south Australian beef industry (including beef sourced from the Dairy industry)

Year	Numbers in millions of Head									
	Beef		Slaughters					Live exports		Beef Herd Change
	Cows Mated	Calves Branded	Beef Calves	Dairy Calves	Finished & cull Beef	Cull Dairy	Finished Dairy	Beef Cattle	Dairy Cattle	
2010	2.75	-	-	-	-	-	-	-	-	-
2011	-	2.40	0.54	0.06	-	-	-	-	-	-
2012	-	-	-	-	2.38	0.33	0.64	0.07	0.01	-
2013	-	-	-	-	-	-	-	-	-	-0.10

Other than in the north, the number of animals sold (beef calves 2011, beef cattle slaughtered and exported 2012) does not exceed the number of calves born to cows mated in 2010, but only makes up for 98% of them. Combining both of these percentages results in a surplus of numbers killed of around 1%. This can be attributed to a small change in the age pattern of slaughtered animals (i.e. animals killed after the assumed 2-year age limit).

Summary of productivity trends

Appendix Table 2.9 presents the summary across sheep and beef. The trends used in the subsequent analysis are 0.285 kg per year for sheep, 2.0 kg per year for both Northern beef and Southern beef.

Appendix Table 2.9. Summary of trends in industry-wide productivity expressed as the weight of carcase sold per female mated per year for the period from 1991 to 2012: A – regression; B – change in multi-year (5-year) means.

	Based on regression analysis		**Based on change in opening and closing 5 year means**		**Estimated Upper bound Productivity (kg per year)**
	Rate of gain (kg per year)	**Compound Annual Growth Rate**	**Rate of gain (kg per year)**	**Compound Annual Growth Rate**	
Sheep meat	0.254 (1991-2012) 0.343 (2000-2012)	1.9% 2.5%	0.291 (5-years from 1991) 0.318 (3-years from 1998)	2.2% 2.3%	0.284[1] (0.340)
Northern Beef	2.032 (1991-2012)	1.0%	2.17 (5 years from 1991 & 5 years from 2008)	1.2%	2.0 kg per year[4]
Southern Beef	0.394 (1991-2012) 1.752 kg per year[2] 1.583 kg per year[3]	0.7%	1.68 (5 years from 1991 & 5 years from 2008)	0.7%	1.6 kg per year[5]

2.9A. Estimated annual gain in productivity from the regression analysis (regression of weight of carcase sold (y) against year (x, where year 1 is the first recorded year, 1991)

	All data	**With drought (& wet) years removed**	**Years excluded**	**Compound Annual Growth Rate**
Sheep	$y = 0.254x + 10.60$ $r^2 = 54\%$ $y = 0.263x + 10.15$ $r^2 = 54\%$[52]	$y = 0.294x + 10.39$ $r^2 = 29\%$	2004 to 2007 inclusive	1.90%
Northern beef	$y = 2.032x + 0176.13$ $r^2 = 20\%$	NA	NA	1.00%
Southern beef	$y = 0.394x + 224.26$ $r^2 = 0\%$	$y = 1.752x + 221.90$ $r^2 = 12\%$ (drought) $y = 1.583x + 222.91$ $r^2 = 7\%$ (drought & wet)	2004 to 2007 inclusive (drought) 2004 to 2007 plus 2010 & 2011 (drought & wet)	0.70%

2.9B. Estimated annual gain in productivity from the change in means (multi-year means on a 5-year basis)

	Mean - 1991 to 1995	**Mean - 2008 to 2012**	**Using 5-year means (1991-95 & 2008-12)**	**Compound Annual Growth Rate**
Sheep	11.55	16.79	0.291	2.20%
Northern beef	169.8	208.9	2.17	1.20%
Southern beef	237.1	267.4	1.68	0.70%

Observations on productivity

Productivity can be measured in a variety of ways depending upon the purpose. Irrespective of how it measured it is important to understand the underlying drivers in trends and differences between producers. Recent analysis funded by MLA, focussing on economic

[52] Based on a lag of one year between the mating of ewes and the sale of lambs

performance, has identified the key performance drivers in the respective red meat industry sectors. The information is summarised in Appendix 1 (Observations on productivity). The key findings were that the in the better operations (which may be also related to scale), profitability was a function of higher animal productivity (performance) and lower costs per head, and higher possibly product price. While genetics is likely to be a contributor to some of these factors, overall managerial ability and systems are also likely to be significant contributors.

Northern beef

McLean *et al* reported that operating scale is a factor differentiating the long-term performance of the industry average and Top 25% performers, with long term averages of 2,000 and 3,900AE respectively.[53] This operating scale effect can hide other factors that differentiate the Top 25% performers from the average.

The analysis applying herd size segmentation provided a means to identify the factors influencing performance independent of operating scale (although operating scale is a factor in the 5,400 head + cohort, with the Top 25% performers being considerably larger than the average in this cohort). In the analysis across all herd size cohorts, the Top 25% had:

- higher income per AE through better productivity (kg beef/AE) due to:
  - higher reproductive rates
  - lower mortality rates, and
  - better sale weights (except for the 5,400 head + cohort where scale is a factor)
- lower operating expenses per AE
- better labour efficiency contributing to lower overhead expenses per AE
- lower asset values per AE, meaning equivalent profits per AE equate to higher profitability

Superior long-term performance is not determined by locality, land type, rainfall or price received. The primary difference is management.

Southern beef

In Southern beef the metrics that differentiate the top 20% of producers from the average (measured as net profit per hectare per 100 mm of rainfall in 2012) include:

- higher stocking rate
- higher production per DSE and per hectare
- higher production per head sold
- lower cost of production
- higher labour efficiency.[54]

It is reasonable to conclude that it has been changes (improvements) in these same factors that has been equally important over the last decade.

Sheepmeat

Holmes and Sackett report that the more profitable businesses in 2012 within both the dual

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[53] McLean et al, The Northern beef report 2013 Northern beef situation analysis, MLA project B.COM.0348, April 2014,pgs 63-64

[54] Holmes and Sackett, Southern beef situation analysis, MLA project B.COM.0351, April 2014, pg 24

purpose and prime lamb groups had 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[55]

The lower cost of production was due to the extra production per DSE whilst incurring similar or slightly lower expenses per DSE.

Production per DSE is the kilograms of lamb produced per unit of energy consumed by the flock, where one DSE equals the amount of energy required to maintain a wether (dry sheep). In the Holmes & Sackett benchmarking methodology, DSE ratings are based on estimates of the requirement of each stock class on a monthly basis depending on reproductive rates and animal size. The DSE ratings of stock are not adjusted monthly for actual weight gains which also affect relative energy requirements. Production per DSE is therefore a measure of the ability to convert a predicted level of energy intake into lamb production.

A notable change from 2008 is that the extra production per DSE is no longer translating into a noticeable increase in production per hectare per 100mm of rainfall for prime lamb flocks. There are a number of possibilities as to why this might be the case:

- the results are confounded by rainfall in 2012 with higher than average rainfall limiting the differences seen; a sizeable increase in rainfall without a substantial increase in stocking rate will see production per hectare per 100mm fall;
- the message of achieving higher production per hectare is well understood and more producers are nearer their long-term average economic limits in terms of this key performance indicator.

The first point was likely to be a major influence on the 2012 results. In a year of above average rainfall, the ability for producers to respond with higher production per hectare is limited as per head performance and stocking rates are not adjusted accordingly. In itself this is an opportunity to improve long-term profits.

Whilst there is no clear evidence from the benchmarking of more producers being nearer their long-term average economic limits for kilograms of lamb per hectare per 100mm of rainfall, there is a definite long-term trend of increased production per hectare.

[55] Holmes and Sackett, Prime lamb situation analysis, MLA project B.COM.0351, April 2014, pg 19

Appendix 3. Ewe numbers and mating types – contribution of genetic trends to industry benefit

Overview of analysis

Given the potential complexity of the analysis and the difficulties with respect to obtaining relevant data, the decision was made to assess the change as that between two time points being 2000 and 2012. In order to integrate estimates of genetic trends and gains in productivity, total numbers of animals generated in each mating type (e.g. Merino x Merino, Terminal x Maternal, Maternal x Merino) are required. However, discrepancies in total numbers of ewes across different data sources make it impossible to derive internally-consistent data. Therefore a range of methods have been applied to cross-check data and generate the required estimates.

Time point comparisons

Data analysis for year 2012

The numbers of ewes mated were generated to analyse industry productivity and hence the proportions by breed group can be applied to these numbers, providing a realistic distribution of breeds or types of sheep.

Although the survey[56] data are not consistent (e.g. nomenclature changes between and within years). However, there were two time points (October 2010, February 2012), where there was a complete breakdown by ewe breed[57], and these were used to create a breed breakdown that could then be applied to overall ewe numbers. The numbers generated are summarized in Appendix Table 3.1, and the mating types are in Appendix Table 3.2.

Appendix Table 3.1: Apportionment of ewes to groups in the Australian flock around 2012[58].

Merino ewes for pure Merino matings	Merino ewes for Crossbreeding	Maternal ewes	Terminal ewes	First Cross Maternal x Merino	First Cross Terminal x Merino
54.13%	15.34%	9.73%	4.81%	15.22%	0.77%

[56] Data from Rebecca Matthews (Livestock Market Analyst with MLA) - MLA lamb survey (Feb 2010 to Oct 2013)

[57] *Pure Merino* (Merino ewes to produce pure Merino lambs, including Dohne Merino or South African Mutton Merino), *Other Merino* (Merinos mated to other breeds), *Maternal* (including, among others, Coopworth, Corriedale, Border Leicester, Bond, Finn, East Friesian), *Terminal* (including Dorper, Suffolk, Poll Dorset, Texel, Wiltipoll, Southdown), First Cross Maternal (Border Leicester x Merino as well as ewes designated as First Cross ewe), and First Cross Terminal (including Suffolk x Merino, Dorper x Merino, Dorset x Merino)

[58] Within these groups, all of the ewes are not mated to the same kind of sires; apart from the pure Merino matings, none of these groups can necessarily be assigned one general mating type; albeit estimates can be and were made. Firstly, Terminal ewes were assumed to be mated to Terminal sires only, to generate the Terminal sires required and to maintain the Terminal flock; secondly, matings of crossbred ewes, no matter of which genetic background, were assumed to always be Terminal matings, to produce lambs for the prime lamb market.

Appendix Table 3.2: Distribution of mating types in the Australian flock around 2012.

Merino ewes Mated to Merino Sires	Merino ewes Mated to Maternal Sires	Merino ewes Mated to Terminal Sires	Maternal ewes Mated to Maternal Sires	Maternal ewes Mated to Terminal Sires	Terminal ewes Mated to Terminal Sires	First Cross (Maternal x Merino) Mated to Terminal Sires	First Cross (Terminal x Merino) Mated to Terminal Sires
54.13%	No data	No data	No data	No data	4.81%	15.22%	0.77%

In order to fill the gaps as per the Table above, data on sheep numbers and mating types from the Australian Bureau of Statistics between 2008/9 and 2011/12 were used. Unfortunately, the split lacked detail, although some years did contain a distinction within Non-Merino into “short-haired meat breed” and “Other”. Based on these data, the number of Merino ewes mated to Terminal sires was very high (45% of all joined ewes), which indicated that cross-breeding of Merino ewes with Border Leicester rams to generate first-cross offspring to be mated with Terminals was counted as “Terminal mating”. In this report we consider Border Leicester as a maternal breed, as they are widely used as the maternal contributor (via the sire) in cross-breeding.

Due to this difference in approach, the ABS data could only be used to estimate the percentages of Merino ewes in the flock and of Merino ewes mated to create pure Merino offspring. To derive the estimates of Merino ewes mated to Maternal and Terminal sires respectively as well as the same split over Maternal ewes, the number of First Cross ewes and of Maternal ewes were used to calculate how many ewes would have to be mated per year to sustain the existing flocks. These calculations were based on the following estimates. A flock needs about 26% of its females replaced every year - about 70% of females are deemed suitable (30% hogget culling rate), and a death rate of 3% before first mating was assumed; weaning percentages of 108% (Maternal x Maternal mating), and 86% (Maternal x Merino matings) were applied. The estimates are presented in Appendix Table 3.3, with the conversion to numbers of matings presented in Appendix Table 3.4.

Appendix Table 3.3: Distribution of mating types in the Australian flock around 2012

	Merino ewe	Maternal ewe	Terminal ewe	Merino x Mat	Merino x Ter
Merino Sire	54.13%	-	-	-	-
Maternal Sire	14.65%	5.30%	-	-	-
Terminal Sire	0.70%	4.42%	4.81%	15.22%	0.77%

In order to turn them into a number of matings that took place, the proportions in Appendix Table 3.3 were then applied to the total number of ewes mated in 2012.

Appendix Table 3.4: Numbers of ewe matings by mating types in 2012 (38 mn ewes mated)

	Merino ewe	Maternal ewe	Terminal ewe	Merino x Mat	Merino x Ter
Merino Sire	20.620 mn	-	-	-	-
Maternal Sire	5.414 mn	2.627 mn	-	-	-
Terminal Sire	0.431 mn	1.078 mn	1,833 mn	5,797 mn	0.294 mn

Data analysis for year 2000

Definition of mating type distribution for the year 2000 proved to be even more difficult than for the year 2012, since the survey data were incomplete. The proportion of ewes mated to certain sires was sourced from an ABARE report for a 1997 survey[59]. Due to a lack of any better dataset, these data were applied to the number of ewes mated in 2000 (ex the productivity trend estimates) as per Appendix Tables 3.5 and 3.6.

Appendix Table 3.5: Proportions of mating types according to 1997 ABARE survey

	Merino ewe	First Cross ewe	Other ewe
Merino Sire	54.66%	0.57%	0.33%
Terminal Sire	18.58%	10.46%	2.37%
Other Sire	8.84%	0.82%	3.97%

In assessing the apparent proportions of matings between Merino and Terminal and Merino and Other, it seemed likely that the Border Leicester x Merino matings that generate most First Cross Ewes were in fact counted as Terminal x Merino. Using the same assumptions as those used to calculate Maternal x Merino matings for the 2012 time point, the number of Merino ewes that had to be mated to Maternal rams in order to maintain the first-cross ewe flock was calculated, except that a lower weaning percentage of 81.5% (ex the data used to calculate the productivity trend); however this weaning percentage was then split into Merino and non-Merino, and estimates of 78% for Merino and 98% for non-Merino derived.

Appendix Table 3.6: Proportions of mating types based on the ABARE survey in 1997, corrected for Merino x Maternal matings[60] necessary to sustain the first-cross ewe flock.

	Merino ewe	First Cross ewe	Other ewe
Merino Sire	54.66%	0.57%	0.33%
Terminal Sire	6.77%	10.46%	2.21%
Other Sire	20.65%	0.82%	3.35%

Further adjustments were necessary[61]. The proportions generated were then in turn used to

[59] Research Report *Australian Prime Lamb Industry 2000*, Connell, Hooper & Brittle; ABARE survey run in 1997; analysis required reverse calculations from the numbers of first cross ewes on hand as per the 2009-12 ABS data as the ABARE dataset used a different nomenclature for mating types. While Merino and First Cross matings were split no distinction was made between Maternal and Terminal ewes, but only in terms of the sires they were mated to.

[60] The estimates of the weaning percentages allowed for calculation of the numbers of Maternal x Merino matings necessary; the adjustment assumes that most of the *Terminals* Merino ewes had been mated to were actually Border Leicesters (which we consider Maternal); therefore the estimate for Maternal x Merino matings to sustain the first-cross flock was not used to substitute the matings between Merino and Other, but was defined as Other x Merino.

[61] The transfer of the rams needed to mate these Merino ewes, since these, and their mothers, respectively, were still part of the “Terminal” subset was also estimated. Based on a ram lifetime of 2.5 years, which leads to a restocking rate of 40%, a 50:50 male/female ratio, a 45% culling rate and allowed for 3% deaths, the matings necessary to produce the required number of Maternal sires to service Merino ewes (one per 110 ewes) were calculated. The resulting number was transferred from Terminal x “Other” to “Other” x “Other”, since “Other” was at this point defined to be Maternal. Another impact of the reassignment of Merino x Maternal matings is a change in “Other” ewes mated, which were assumed to be combined Maternal and Terminal ewes. In order to cater for the definition of “Other” as Maternal, these ewes needed to be divided into Maternal and Terminal ewes. This split

calculate the matings necessary to produce these rams. The summary is presented in Appendix Table 3.7, with the conversion to actual numbers of ewes mated in Appendix Table 3.8.

Appendix Table 3.7: Proportions of mating types based on the ABARE survey in 1997

	Merino ewe	First Cross ewe	Maternal ewe	Terminal ewe
Merino Sire	54.66%	0.57%	0.33%	-
Terminal Sire	6.77%	10.46%	1.88%	0.33%

Appendix Table 3.8: Numbers of matings in different mating types in Australia in 2000 (54.2 million ewes mated)

	Merino ewe	First Cross ewe	Maternal ewe	Terminal ewe
Merino Sire	29.653 mn	0.311 mn	0.178 mn	-
Terminal Sire	3.669 mn	5,771 mn	1.020 mn	0.181 mn
Maternal Sire	11.201 mn	0.444 mn	1.818 mn	-

was generated by assessing the number of Terminal sires that would be needed to service the 19.58% of the overall flock that are mated to Terminal sires at 110 ewes per ram lifetime.

Appendix 4A. Industry sector genetic trends

Sheep

Average genetic merit (EBV) for number of lambs weaned (NLW), post-weaning weight (PWT, kg), and adult weight (AWT, kg) for Merino, terminal and maternal sheep (Appendix Table 4.1, 4.2 and 4.3 respectively) from the Sheep Genetics (SG) database[62] for 1993 to 2013, with trait genetic trends (base year is 1990). For the analysis, the trends from 2000 to 2012 are used.

Appendix Table 4.1. Merinos: Average genetic merit (EBV) for traits with the overall annual trend from 2000 to 2012 (individual for weight traits or per 100 ewes mated for NLW).

Year	PWT eBV	AWT eBV	NLW eBV	Year	PWT eBV	AWT eBV	NLW eBV
1993	-0.36	-0.34	-0.4	**2004**	-0.30	0.22	-0.3
1994	-0.44	-0.43	-0.4	**2005**	0.03	0.45	-0.6
1995	-0.45	-0.44	-0.5	**2006**	0.36	0.90	-0.3
1996	-0.44	-0.38	-0.6	**2007**	0.42	0.89	-0.1
1997	-0.29	-0.25	-0.8	**2008**	0.66	1.25	0.1
1998	-0.37	-0.33	-0.6	**2009**	0.97	1.65	0.5
1999	-0.49	-0.51	-0.5	**2010**	1.39	2.16	0.5
2000	-0.59	-0.46	-0.6	**2011**	1.67	2.46	0.8
2001	-0.64	-0.39	-0.8	**2012**	1.89	2.66	0.7
2002	-0.46	-0.05	-0.7	**2013**	2.07	2.98	1.2
2003	-0.34	0.03	-0.5	**Trend (1997 - 2009)**	**0.113**	**0.170**	**0.08**

Appendix Table 4.2. Terminal: Average genetic merit (EBV) for traits

Year	PWT eBV	Year	PWT eBV
1993	0.91	**2004**	6.28
1994	1.26	**2005**	6.92
1995	1.39	**2006**	7.60
1996	1.95	**2007**	8.13
1997	2.34	**2008**	8.67
1998	2.73	**2009**	9.14
1999	3.24	**2010**	9.56
2000	3.94	**2011**	10.02
2001	4.53	**2012**	10.50
2002	5.05	**2013**	11.85
2003	5.68	**Trend (1997 – 2009)**	**0.588**

[62] Extract provided by Hamish Chandler, 23 January 2014

Appendix Table 4.3. Maternal: Average genetic merit (EBV) for traits

Year	PWT eBV	AWT eBV	NLW eBV	Year	PWT eBV	AWT eBV	NLW eBV
1993	-1.47	-2.02	0	**2004**	3.40	4.55	0.5
1995	-0.64	-0.91	0	**2006**	4.50	5.94	1.3
1996	-0.15	-0.30	0	**2007**	4.97	6.53	1.6
1997	0.23	0.20	0.1	**2008**	5.48	7.12	1.7
1998	0.71	0.78	0	**2009**	6.02	7.82	2.0
1999	1.19	1.38	0.1	**2010**	6.33	8.09	2.1
2000	1.79	2.31	0	**2011**	6.86	8.80	2.7
2001	2.27	2.95	0.1	**2012**	7.30	9.29	3.6
2002	2.48	3.29	0.2	**2013**	8.42	10.76	5.9
2003	2.99	4.00	0.3	**Trend (1997 – 2009**	**0.474**	**0.631**	**0.176**

Genetic trend estimates were converted from individual trait units into kgs of CW per ewe mated. The equation describes how eBVs for Merinos and maternal breeds on SG database were converted to kg of carcase weight (CW) per ewe joined in each year (n) since 2000:

$$CW_n = \left[(NLW_0 + n \times \Delta NLWeBV_b) - R)\right] \times CW_0 + [n \times \Delta PWTeBV_b \times KP_L] + (AS_b \times AWT + n \times \Delta AWTeBV_b \times KP_E)$$

where for breed b (b = Merino or maternal), and year n, NLW_0 is the average number of lambs weaned in the first year of the analysis (Merino = 0.87, Maternal = 1.1), $\Delta NLWeBV$ is the average genetic trend for number of lambs weaned (Appendix Tables 4.1 and 4.3), R is the average replacement rate, CW is the carcase weight in the first year of the analysis (19.90 kg from report 7218.0.55.001 Livestock and Meat, Australia, Australian Bureau of Statistics), $\Delta PWTeBV$ is the average genetic trend for post-weaning weight (Appendix Tables 4.1 and 4.3), KP_L is the lamb killing out percentage (48%), AS is the number of adult sheep slaughtered per maternal ewe (as Appendix Figure 4.1 on a breed basis, Merino 0.53 including wethers, Maternal 0.18 culls only), AWT is the average adult ewe weight in the first year of the analysis (Merino 50 kg, Maternal 65 kg), $\Delta AWTeBV$ is the average genetic trend for adult weight (Appendix Tables 4.1 and 4.3), and KP_E is the adult killing out percentage (44%). Note that the eBVs would normally need to be halved to express the trait change in the progeny of a genetically-improved ram in a commercial flock. However, given the long term nature of the trend, it is assumed that, while lagged, the ewes mated to maternal sires are also achieving the same genetic trend. Thus, there is no halving of benefits. This is not the case with terminal sires (see equation below) as no replacements are retained from commercial use of terminal sires mated to maternal ewes.

The calculation below describes how the eBVs for terminal (terminal as listed on SG database) were converted to annual changes in kilograms of carcase weight (ΔCWT) per ewe joined:

$$\Delta CWT = 0.5 \times (LS_b \times \Delta PWTeBV_b \times KP_L)$$

where for breed b (b = terminal), LS is the number of lambs killed per ewe (Terminal =1.1), and the other factors are as in the equation above.

The estimated genetic change in Productivity (carcase weight sold per ewe mated) over the period of 2000 to 2012, based on the equations above, is **0.052 kg**, **0.155kg**, and **0.278 kg** for **Merino**, **Terminal** and **Maternal sheep**, respectively.

Summary of genetic trends for sheep

The trends used in the subsequent analysis are presented in Appendix Table 4.4, and these have been applied at a sub-sector level with inputs in Appendix Table 4.5.

Appendix Table 4.4. Annual trends (2000-2012) in EBVs for the traits applied in the analysis

Breed group	Post-weaning weight (PWT eBV (kg))	Adult weight (AWT eBV (kg))	Numbers lambs weaned per 100 ewes mated (NLW eBV)	Genetic trend in ewe productivity (kg carcase sold per ewe mated)
Merino (Appendix Table 4.1)	0.113	0.170	0.08	0.052
Terminal (Appendix Table 4.2)	0.558	[0.704]	[0.129]	0.155
Maternal (Appendix Table 4.3)	0.474	0.631	0.176	0.278

Appendix Table 4.5. Inputs into analyses to define whole-of-industry sector impact of genetics

	Merino	Terminal	Maternal
Number of lambs weaned per ewe mated (NLW)	0.87	1.1	1.1
Carcase weight (CW, kg) Lamb Dressing-out Proportion (DP)	19.9 (0.48)	19.9 (0.48)	19.9 (0.48)
Ewe weight (kg)	50	65	65
Ewe DP	0.44	0.44	0.44
Ewe annual death rate (Ewe replacement rate)	0.07 (0.25)		0.07 (0.25)
Lambs slaughtered per ewe mated	0.56	NA	0.85
Ewes slaughtered annually (per ewe mated)	0.18	NA	0.18
Annual trends (1993 - 2012)			
PWWT trend	0.124	0.548	0.474
AWT trend	0.173	0.655	0.615
NLW trend per 100 ewes mated	0.076	[0.116]	0.208
Annual trends (1993 - 2008)			
PWWT trend	0.067	0.540	0.461
AWT trend	0.103	0.664	0.613
NLW trend per 100 ewes mated	0.000	[0.001]	0.001
Annual trends (2009 - 2013)			
PWWT trend	0.270	0.636	0.576
AWT trend	0.316	0.730	0.710
NLW trend per 100 ewes mated	0.160	[0.210]	0.930
Annual trends (2000 - 2012)			
PWWT trend	0.220	0.556	0.471
AWT trend	0.270	0.640	0.594
NLW trend per 100 ewes mated	0.137	[0.111]	0.276

Appendix Table 4.6. Genetic trend inputs into analyses to define whole-of-industry sector impact of genetics

Breed group	Post-weaning weight (PWT eBV (kg))	Adult weight (AWT eBV (kg))	Numbers lambs weaned per 100 ewes mated (NLW eBV)	Genetic trend in ewe productivity (kg carcase sold per ewe mated)
1993 to 2008 (16 years)				
Merino	0.067	0.103	0.025	0.081
Terminal	0.540	0.664	[0.111]	0.145
Maternal	0.461	0.613	0.112	0.259
2000 to 2012 (13 years)				
Merino	0.220	0.270	0.137	0.068
Terminal	0.556	0.640	[0.111]	0.145
Maternal	0.471	0.594	0.276	0.284
2009 to 2013 (5 years)				
Merino	0.270	0.316	0.160	0.132
Terminal	0.636	0.730	[0.210]	0.168
Maternal	0.576	0.710	0.930	0.476

Beef

Weighted (by numbers of calves) average genetic merit (estimated breeding value - EBV) for 600 day weight (600WT, kg), and mature cow weight (MWT, kg) for Southern maternal (Angus and Hereford), Southern terminal (Charolais, Simmental, and Limousin), and Northern (Brahman, Santa Gertrudis and Droughtmaster) breeds from the breed society databases[63] are presented below for the years 1994 to 2013. Trait genetic trends are also presented in each of the tables. Note that the base year for analysis is 1990. However, data have been provided from 1994. For the purposes of this analysis, the traits genetic trends from 2000 to 2012 are used.

[63] Extract provided by Sam Gill, 12 March, 2014

Appendix Table 4.7. Southern maternal (Angus and Hereford): Average genetic merit (EBV) for traits with the overall trend from 1993 to 2013 (expressed in productivity terms).

Year	600WT eBV	MWT eBV	Year	600WT eBV	MWT eBV
1994	36.3	36.9	**2005**	67.9	64.8
1995	39.4	40.4	**2006**	70.8	66.0
1996	42.7	43.8	**2007**	72.7	68.2
1997	46.2	47.2	**2008**	75.6	70.7
1998	48.6	49.6	**2009**	77.5	72.0
1999	51.5	52.0	**2010**	79.9	73.9
2000	54.6	54.5	**2011**	81.9	75.2
2001	57.1	56.4	**2012**	84.8	77.7
2002	60.3	58.9	**2013**	90.3	80.8
2003	63.2	61.7	**Trend (1994– 2006)**	**2.86**	**2.42**
2004	65.7	63.3	**Days to calving trend (per day earlier)**		**1.65**

Appendix Table 4.8. Southern terminal (Charolais, Simmental, and Limousin): Average genetic merit (EBV) for traits with the overall trend from 1994 to 2013 (expressed in productivity terms).

Year	600WT eBV	Year	600WT eBV
1994	13.4	**2005**	23.9
1995	14.7	**2006**	25.2
1996	16.9	**2007**	26.2
1997	17.8	**2008**	27.0
1998	18.7	**2009**	27.9
1999	20.0	**2010**	28.6
2000	19.7	**2011**	29.7
2001	21.1	**2012**	31.2
2002	22.3	**2013**	33.6
2003	23.4		
2004	22.6	**Trend (1994 – 2006)**	**0.91**

Appendix Table 4.9. Northern (Brahman, Santa Gertrudis and Droughtmaster): Average genetic merit (EBV) for traits with the overall trend from 1994 to 2013 (in productivity terms).

Year	600WT eBV	MWT eBV	Year	600WT eBV	MWT eBV
1994	9.4	9.5	**2005**	20.2	22.4
1995	10.9	10.5	**2006**	21.0	23.4
1996	10.7	10.8	**2007**	22.9	25.1
1997	11.9	12.4	**2008**	24.2	26.9
1998	12.9	13.5	**2009**	24.9	27.7
1999	13.6	14.2	**2010**	26.2	29.4
2000	14.0	15.1	**2011**	26.8	30.4
2001	15.0	17.1	**2012**	27.2	31.0
2002	17.3	19.0	**2013**	27.4	31.3
2003	18.4	20.6			
2004	19.7	21.3	**Trend (1994 – 2006)**	**1.00**	**1.23**

Genetic trend estimates have been converted from individual trait units to units of kilograms of carcase sold per cow mated. The following calculation describes how eBVs for maternal breeds were converted to kilograms of carcase weight (CW) per cow joined in each year n since 2000:

$$CW_n = (NCW - R) \times (600WT_0 \times KP_P + n \times \Delta 600WTeBV_b \times KP_P] + AS_b \times (MWT_0 \times KP_C + n \times \Delta MWTeBV_b \times KP_C)$$

where for breed *b* (*b* = Southern maternal or Northern), and year n, NCW is the average number of calves weaned per cow mated, R is the average replacement rate, $600WT_0$ is the 600 day weight in the first year of the analysis (490 kg from report 7218.0.55.001 MLA, Aust Bureau of Statistics), $\Delta 600WTeBV$ is the average genetic trend for 600 day weight (Appendix Table 4.7 and Table 4.9), KP_P is the prime killing out (KO%, 53%), AS is the number of adult cows slaughtered per cow, MWT is the average adult cow weight in the first year of the analysis, $\Delta MWTeBV$ is the average genetic trend for mature cow weight (Appendix Table 4.7 and Table 4.9), and KP_C is the adult KO (49%).

The contribution of days to calving (estimate of genetic merit for fertility) to the genetic trend in productivity is calculated assuming that one day earlier to calving is equivalent to 1.32 kilograms of live weight at 600 days. This is based on the proportional contribution of days to calving genetic trend to the overall genetic trend, in dollar terms (200 cents per day of calving).

EBVs would normally be halved to express the trait change in the progeny of a genetically-improved bull in a commercial herd. However, given the long term nature of the trend, it is assumed that, while lagged, the cows involved in mating to maternal sires are also achieving the same genetic trend. Thus, there is no halving of the benefits realised. This is not the case with terminal sires (equation below) as no replacements are retained from the commercial use of terminal sires mated to maternal cows. The equation below describes how eBVs for Southern terminals was converted to annual changes in kg of carcase weight (ΔCWT) per cow joined:

$$\Delta CWT = 0.5 \times (CS_b \times \Delta 600WTeBV_b \times KP_P)$$

where for breed *b* (*b* = terminal), *CS* is the number of cattle killed per cow (Terminal = 0.6), and the other factors are as in the equation above.

The estimated genetic change in carcase weight per cow joined over the period of 2000 to 2012, based on the equations above, is **1.34 kg, 0.38 kg, and 0.37 kg, for Southern maternal, Southern terminal, and Northern beef**, respectively.

Summary of genetic trends for beef

Appendix Table 4.10 Annual trends from 2000 to 2012 (13 years) in EBVs for traits and the derived integrated (composite) upper bound of the genetic trend in cow productivity

Breed group	Weight (600WT eBV)		Cow weight (MWT eBV)	Genetic trend in cow productivity (kg carcase sold per cow mated)
	Direct	Impact of fertility[64]		
Southern maternal (Angus and Hereford)	2.86	0.23	2.42	1.34
Southern terminal (Charolais, Simmental & Limousin)	0.91	0	0	0.38
Northern (Brahman, Santa G & Droughtmaster)	1.00	0	1.23	0.37

Economic genetic trends

The annual rates of genetic gain multiplied by economic weights (Appendix Table 4.11) have been used to create an economic genetic trend to provide an estimate of the upper bound of contribution of genetic improvement via the mating type structure (Appendix 3) of the national flock/herd.

[64] The estimated contribution of reduction in days to calving is based on the assumption that one day is equivalent to 1.60 kg in terms of 600 day (live) weight based on 1 day earlier being valued at $2.00 and carcase weight being valued at $2.32 per kg ($1.24 per kg of 600-day weight). The genetic trend for days to calving in Southern breeds is -0.144 days; there is no genetic trend in the Northern breeds.

Appendix Table 4.11: Annual rates of genetic gain (i.e. average progeny merit) by mating type expressed in economic terms for sheep and beef

Mating type (male x female)[65]	Number of ewes mated	Fate of progeny	Annual rate of genetic gain ($) per ewe mated	
			1997 to 2009	2009 to 2012
Sheep				
Merino x Merino	20.6	Replacements retained	0.07	0.20
Maternal x Merino	5.4	Replacements retained	0.16	0.36
Terminal x Merino	0.4	All slaughtered	0.34	0.37
Maternal x Maternal	2.6	Replacements retained	0.46	0.65
Terminal x Maternal	1.1	All slaughtered	0.65	0.55
Terminal x Terminal	1.8	Replacements retained	0.57	0.47
Terminal x Maternal x Merino	6.1	All slaughtered	0.52	0.64
Southern Beef				
Mating type (male x female)[66]	**Number of cows mated**	**Fate of progeny**	**Annual rate of genetic gain ($) per cow mated[67]**	
			1994 to 2006	**2009 to 2012**
Maternal x Maternal	2.62 mn	Replacements retained	1.78	1.66
Terminal x Maternal	0.58 mn	All slaughtered	1.95	1.78

Estimating adoption

Sheep

Ex-post adoption

The number of rams required to mate the commercial flock was estimated and compared with the capacity of the recorded industry to supply rams (from the expected ram output from Merino, maternal, and terminal breeding dams on the SG database[68]; Appendix Table 4.13).

65 These numbers are used to derive requirements for rams: 20.6 mn ewes mated to Merino, 8.0 mn ewes mated to Maternal rams, and 9.4 mn ewes mated to Terminal rams.

66 These numbers are used to derive requirements for rams: 20.6 mn ewes mated to Merino, 8.0 mn ewes mated to Maternal rams, and 9.4 mn ewes mated to Terminal rams.

67 Made up of 600 day weight ($3.80 for 2000-12, and $4.68 for 2009-13 with a negative value for cow weight in maternal breeds (-$0.73 in 2000-2012, and -$0.83 in 2009-13)

68 Sheep Genetics database: Data provided by Steven Field via Sam Gill, Genetics R & D Project Manager, MLA, 11 February 2014; Average weaning rates in ram breeder flocks were assumed to be of 0.95, 1.3 and 1.2 for Merino, Terminal and Maternal ewes, respectively (Alex Ball, personal communication, 11 March 2014), with 50% of weaned rams sold to commercial producers where they are mated on average to 150 ewes per lifetime.

Appendix Table 4.12. Numbers of ewes in recorded flocks by year.

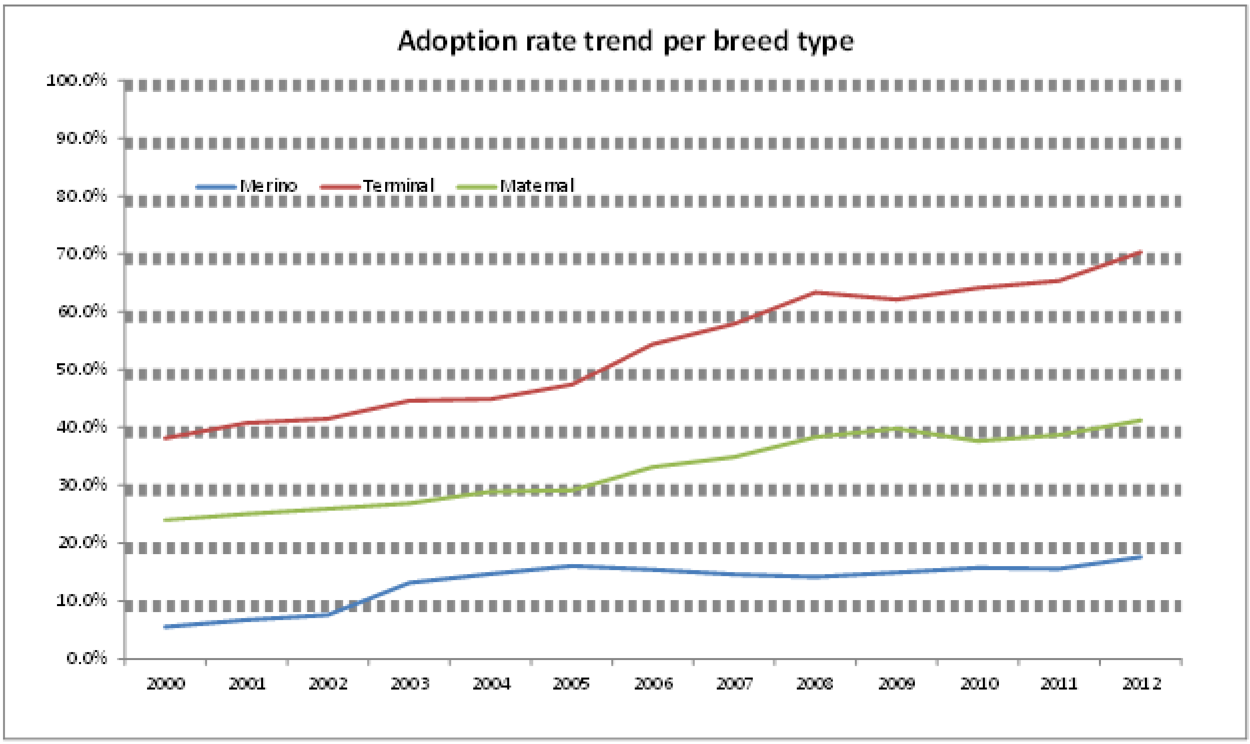
Year	Merino	Terminal	Maternal	Year	Merino	Terminal	Maternal
2000	59,748	87,516	70,949	2007	95,688	120,718	82,415
2001	100,764	93,034	70,943	2008	97,435	123,055	74,382
2002	109,598	92,515	73,579	2009	93,280	123,907	72,776
2003	116,523	96,584	71,470	2010	101,740	131,626	73,619
2004	108,466	109,655	78,074	2011	117,131	133,576	82,139
2005	99,723	115,303	78,840	2012	126,624	128,660	80,919
2006	93,608	124,583	83,043				

Appendix Table 4.13. Estimate of rams required annually to service the sheep sector

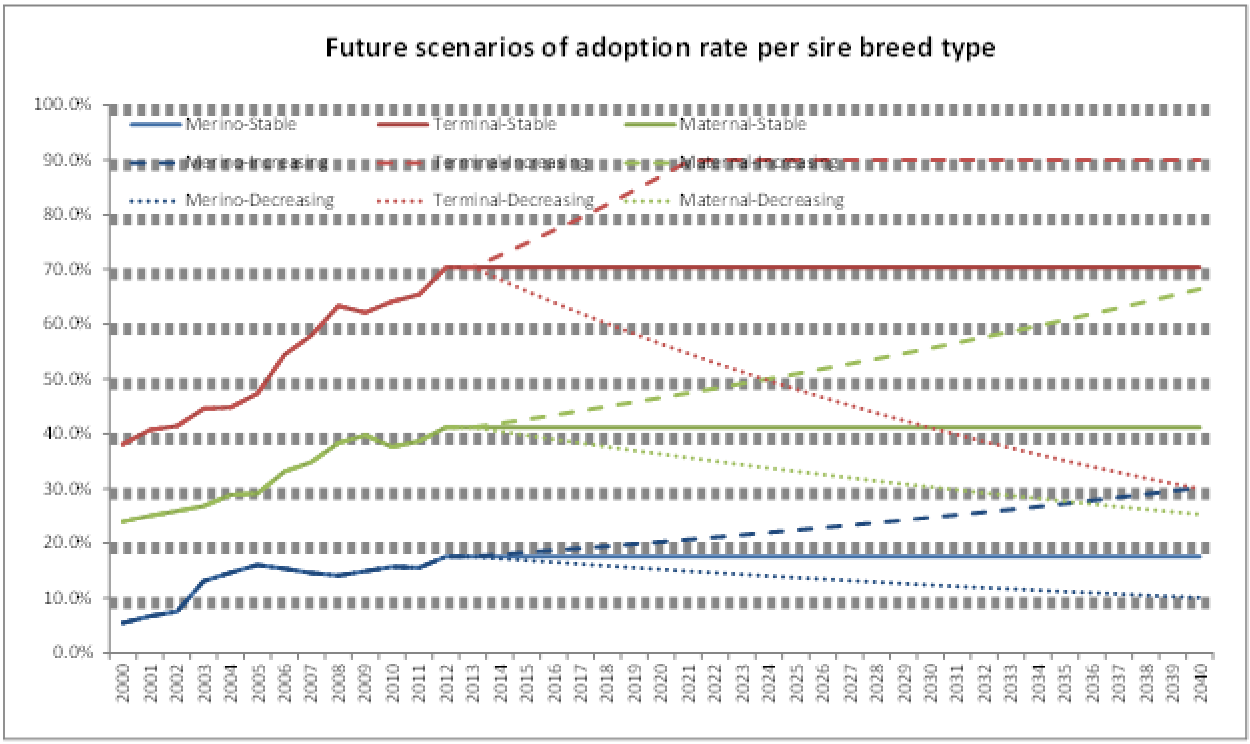
Sheep (38 mn ewes mated)		**Joining rates (females per male per lifetime)**		
Requirement for	Estimated joinings per ram per lifetime (3 year average service life)	200	150	100
	Joining percentage	1.5%	2%	2.5%
Merino rams	Required to be purchased in 2012 to mate 20.6 mn ewes	103,100	137,500	206,200
Terminal rams	Required to be purchased in 2012 to mate 9.4 mn ewes	47,000	63,000	94,000
Maternal rams	Required to be purchased in 2012 to mate 8.0 mn ewes	40,200	53,600	80,400
Capacity to produce Merino rams ex MERINOSELECT (127,000 ewes mated - 50% rams sold)		30,100		
Capacity to produce Terminal rams ex LAMBPLAN (129,000 ewes mated - 50% rams sold)		41,900		
Capacity to produce Maternal rams ex LAMBPLAN (81,000 ewes mated - 50% rams sold)		24,300		

Ex-ante adoption scenarios

Ex-ante scenarios are based on differing trends in adoption including increasing (equivalent rate to the average of 2010/11 and 2011/12 years), no change from current levels (stable), and falling adoption (at the same rate as the average of the 2010/11 and 2011/12, but in the opposite direction), by breed group. For all scenarios, the maximum level of adoption is 90%.



Appendix Figure 4A1. Ex-post adoption rates for predictions of the benefits of genetic improvement, by sire breed



Appendix Figure 4A2. Ex-post and ex-ante (modelled) adoption rates for predictions of the future benefits of genetic improvement, by sire breed

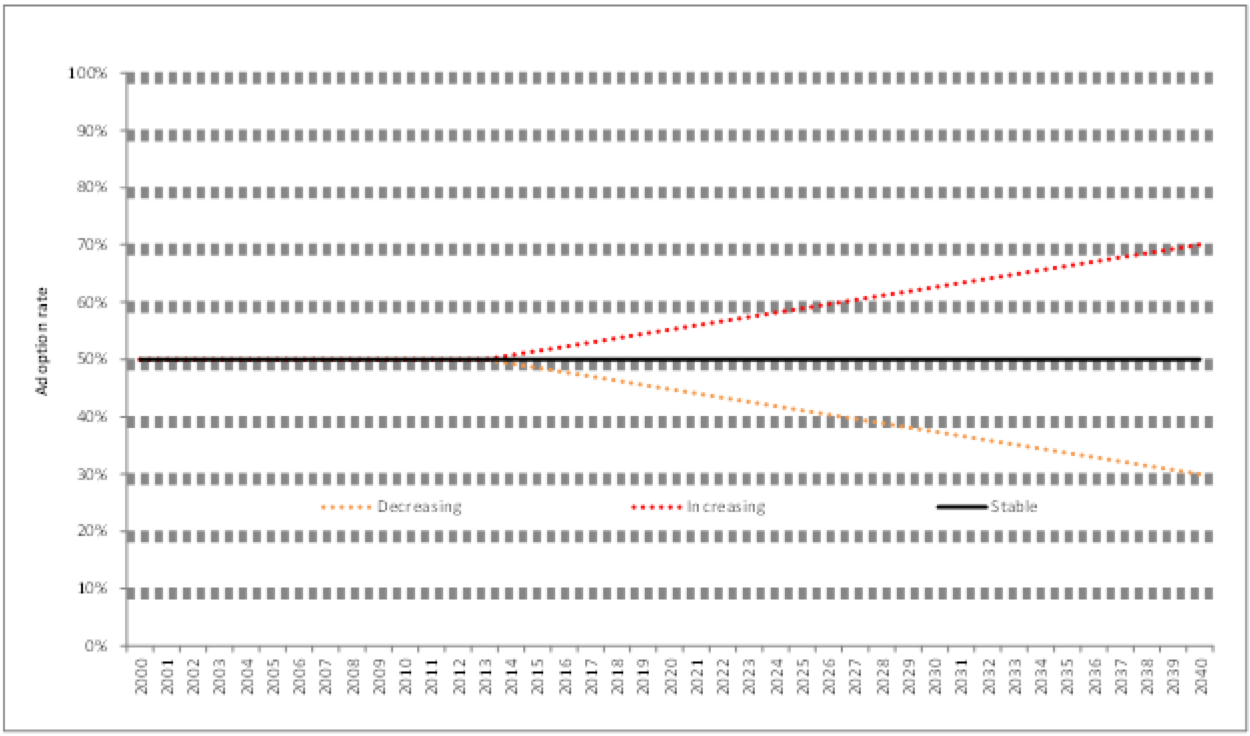
Beef

Ex-post adoption

Ex-post adoption rates were calculated from 2000 to 2011 based on the number of commercial cows mated to improved bulls as a proportion of the total number of cows in the industry per year. The number of cows mated to improved bulls was calculated from the expected bull output from the maternal and terminal breeding dams (Southern breeds) in herds on the ABRI databases[69]. The total of *Bos taurus* cows on the database in 2000 was 139,492 (115,853 maternal and 23,639 terminal cows). In 2012 the equivalent number was 138,955 (115,340 maternal and 23,615 terminal cows). While there has been a significant shift from Hereford to Angus and from Simmental (and, to a lesser extent, Limousin) to Charolais, the number of dams producing genetically improved bulls did not change between 2000 and 2012. The cow numbers include both New Zealand and Australian dams. Data on the number of dams producing bulls in Australia were not available. The bull penetration model was adjusted so that 80% of commercial cows were mated to genetically improved bulls each year between 2000 and 2012.

Ex-ante adoption scenarios

Ex-ante scenarios are based on potential differing trends in adoption including no further adoption from current levels (stable), and falling adoption at two different rates, by breed group.



Appendix Figure 4A3. Ex-post (estimated) and ex-ante (modelled) adoption rates for predictions of the future benefits of genetic improvement, by sire breed

[69] Data ex Christian Duff, Manager, ABRI Beef Breeding Extension Division via Sam Gill, MLA 12 March 2014

Appendix 4B. Economic values for profit traits - BREEDPLAN

Issues and approach

Amongst others, the important genetic traits that have contributed the majority of genetic progress over the time period from 2000 to 2012 are weight gain traits reflected in the growth rate of slaughter cattle and in adult size.

Faster growth of cattle means either heavier slaughter weights at the same age or a shorter production time for the same weight. Thus:

- a heavier animal at the same age has a higher gross return (given a constant $/kg return within broad carcase weight categories);
- a faster growing animal of the same carcase weight has a shorter production time.

Again there is an additional feed requirement to produce an animal with the faster growth rate and thus there are costs associated with this faster growth. Measured on an age constant basis, there are additional days of maintenance and additional feed energy to achieve the higher weight. The weight-constant approach means fewer days of feed energy to meet maintenance energy requirements. In each case feed conversion efficiency is taken as the same.

Methodology and estimates

The following analysis provides estimates of the net economic return for faster growth rate.

The cost of feed

Feed savings are a key factor in both cases. Feed saved has a value: it can be used for other purposes; in other words, it has an opportunity cost. Moreover, the value of this saved feed (opportunity cost) varies across the year, depending upon the alternative uses of the saved feed or what supplementary feed costs to buy in. The value will also vary between years and obviously between farms depending upon individual situations. The present analysis is an approximation of an *average season for typical prime cattle producers*.

In addition, to the additional feed energy costs of growth of slaughter cattle, the reality is that to realise the full potential of genetically faster growth rate on farm requires cows of higher bodyweight. This is an additional net cost against the faster growth cattle beast and is included in the analysis.

Price and performance parameters

Underlying revenue stream data have been used in the calculation of economic weights. Appendix Table 4.14 includes the estimates of price used to compute the opportunity cost of feed energy, which underpins the economic weight for growth rate.

Appendix Table 4.14. Key price and performance assumptions used to compute economic weights

Parameter and units	
Carcase weight price for prime steers (c/kg)[70]	375 cents per kg
Carcase weight price for prime steers (c/kg)	265 cents per kg
Prime carcase weight steer (kg)[71]	290 kg
Prime carcase weight heifer (kg)	260 kg
Average slaughter age (days)	600 days
Prime killing out (%)	51%
Average cow mature weight (kg)	600 kg
Cow killing out (%)	49%

Feed and the cost of energy

Differences in feed value can be defined by accounting for the direct (purchased) or opportunity cost of feed when fed to different classes of stock, by season. The opportunity cost might be the value of using on-farm conserved fodder or grain (which could otherwise be sold) or the revenue from adding weight to a steer/ heifer.

The impact of changes in traits of interest on feed costs is accounted for by estimating feed requirements per unit of trait change and the feed costs by season. For the purpose of valuing feed, the calendar year was divided into three periods, representing spring, summer plus autumn combined, and winter (60 days, 245 days, and 60 days respectively).

Spring feed is estimated to be, on average, ‘in excess’, and therefore free. In summer and autumn, additional feed requirements impinged on feed available to finish steers or heifers (i.e. either slowing growth rate or requiring supplementary feeding of cows to maintain the growth rate). In winter, additional feed requirements were met by feeding out grain.

Prime cattle – summer and autumn

Incorporating the opportunity cost of feed energy in summer/ autumn enables the benefit of increased growth rate to be accounted for in full.

On the basis that a steer weighing 290kg live weight and growing at 0.95 kg/ day requires 1.05 days eating 7.90 kg of DM per day to gain 1 kg of live weight (with a carcase weight price of $3.75 per kg, Appendix Table 4.15), the opportunity cost of summer/ autumn feed can be calculated at **$0.022 per MJME** or **$0.23 per kg DM** (10.5 MJME per kg of DM consumed). For heifers, an equivalent cost model is described such that a heifer weighing 260kg live weight and growing at 0.85 kg/ day requires 1.2 days eating 7.3 kg of DM per day to gain 1kg of live weight; the opportunity cost is **$0.021 per MJME** or **$0.22 per kg DM (**10.5 MJME per kg DM).

The average opportunity cost is therefore **$0.0215 per MJME** or **0.225 per kg DM** at 10.5 MJME per kg of DM consumed

Cows – summer and autumn

The additional feed requirement for adult cows in summer and autumn was estimated to

[70]Weighted average price paid per kg CW (7218.0.55.001 Livestock and Meat, Australia, Australian Bureau of Statistics and Eastern Young Cattle Index data)

[71]Average CW in 2012 (7218.0.55.001 Livestock and Meat, Australia, Australian Bureau of Statistics)

impact on the feed available to finish steers and heifers, with an adjustment for pasture utilisation by grazing cows (70%) compared with growing animals (50%). The resulting value of summer/autumn feed when fed to cows is **$0.015 per MJME** or **$0.16 per kg of DM** at 10.5 MJME per kg of DM consumed. That is, the revenue foregone by feeding cows instead of finishing cattle. It is assumed that the adult cow competes with the prime animals for 50% of this feed. The remainder is free.

Winter feed costs for all stock

Winter feed costs are calculated assuming that the extra energy demand has to be met by feeding out conserved feed in the form of grain, valued at $250 per tonne (calculated on a 90% DM basis). The resulting winter feed costs are calculated at **$0.0210/ MJME** at 13.5 MJME per kgDM consumed (Holmes and Sackett. 2013. Supplementary feed options – On farm, 143: 2 – 5).

Discounted genetic expressions

The approach taken for computing discounted genetic expressions (DGE) is analogous to that used for sheep breeding objectives in New Zealand (Byrne *et al.*, 2012) and Ireland (Byrne *et al.*, 2010) and to those for beef in Ireland (Amer *et al.*, 2001; Berry *et al.*, 2006), and in the UK (Roughsedge *et al.*, 2005). The equations are complex and are not presented here. Amer (1999) presents methodology where indexes are in units which represent the contribution to profitability of the selection candidates' genes per cow mated, over a 10 year investment period.

The assumptions used to compute the discounted genetic expressions include:

- A cow herd age distribution (Appendix Table 4.15)
- Cow losses where the cow is dead on farm and no cull value is salvaged
- Pre-weaning calf survival rate of 93%
- Post weaning calf survival (to slaughter or first calving) of 95%
- Cull for age threshold of 10 years after which all commercial cows are culled
- A planning horizon of 20 years after which any economic benefits (at this point trivial) are ignored
- A discount rate of 7% per annum taken as the farm mortgage rate after adjustment for inflation (note that this is quite variable, but over the last 10 years, has averaged very close to 7%)
- That 53% of a maternal sire’s surviving heifer calves are kept as replacements assuming the goal is to maximise use of terminal sires in the herd, but also allowing for 20% of heifers either not achieving mating weights, not getting in calf or being culled for faults
- That surplus animals are slaughtered at 20 months of age

Appendix Table 4.15. Parameters for discounted genetic expressions coefficients (cow age)

Cow age	Survival	Proportion of herd (%)	Proportion of animals within an age group that do not express cull carcase traits as they die on farm (%)
1	1	-	-
2	0.88	0.204	25%
3	0.91	0.167	15%
4	0.9	0.141	10%
5	0.9	0.119	10%
6	0.85	0.100	10%
7	0.8	0.085	10%
8	0.7	0.072	20%
9	0.6	0.061	30%
10	0.5	0.035	40%

The resulting discounted genetic expressions for the key trait types of interest expressed as discounted number of expressions of the bulls genes per cow mated are in Appendix Table 4.16. The coefficients are expressed on a progeny basis so index values do not need to be halved when evaluating the expected profitability of a bull's progeny. The following notes describe how these DGEs are used.

- These coefficients can be translated to discounted expressions of the bull's genes from his lifetime matings by multiplying by the product of the average number of working years for a bull, and the average number of cows calving per bull joined per year in the herd of interest. Discounting for the delays with multiple mating years has already been taken account of in Appendix Table 4.16.
- The expressions of annual cow traits reflect the proportion of daughters kept as replacements, plus the average number of calving events through a typical cow's life, plus further female descendants and discounting
- Slaughter traits are proportionally less because of a smaller number of animals slaughtered per female descendant kept as a replacement; a discounting factor accounts for the time lag from birth to slaughter.
- Heifer replacement traits are approximately the value for cow expressions at birth multiplied by the proportion of the herd which are heifers.
- Cull cow expressions are less than heifer expressions because of substantial discounting effects for the additional delay, plus an allowance for dead-on-farm cows for which no slaughter value can be salvaged.

Appendix Table 4.16. Discounted genetic expressions coefficients used in index construction

Trait type	Maternal sire	Terminal sire
Slaughter	0.531	0.404
Heifer replacement	0.159	N/A
Annual cow	0.644	N/A
Cull cow	0.109	N/A

Economic values

Economic value of 600 day weight

The economic value of growth rate can be calculated assuming slaughter at a constant age, such that faster growing animals result in heavier carcasses at slaughter, and thus more revenue. Extra feed costs to achieve a heavier carcase weight (through higher maintenance and growth) are subtracted from the revenue resulting from this higher carcase value.

The value of faster growth rate can also be calculated through a reduction in days to slaughter (i.e. slaughter at constant carcase weight). Realised benefits of a reduction in days to slaughter manifest in less feed costs for maintenance.

Age constant: The value of a heavier carcase at slaughter resulting from 1 kilogram of 600 day weight is $1.97 ($3.75 x 0.53). For a steer growing to 574 kg kilograms live weight (290 kg /0.53), the total feed energy requirements are 51,087 MJME. For a steer growing to 575 kilograms of live weight, the total feed energy requirements are 51,134 MJME (Nicol and Brookes, 2007). Taking into account seasonal feed costs (above) during finishing animal growth, this 47 MJME difference in energy requirements equates to a feed costs to achieve the heavier 600 day weight (through higher maintenance and growth) of $0.85. For a heifers growing to 508 kg kilograms live weight (260 kg /0.53), the total feed energy requirements are 47,098 MJME. For a heifer growing to 509 kilograms of live weight, the total feed energy requirements are 47,158 MJME. This difference of 60 MJME has a cost of $1.11.

The economic value of 600 day weight at age constant slaughter is therefore **$1.12** per kg of 600 day weight in steers and **$0.86** per kg of 600 day weight in heifers.

Weight constant: Based on a growth rate at slaughter of 0.8 kilograms per day, and a slaughter weight of 574 kilograms, a faster growing steer slaughtered at the same weight will reach that weight 1.25 days earlier. A reduction in days to slaughter is manifest in a lower feed cost for maintenance, as a result of fewer days on farm, but also slightly higher maintenance and growth costs for the period on farm. The feed savings as a result of 1.25 days saved maintenance is 164 MJME, while the higher maintenance and growth costs for the days on farm equates to 56 MJME (Nicol and Brookes, 2007). Therefore the net feed saving is 108 MJME.

When accounting for feed costs, the economic value of 600 day weight at weight constant slaughter is therefore **$2.84** per kg 600 day weight for steers. Based on a growth rate at slaughter of 0.7 kilograms per day, and a slaughter weight of 508 kilograms, a faster growing heifer slaughtered at the same weight will reach that weight 1.43 days earlier. The equivalent economic value of 600 day weight at weight constant slaughter is **$2.62** per kg 600 day weight for heifers.

Weight change data (7218.0.55.001 Livestock and Meat, Australia, Australian Bureau of Statistics) suggests that beef carcase weight has increased with no change in the slaughter distribution. Thus, it is apparent that farmers are capturing the benefits of faster growth rates through age constant slaughter.

Economic value of cow mature weight (EWT)

The genetic expression of a faster growth rate in steers and heifers has implication for the genetic expression of replacement and adult cow traits. The factors to consider include:

- Genetically higher growth rate in steers and heifers produces cows of higher bodyweight, which in turn, means higher feed energy maintenance requirements.
- Supplying replacement heifers of a higher bodyweight means higher feed requirements to reach the required weight. Thus there are additional feed requirements on the same farm or other farms supplying breeding cows.

- Heavier cows also have a higher slaughter value when culled and sold, thus off-setting the higher feed costs, to some degree.

These factors are reflected in the economic value of cow mature weight.

- The increase in annual maintenance feed requirements for breeding cows was calculated assuming the breeding cows are fed grain for 60 days each winter, and for a further 245 days cows compete with finishing cattle for 80% of their energy requirements during summer/ autumn (with higher utilisation, as above), with the remainder of summer pasture for cows being free (see feed cost calculations above). The daily maintenance requirement of 85 MJME for a 600 kg cow was assumed to increase proportionally by the ratio $[(LW+1)^{0.75}-LW^{0.75}]/LW^{0.75}$ throughout the year with each 1 kg increase in mature cow live weight. This equated to 0.11 MJME per day and resulted in an economic value of -$0.47 per kg increase in cow mature weight.
- The increase in feed costs to rear a heifer replacement to a higher live weight and a higher ultimate mature weight were calculated using the same model as for weight traits above, but with a different growth rate profile. Replacements were assumed to reach mature weight at 910 days-of-age (30 months). The total additional feed requirements equated to 86 MJME. Seasonal feed costs were assumed identical to the cattle finishing systems. This resulted in an economic value of -$1.54 per kg increase in mature weight.
- Heavier cows result in higher cull value for those cows that are slaughtered (note that cows dying before slaughter are taken into account in the calculation of the appropriate discounted genetic expressions coefficient). Thus, the economic value can be taken as 0.49 (cow killing out %) multiplied by the price premium per kg for cull cows of $2.65 per kilogram giving an economic value of $1.30 per kilogram of mature weight.

Economic weights

Economic weights (detailed in Appendix Table 4.17) incorporate economic values multiplied by appropriate DGE coefficients such that the economic weight can be used to value genetic improvement. Farm economic models, or the information required to build them, were not available for the North. Therefore for Northern beef, the economic weights were assumed to be half that of Southern beef, based on reduced feed availability in the North.

Appendix Table 4.17: Summary of economic values and economic weights for breeding objective traits to value genetic change

Component		EV ($/trait unit)	EW ($ per cow mated) by bull type	
			Maternal	**Terminal**
Cattle growth				
600 day weight				
	Earlier slaughter heifers	2.62	1.39	1.06
	Earlier slaughter steers	2.84	1.51	1.15
	Heavier carcase weight heifers	0.86	0.46	0.35
	Heavier carcase weight steers	1.12	0.60	0.45
Adult size				
Cow mature weight			-0.28	
	Cow feed costs	-0.34		
	Cow replacement feed	-1.29		
	Carcase salvage value	1.30		

Appendix 4C. Economic values for profit traits - LAMBPLAN

Issues and approach

Amongst others, the important genetic traits that have contributed the majority of genetic progress over the time period from 2000-01 to 2011-12 are numbers of lambs weaned, lamb growth rate, and adult size.

The value of an additional lamb is the sale value of an additional lamb less the additional production costs (in particular feed energy) as well as the fixed costs.

Faster growth of lambs means either heavier slaughter weights at the same age or a shorter production time for the same weight. Thus:

- a heavier lamb at the same age has a higher gross return (given a constant $/kg return within broad carcase weight categories).
- a faster growing lamb of the same carcase weight has a shorter production timeframe.

Again there is an additional feed requirement to produce the faster growth rate lamb and thus costs associated with this faster growth. Measured on an age constant basis, there are additional days of maintenance and additional feed energy to achieve the higher weight. The weight constant approach means fewer days of feed energy to meet maintenance energy requirements. In each case feed conversion efficiency is the same.

Methodology and estimates

The following analysis provides estimates of the net economic return for an additional lamb and faster growth rate.

<u>The cost of feed</u>

Feed savings are a key factor in both cases. Feed saved has a value: it can be used for other purposes; in other words, it has an opportunity cost. Moreover, the value of this saved feed (opportunity cost) varies across the year, depending upon the alternative uses of the saved feed or what supplementary feed costs to buy in. It will also vary between years and obviously between farms depending upon individual situations. The present analysis is an approximation of an ‘average season for typical prime lamb producers’.

In addition, to the additional feed energy costs realising the full potential of genetically faster growth rate on farm requires ewes of higher bodyweight. This is an additional net cost against the faster growth lamb and is included in the analysis.

<u>Price and performance parameters</u>

Underlying revenue stream data have been used in the calculation of economic weights (Appendix Table 4.18) includes the estimates of price used to compute the opportunity cost of feed energy, which underpins the economic weight for growth rate.

Appendix Table 4.18. Key price and performance assumptions used to compute economic weights

Parameter and units	Price
Price premium for a 22kg carcass weight lamb versus 21kg (c/kg)[72]	385 cents per kg
Price premium for a 25kg carcass weight ewe versus 24kg (c/kg)[73]	230 cents per kg
Lamb carcase weight (kg)[74]	22.0 kg
Weaning weight single lamb (kg)	29.5 kg
Weaning weight twin lamb (kg)	26.5 kg
Post-weaning lamb survival single lamb (%)	98%
Post-weaning lamb survival twin lamb (%)	95%
Average slaughter age (days)	200 days
Lamb dressing (%)	48%
Average ewe mature weight (kg)	60 kg
Ewe killing out (%)	44%
Lamb fixed costs ($ per lamb)	$5 per lamb

Feed and the cost of energy

Differences in feed value can be defined by accounting for the direct (purchased) or opportunity cost of feed when fed to different classes of stock, by season. The opportunity cost might be the value of using on-farm conserved fodder or grain (which could otherwise be sold) or the revenue from adding weight to a lamb.

The impact of changes in traits of interest on feed costs is accounted for by estimating feed requirements per unit of trait change and the feed costs by season. For the purpose of valuing feed the calendar year was divided into three periods, representing spring, summer plus autumn combined, and winter (60 days, 245 days, and 60 days respectively).

Spring feed is estimated to be, on average, 'in excess', and therefore free. In summer and autumn additional feed energy requirements impinged on feed available to finish lambs (i.e. either slowing growth rate or requiring supplementary feeding of ewes to maintain lamb growth). In winter, additional feed requirements were met by feeding out grain.

Appendix Table 4.19. Feed costs

	Price per tonne	MJ ME per kg DM	DM	Utilisation	$ per tonne consumed	$ per kg DM consumed	Cost per MJ ME consumed
Grain	$230	13	90%	85%	$301	0.301	0.0231
Pasture	Summer	Lambs					0.0154
		Ewes					0.055

[72] Weighted average price paid per kg CW (7218.0.55.001 Livestock and Meat, Australia, Australian Bureau of Statistics and Eastern States Trade Lamb Indicator data)

[73] Eastern States Daily Indicators; Livestock indicator report. National Livestock Reporting Service

[74] Average CW in 2012 (7218.0.55.001 Livestock and Meat, Australia, Australian Bureau of Statistics and Eastern States Trade Lamb Indicator data).

Cost of summer/ autumn feed for prime lamb production

Incorporating the opportunity cost of feed energy in summer/ autumn enables the benefit of increased growth rate to be accounted for in full.

On the basis that 250 MJME increases carcase weight in a 43 kg lamb growing at 150 g per day by 1 kg (Nicol and Brookes, 2007) (and with a carcase price of $3.77 per kg (16)), the opportunity cost of summer/ autumn feed can be calculated at **$0.0154 per MJME** or **$0.162 per kg of DM** at 10.5 MJME per kg of DM consumed (i.e. 23.80 kg of DM is required to add 1 kilogram of carcase weight (valued at $3.77/kg) = $0.158/kg DM).

Summer/ autumn feed costs for ewes

The additional feed requirement for adult ewes in summer/ autumn was estimated to impinge on the feed available to finish lambs, with an adjustment for pasture utilisation by grazing ewes (70%) compared with lambs (50%). The resulting value of summer/autumn feed when fed to ewes is **$0.0110 per MJME** or **$0.115 per kg of DM** at 10.5 MJME per kg of DM consumed. That is, the revenue foregone by feeding ewes instead of finishing lambs. It is assumed that the adult cow competes with the prime animals for 50% of this feed. The remainder is free.

Winter feed all stock classes

Winter feed costs are calculated assuming that the extra energy demand has to be met by feeding out conserved feed in the form of grain, valued at $280/ tonne (calculated on a 90% DM basis). The resulting winter feed costs are calculated at **$0.0230/ MJME** at 13.5 MJME per kg DM consumed (Holmes & Sackett 2013. Supplementary feed options – On farm, 143: 2 – 5).

Discounted genetic expressions

The approach taken for computing discounted genetic expressions (DGE) is analogous to that used for sheep breeding objectives in New Zealand (Byrne *et al.*, 2012) and Ireland (Byrne *et al.*, 2010) and to those for beef in Ireland (Amer *et al.*, 2001; Berry *et al.*, 2006), and the UK (Roughsedge *et al.*, 2005). The equations are complex and are not presented here. Amer (1999) presents methodology where indexes are in units which represent the contribution to profitability of the selection candidates' genes per lamb born, over a 10 year investment period.

The assumptions to compute the DGE are detailed include:

- For the economic weights presented, average NLB was assumed to be 1.22 (1.1 weaned) for maternal and terminal breeds and 0.93 (0.87 weaned) for Merinos; cross-breds (Maternal x Merino and Maternal x Terminal, as dams) were assumed to have the same NLB as Maternal breeds;
- Replacement rate is assumed to be 0.25;
- Proportion of maternal rams' daughters retained is 0.45 with NLB at 1.22, and 0.58 at NLB of 0.93;
- Weighted average pre-weaning lamb survival is 0.923 at NLB of 1.22, and 0.951 at NLB of 0.93;
- Post-weaning lamb survival is assumed to be 0.98;
- Annual ewe death rate of 5.2%;
- A discount rate of 7% per annum taken as the farm mortgage rate after adjustment for inflation; note that this is quite variable, but over the last 10 years, has averaged very close to 7%;
- Surplus animals are slaughtered at an average age of 200 days;

- Cull for age threshold of 6 years after which all commercial ewes are culled;
- Flock age distributions and the proportion of ewes salvaged by age group are presented in Appendix Table 4.20 below.

Appendix Table 4.20. Parameters for DGE coefficients by ewe age

Ewe lambing age	Survival proportion	Proportion of flock	Salvage proportion
1	1.00	-	-
2	0.94	0.25	0.94
3	0.88	0.234	0.94
4	0.82	0.218	0.88
5	0.68	0.181	0.75
6	0.44	0.117	0.60

The resulting DGE coefficients for traits expressed at various times in an animal's life, in the units of expressions of a rams' genes per ewe mated, are presented in Appendix Table 4.21.

Appendix Table 4.21. Discounted genetic expression coefficients, per ewe mated, used in calculation of economic weights

	Merino		**Maternal**		**Crossbred**	**Terminal (self-replacing)**
Ewe type	**Replacements**	**Surplus**	**Replacements**	**Surplus**		
Ram type	***All***	***Terminal***	***All***	***Terminal***	***Terminal***	***Terminal***
Trait type						
Lambs at slaughter – direct	0.569	0.43	0.684	0.55	0.55	0.684
Ewe replacement	0.218	0	0.174	0	0	0.174
Annual ewe	0.768	0	0.000	0	0	0.000
Cull ewe	0.135	0	0.135	0	0	0.135

Increasing the Number of Lambs Weaned (NLW) increases the relative emphasis placed on traits expressed in lambs relative to traits expressed in ewe replacements and adult ewes in a maternal index. This is because with higher NLW, a smaller proportion of females are kept to sustain the flock per ewe mated, and so expressions of ewe traits are reduced. The following notes describe how these DGEs are used.

- The coefficients in Appendix Table 4.21 are expressed on a progeny basis so index values do not need to be halved when evaluating the expected profitability of a ram's progeny.
- These coefficients can be translated to discounted expressions of the ram's genes from his lifetime matings by multiplying by the product of the average number of working years for a ram, the average number of ewes mated to the ram in the flock of interest. Discounting for the delays with multiple mating years has already been taken account of in Appendix Table 4.21.
- The expressions of annual ewe traits reflect the proportion of daughters kept as replacements, plus the average number of lambing events through a typical ewe's life, plus further female descendants and discounting.

- Slaughter traits are proportionally less because of a smaller number of animals slaughtered per female descendant kept as a replacement; a discounting factor accounts for the time lag from birth to slaughter.
- Ewe replacement traits are approximately the value for ewe expressions at birth multiplied by the proportion of the flock which are 2 years old.
- Cull ewe expressions are less than those of replacements because of substantial discounting effects for the additional delay, plus an allowance for dead-on-farm ewes for which no slaughter value can be salvaged.

Economic values

Economic value of number of lambs weaned (NLW)

The economic value of an additional lamb has been estimated as the difference in margin from producing/marketing twin lambs compared to a single lamb. That is, the returns from selling twins (recognising additional losses to weaning) less the additional feed costs (ewe maintenance during pregnancy and during lactation) and the longer time to finish a twin lamb to the same carcase weight as a single lamb.

- The extra energy required during pregnancy by a twin-bearing ewe and lambs relative to a single bearing ewe and lamb are estimated at 145 MJME (Nicol and Brookes, 2007).
- In addition there is extra feed energy required from birth to weaning by a twin-bearing ewe and her lambs estimated at 1,075 MJME (Nicol and Brookes, 2007).
- Therefore, a total of 1,220 MJME is required for the additional lamb up to weaning

Based on the weight difference (3 kg) between a single lamb and twin lambs at weaning (Table 4.16), a post-weaning growth rate of 0.2 kilograms per day, and a slaughter weight of 47.8 kilograms, a twin requires an additional 15 days of feeding to reach slaughter. Therefore, total post weaning feed energy costs for a single lamb are estimated at 1,160 MJME, and for a twin lamb at 1,417 MJME (Nicol and Brookes, 2007). The survival rate for a single lamb is 0.98 and lamb production fixed costs are $5 (Table 4.19).

The revenue from a single litter is thus $82.90 ($3.85/ kg CW x 22 kg x 0.98). Single lamb feed costs are $17.18 (1,160 MJME post weaning x 0.0154 per MJME summer/ autumn feed), and fixed costs are $5. The margin from a single lamb is therefore $60.08.

The revenue from twins is $160.80 ($3.85/ kg CW x 22 kg x 0.95 x 2 lambs). Lamb feed costs are $43.60 (1,417 MJME post weaning x 0.0154 per MJME summer/ autumn feed x 2 lambs). Additional ewe feed costs are $5.30 [(145 MJME pregnancy energy x 0.021 per MJME winter feed + (1075 x (60/100) x 0[75]) + (1075 x (100-60)/100) x 0.0110), and fixed costs at $10 ($5 x 2). The margin from a twin litter is therefore $99.10.

The economic value of NLW is therefore **$41.75** ($101.82 – $60.08) per additional lamb weaned.

Economic value of post weaning weight (PWT)

The economic value of growth rate can be calculated assuming slaughter at a constant age, such that faster growing animals result in heavier carcasses at slaughter, and thus more revenue. Extra feed costs to achieve the heavier carcase weight (through higher maintenance and growth) are subtracted from the revenue resulting from this higher carcase value.

The value of faster growth rate can also be calculated through a reduction in days to

[75] This is based on the assumption that spring feed is in surplus and is therefore notionally free

slaughter (i.e. carcase weight constant slaughter). Realised benefits of a reduction in days to slaughter manifest in less feed costs for maintenance.

Age constant: The value of a heavier carcase at slaughter resulting from 1 kilogram of PWT is $1.85 (3.85 x 0.48). For a lamb growing to 47.8 kilograms live weight (22 kg /0.48), the total feed requirements before weaning are 1,600 MJME, and total feed requirements after weaning are 1831 MJME. For a lamb growing to 48.8 kilograms of live weight, the total feed requirements before weaning are 1,631 MJME, and total feed requirements after weaning are 1864 MJME (Nicol and Brookes, 2007). Taking into account seasonal feed costs during lamb growth, the energy requirements in the first 60 days (spring), for a lamb growing to 48.8 kilograms compared to a lamb growing to 47.8 kilograms, is 15 MJME. The equivalent figure for the following 140 days (summer/ autumn) to slaughter is 50 MJME. Therefore the feed costs to achieve the heavier carcase weight (through higher maintenance and growth) are $0.73 (18 x 0 + 47 x 0.0154).

The economic value of PWT at age constant slaughter is therefore **$1.12** per kg of PWT.

Weight constant: Based on a post-weaning growth rate of 0.2 kilograms per day, and a slaughter weight of 47.8 kilograms, a faster growing lamb slaughtered at the same post weaning weight will reach that weight 5 days earlier. A reduction in days to slaughter manifests in less feed costs for maintenance, as a result of fewer days on farm, but also slightly higher maintenance and growth costs for the days on farm. The feed savings as a result of 5 days saved maintenance is 100 MJME, while the higher maintenance and growth costs for the days on farm equates to 58 MJME (Nicol and Brookes, 2007). Therefore the net feed saving is 42 MJME.

With the value of this feed at 0.0154, the economic value of PWT at weight constant slaughter is therefore **$0.64**.

Weight change data (7218.0.55.001 Livestock and Meat, Australia, Australian Bureau of Statistics) suggests that lamb carcase weight has increased with no change in the slaughter distribution. Thus, it is apparent that farmers are capturing the benefits of faster growth rates through age constant slaughter. The appropriate economic value is **$1.12** per kg of PWT.

Economic value of ewe mature weight (EWT)

The genetic expression of a faster growth rate in lambs has implication for the genetic expression of replacement and adult ewe traits. The factors to consider are detailed below.

- Genetically higher growth rate in lambs produces ewes of higher bodyweight, which in turn, means higher feed energy maintenance requirements.
- Supplying replacement ewes of a higher bodyweight means higher feed requirements to reach the required weight. Thus there are additional feed requirements on the same farm or other farms supplying breeding ewes.
- Heavier ewes also have a higher slaughter value when culled and sold, thus offsetting the higher feed costs, to some degree.

These factors are reflected in the economic value of ewe mature weight.

- The increase in annual maintenance feed requirements for breeding ewes. This was calculated assuming the breeding ewes are fed grain for 60 days each winter, and for a further 245 days ewes compete with finishing lambs for 80% of their energy requirements during summer/ autumn (with higher utilisation, as outlined above), with the remainder of summer pasture for ewes being free (see preliminary feed cost calculations above). The daily maintenance requirement of 11.2 MJME for a 60kg ewe was assumed to increase proportionally by the ratio $[(LW+1)^{.75}-LW^{.75}]/LW^{.75}$ throughout the year with each 1 kg increase in mature ewe live weight. This equated to 0.14 MJME per day and resulted in an economic value of -$0.32 per kg increase in ewe mature weight.

- The increase in feed costs to rear a ewe replacement to heavier live weight targets and a higher ultimate mature weight was calculated using the same model as for weight traits above, but with a different growth rate profile. Replacements were assumed to reach mature weight at 580 days-of-age (19 months). The total additional feed requirements equated to 100 MJME. Seasonal feed costs were assumed identical to the lamb finishing systems. This resulted in an economic value of -$0.884 per kg increase in mature weight.
- Heavier ewes result in higher cull value for those ewes that do not die prior to slaughter (note that ewes dying before slaughter are taken into account in the calculation of the appropriate discounted genetic expressions coefficient). Thus, the economic value can be taken as 0.44 (ewe killing out %) multiplied by the price premium per kg for cull ewes of $2.30 per kilogram giving an economic value of $1.01 per kilogram of mature weight.

Economic weights

Economic weights (detailed in Table 4.22) incorporate economic values multiplied by appropriate DGE coefficients such that the economic weight can be used to value genetic improvement.

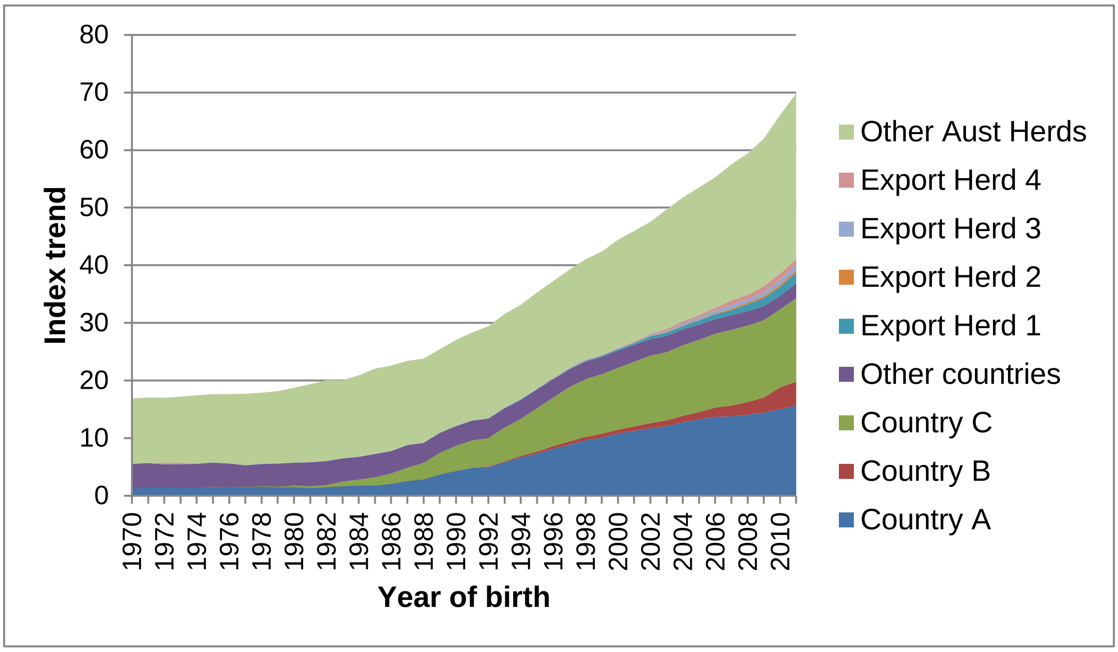
Appendix Table 4.22. Summary of economic values and economic weights for breeding objective traits to value genetic change

			Ewes: Merino	
			Self-replacing	Merino
Breeding objective goal trait	Component	*Ram type*	*All Maternal*	*Terminal*
		EV ($/trait unit)	EW ($ per ewe mated)	
Lamb growth				
Post weaning weight			0.64	0.48
	Earlier slaughter			
	Heavier carcase weight			
Adult size				
Ewe mature weight			-0.30	0.00
	Ewe feed costs			
	Ewe replacement feed			
	Carcase salvage value			
Reproduction				
Number of lambs weaned		41.75	32.04	0.00

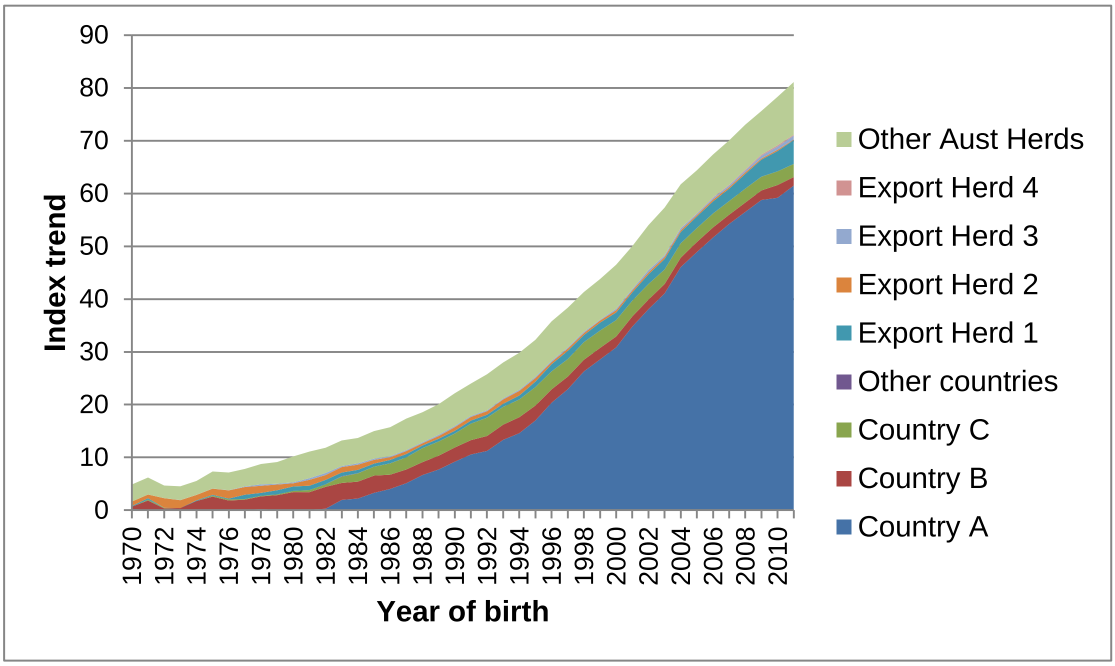
			Ewes: Maternal		Ewes: Crossbred
			Self-replacing	Maternal	
Breeding objective goal trait	Component	*Ram type*	*All Maternal*	*Terminal*	*Terminal*
		EV ($/trait unit)	EW ($ per ewe mated)		
Lamb growth					
Post weaning weight			0.76	0.62	0.62
	Earlier slaughter				
	Heavier carcase weight				
Adult size					
Ewe mature weight			-0.23	0.00	0.00
	Ewe feed costs				
	Ewe replacement feed				
	Carcase salvage value				
Reproduction					
Number of lambs weaned		41.75	25.48	0.00	0.00

Appendix 4D: Counter-factual: genetic contribution from imports

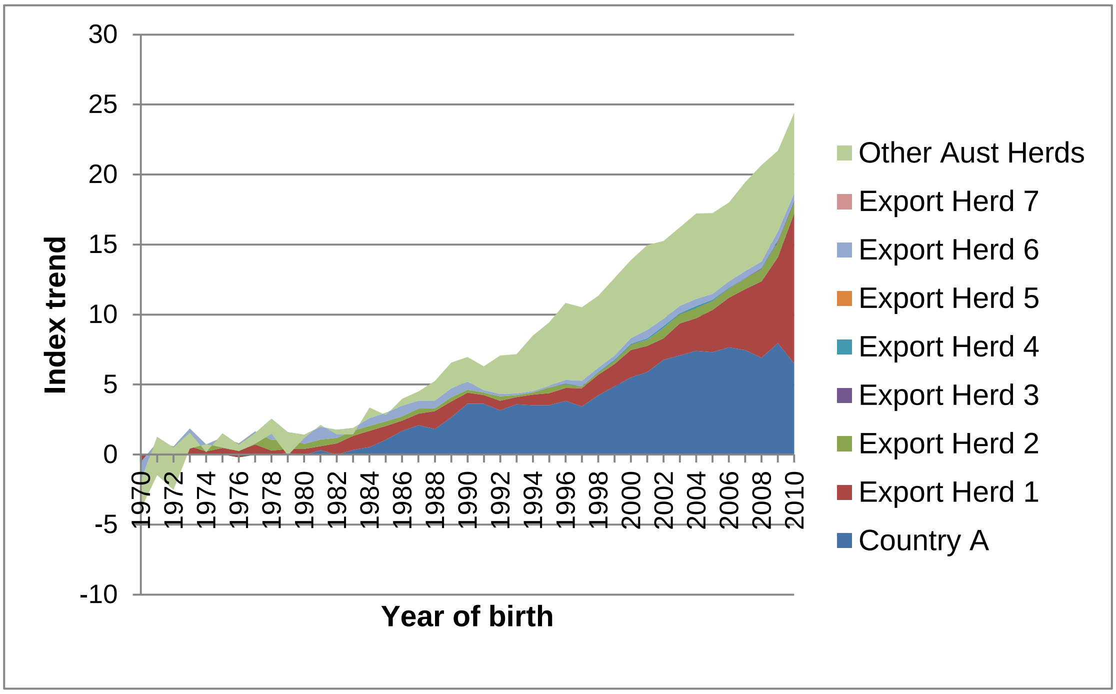
Hereford



Angus



Brahman


30
25
20
15
10
5
0
-5
-10
Index trend
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Year of birth
Other Aust Herds
Export Herd 7
Export Herd 6
Export Herd 5
Export Herd 4
Export Herd 3
Export Herd 2
Export Herd 1
Country A

Appendix 5. Impact studies

The value proposition for buying a genetically superior bull

Background

The value proposition behind the purchase of a superior bull by a commercial producer from a BREEDPLAN-recorded herd is derived by consideration of the comparative genetic merits of the candidate bulls is bought. The methodology is included in Appendix 4B.

The beef cattle selection indexes developed by BREEDPLAN multiply eBVs by economic weights (Appendix 4B) which are expressed per cow mated and on a sire (estimated breeding value, rather than expected progeny difference) basis. This means that index values need to be halved when evaluating the expected profitability of a bull's progeny. As such, the difference in the commercial farm value of two bulls based on their index merit is equal to half the difference in index value multiplied by the number of cows mated over their lifetime. It is important to note that these index merit estimates are deviations from the average of the animals in the base year of the genetic evaluation system, and thus the estimates represent the appropriate information required to compare the genetic value offered by different animals. It is also important to note that the accumulation of benefits arising from descendants of the bulls, including those slaughtered and those retained as replacements in the herd, are accounted for the in calculation of the economic weights for relevant traits. The accumulation of expressions of the bulls' genes in his progeny and then discounting for the time-frame, over which the benefits are received, is captured through the calculation of discounted genetic expression (DGE) coefficients (Appendix 4B). These are then factored in to the economic weights which describe the profit arising from a unit change in each trait.

The value of differences in index

By way of example, if bull A has an economic index $10 greater than bull B for 600 days weight, then each offspring of bull A is predicted to differ in profitability realised through growth rate, relative to bull B, by $10. Assuming the bulls would be mated to 120 cows on average over their lifetime, bull A is expected to generate a $1,200 higher gross margin over his lifetime for the commercial farmer, compared to bull B. This captures the value generated through direct descendants (slaughtered) and retained descendants who contribute via growth rate in their progeny, in this case, to future generations within the herd. As a result if explicit discounting of the economic weights, to account for time delays in direct and future descendants, this value is represented in present value terms. This type of calculation can be used to establish the addition price that can be paid for a bull, relative to different bull, based on expected differences in gross margin arising from the bulls' descendants.

Efficiency gain due to selection

Economic weights for growth traits are calculated as marginal changes in profit, where an increase in genetic merit for growth is assumed to have a linear relationship with associated revenue streams and costs. However, there is potential for efficiency to arise implicitly, as a result of selection for genetic merit for growth traits in particular. This will impact the magnitude of the cost component associated with the trait change. The efficiency gain due to selection can therefore have a profound effect on the estimated benefits of genetic improvement.

In simple terms, the estimated benefits of realised efficiency can be included in the value of genetic improvement via adjustments to the cost component in proportion to the level of efficiency gain. For example, the value of a heavier carcase at slaughter resulting from 1 kilogram of 600 day weight is $1.91 ($3.75/ kg carcase weight x 0.51 killing out percent). For a steer growing to 574 kg kilograms live weight (290 kg /0.51), the total feed energy requirements are 51,087 MJME. For a steer growing to 575 kilograms of live weight at the same age, the total feed energy requirements are 51,134 MJME (Nicol and Brookes, 2007); a difference of 47 MJME. Taking into account seasonal feed costs during finishing animal growth, this 47 MJME difference in energy requirements equates to a feed costs to achieve the heavier 600 day weight (through higher maintenance and growth) of $0.84. The economic weight of 600 day weight at age constant slaughter is therefore **$1.07 per kg of 600 day weight** in steers, in this example. If we assume that efficiency gain as a result of selection for genetic merit for growth is 50%, then this halves the feed cost component to $0.42. The economic weight of 600 day weight at age constant slaughter would therefore be **$1.49 kg of 600 day weight**. There is a linear relationship between the estimated level of efficiency gain as a result of selection for genetic merit for growth, and the benefits of genetic improvement for growth.

The value proposition for continuously purchasing bulls from recorded herds

Background

The value proposition for the use of bulls from a recorded herd is defined. The estimates are for a Southern beef herd with 2,000 cows requiring 50 bulls per year (13 bulls purchased per year, and retained for a maximum of 5 years). The estimates are presented in Appendix Table 5.1..

Appendix Table 5.1. Herd structure and performance data for the Southern beef herd

Age at mating (years)	Mated	Pregnant	Age at calving	Parameters	
Heifers	0.200	0.172	2	Heifer death rate	0.030
2	0.166	0.152	3	Heifer pregnancy rate	0.860
3	0.144	0.131	4	Cow pregnancy rate	0.915
4	0.124	0.114	5	Cow deaths & cull rate	0.050
5	0.107	0.098	6	Open heifer culling rate	0.140
6	0.093	0.085	7	Open cow culling rate	0.085
7	0.080	0.074	8	Calf deaths	0.040
8	0.052	0.048	9	Old cow cull rate	0.300
9	0.034	0.031	10	Steer calves weaned	0.434
TOTAL	**1.000**	**0.905**		Heifer calves weaned	0.434
		Calves weaned	**0.869**	Heifers retained	0.200
Average age of the cow at birth of the calf (years)			4.87		

Age of bulls when at progeny are born	**3**	**4**	**5**	**6**	**7**
Number of bulls	13	11	10	9	7

The annual average sire and cow merit is estimated by contributions from animals of different age groups. This drives the average calf merit. The average merit of the sire team in year 1 is based on 13 bulls (0.26) having a genetic merit of $3, with the remainder having merit of 0. In year 2, 13 bulls have a genetic merit of $6, with 11 having a genetic merit of $3, and so on. The genetic merit of the cows is generated in the same way, with the average cow merit in the year based on the average of cows lagged by 2 years and bull team used 2 years earlier.

The gains have been calculated assuming new bulls are purchased each year (Appendix Table 5.1), and the cumulative benefit which is presented in Appendix Table 5.2 has been calculated when compared with a producer who has bought bulls from herds that have not invested in BREEDPLAN. The benefits are defined for the year in which the bulls are purchased; thus the herd will contain bulls that are older than the new bulls and the average age of the cows will reflect the fact that they are the progeny of earlier generations of selected bulls[76]. A producer purchasing new bulls from a BREEDPLAN herd will acquire the genetic improvement of that herd. The assessment below is based on buying average bulls each year. The financial benefit of using these bulls each year has been estimated and is presented in Appendix Table 5.3.

Appendix Table 5.2. Genetic merit expressed in units of merit

Year of BREEDPLAN in which new bulls are purchased	Genetic merit of bulls in the commercial herd assuming all bulls sold by bull-breeders are from top two-thirds of their herd		Genetic merit of the cows in the commercial herd at mating	Genetic merit of the progeny born a year later
	New bulls purchased in that year	All bulls used in that year for mating		
Year 1	3	0.8 (0.78)	0	0.4 (0.39)
Year 10	30	25 (24.8)	11 (11.0)	18 (17.9)
Year 20	60	55 (54.8)	36 (36.1)	45 (45.4)

Appendix Table 5.3. Estimated additional value realised through the use of bulls from a BREEDPLAN-recorded herd (discount rate of 7%)

Year of BREEDPLAN in which new bulls are purchased	Total number of bulls purchased	Estimated additional value at a discount rate of 7% (Nil discount)	
		Value in that year	Cumulative value to that point
Year 1	13	0	0
Year 10	130	$15.7 ($30.8K)	$72K ($122K)
Year 20	260	$22.0 ($85.2K)	$276K ($723K)

Accuracy of estimated genetic merit improves when buying a team of bulls

A further aspect to consider is the fact that the accuracy of estimation of the genetic merit of a group of bulls is higher than the accuracy of the estimate of a single bull. This means that although individual bulls may not perform as expected, the greater the number of bulls selected the more accurate will be the estimated genetic merit of the group of bulls. For example while the accuracy of selection for one bull is 45% for a trait with a heritability of 20%, the average accuracy for a group of 13 bulls for a trait with a heritability of 20% is 93%.

[76] This analysis does not include a one-off lift in merit in the first year (based on how much better the bulls would be compared to the average in the base year of the analysis – 1993).

BOX 1: Accuracies

Estimated Breeding Values or EBVs provide an estimate of the genetic merit of an animal *relative* to other animals in its group. The accuracy is a function of how the EBV has been estimated. The bases for the estimation are performance records on the respective trait. These records usually are combinations of the animal's own performance records, the performance records of relatives, and in the cases of older animals, the performance records of progeny. Because they are a sample the parent's genetics, progeny records are of particular value, but:

- parental genes, and therefore their genetic merit, are split in half in the "construction" of their progeny – since this half is not the same in every one of their offspring, higher numbers of progeny greatly increase accuracy as more and more combinations of different parental genes get sampled
- most important production traits are due to the effects of combinations of genes – there is also variation due to the interactions between the genes of the animal and the environment (environment includes that during the animal's fetal growth stage);
- heritability is an estimate of the proportion of the variation that is due to genetics – it is estimated from the performance records and the relationships between animals

Potential impact of not realising expected genetic merit in commercial settings

There is a common belief that the genetic trends realised in the sire breeding sector are not realised in the commercial sector. In effect, this could reflect a genotype x environment interaction or a simple dampening due to differences in environment between the stud and commercial situations. In other words the proportion of the estimated genetic gain realised in the commercial sector is less than that in the recorded sector; this could be due to differences in management input or in environments between the two sectors. Two examples would be different levels of nutrition and different levels of animal health management. While such concerns may be valid, obtaining the data that would provide any confidence around such issues is problematic (the fact that the potential rate of growth is much greater than the actual rate of growth does not mean that the proportional impact of genetic improvement is not being realised). This is dealt with in the estimation of benefits by applying a realization factor of 75%.

Examples of such an impact are in Appendix Table 5.4. However even with allowance for a substantial effect so that only a third of the value is realised, the benefits are still considerable.

Appendix Table 5.4. Estimated additional value realised after 10 and 20 years (discounted at 7% per annum) through the use of bulls from a BREEDPLAN-recorded herd with allowance for a lower realisation such that only one-third or two-thirds of the benefit is realised

Proportion of benefit realised (Realisation factor)	Estimated additional value at a discount rate of 7%			
	10 years (130 Bulls purchased)		20 years (260 bulls purchased)	
	Value in that year	Cumulative value to that point	Value in that year	Cumulative value to that point
Full benefit	$15.7K	$72K	$22.0K	$276K
Two-thirds	$10.5K	$48K	$14.7K	$184K
One-third	$5.2K	$24K	$7.3K	$92K

Ability to enhance market compliance: Southern beef graded under MSA[77]

Meat Standards Australia: Incentives to guarantee high product quality

In the mid-1990s, MLA and the CRC for Cattle and Meat Quality (Beef CRC) invested in a R&D program to investigate characteristics in live cattle and beef that could be used to predict eating quality and, thus, offer the possibility to ensure a higher level of consumer satisfaction. This program resulted in a voluntary meat grading program targeted towards accurate predictions of beef palatability, known as Meat Standards Australia (MSA). It was implemented in 1999/2000 and adoption by beef producers and processors as well as consumers[78] has been steady. The benefits to the producer in raising and selling MSA-compliant cattle can be measured directly via a per-kg premium paid for carcasses (or single cuts) graded 3 stars or higher.

Due to restrictions on the age of the animals, the transport times before slaughter and the traceability of each animal, not all cattle slaughtered actually qualify for MSA grading. Moreover, beef industries in the north and the south differ not only in their production systems, but also in their marketing channels. This leads to different portions of slaughtered cattle eligible for grading under MSA.

This case study, while within an MSA framework does not evaluate MSA, but seeks to investigate possible benefits that a producer of MSA-compliant cattle could have gathered from using genetically-improved bulls. A survey of Australian beef retailers and wholesalers (for the period from 2004/05 to 2010/11, Griffith & Thompson 2012) indicated that beef consumers were prepared to pay around $0.30/kg extra (carcass weight equivalent basis) or about 5% for MSA-branded beef to guarantee tenderness. Of this, retailers retained about $0.06/kg and wholesalers about $0.11/kg, with the remaining $0.13/kg (45%) passed back to producers[79]. The retail premium for 2012/13 was similar at $0.28/kg[80]. This increased value and the demand for marbled beef, especially from Japan, has stimulated an interest in meat quality among bull breeders which is reflected in the trend in intramuscular fat in Angus (Appendix Table 5.5)[81]

[77] Data for this case study came from several different sources. The foundation dataset was from MLA (Thomas), and was used for basic industry data (as previously noted). Other data sources included *Evaluation of Meat Standards Australia* (CIE Report to MLA, March 2012) and *Red Meat Eating Quality – Recent Program Performance* (CIE Report to MLA, October 2012), Griffith & Thompson (*2012, The Adoption of Meat Standards Australia: updated to 2010/11. Australasian Agribusiness Review, 20: 11-38*) and *MSA Annual Outcomes Report 2013* (October 2013, MLA). Genetic trends from BREEDPLAN were provided by Christian Duff, ABRI Armidale.

[78] The number of graded carcases has shown steady growth between the implementation of the grading system in1999/2000 and 2013, with an average additional 17% graded each year.

[79] They estimated that '*the cumulative retail-level economic benefit of the MSA system to 2010/11 is estimated to be around $523 million, with a current annual benefit of around $77 million over the past three years. After accounting for all the costs of development and implementation, net benefits are at least $200 million'*.

[80] "Meat Standards Australia Annual Outcomes Report", October 2013, MLA

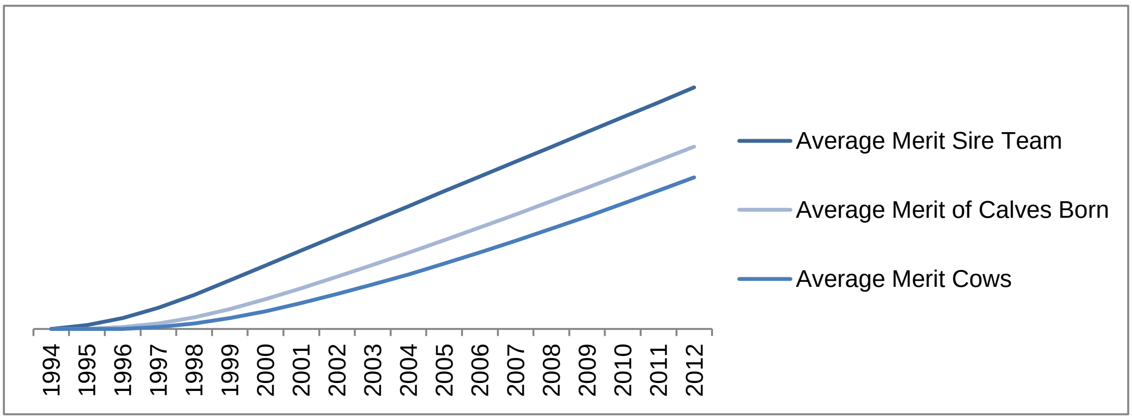
[81] It is likely that an export-related impact is being realised through the Japanese market for marbled beef but; unfortunately data from feedlot operators are commercially-sensitive and not available; however the expectation is that the proportion of carcasses meeting a defined Marbling Score (MS) in long-fed cattle is expected to have increased through better genetics.

Appendix Table 5.5. Genetic trends in Intramuscular Fat by Breed

Calving Year	Angus	Hereford	European
2000	0.2	0	0.07
2001	0.4	0	0.10
2002	0.5	0	0.13
2003	0.5	0	0.13
2004	0.7	0	0.07
2005	0.8	0	0.07
2006	0.8	0	0.04
2007	0.9	0	0.08
2008	1.0	0	0.07
2009	1.0	0	0.10
2010	1.1	0	0.10
2011	1.2	0	0.13
2012	1.3	0.1	0.10
Trend 2000-2012	0.09		

Increased profit through genetic improvement

In order to assess the value of genetic improvement to the southern beef industry, a beef herd was modelled on 2,000 cows[82] (2.5% bulls), with 13 genetically-improved bulls entering the herd every year, starting in 1994[83]. The trend in genetic merit of the animals in this herd is shown in Appendix Figure 5.1. The lag in improvement apparent in both calves born and cows is due to the fact that the improved genetics of introduced bulls are first realised in calves born one year later and cows mated two years later. Nevertheless, steady improvement is made every year.



Appendix Figure 5.1. Change in genetic merit based on the introduction of better bulls into a self-replacing herd.

In order to assess the additional value of this improvement, a threshold for MSA-compliant

[82] Calving rate 86% [ABARES], cow replacement rate 20%, bull replacement rate 26%

[83] The genetic trend data from ABRI shows that the first EBVs were accessible in 1994.

slaughter was assumed based on the personal preference of the farmer. Animals that reached 530kg live weight at 600 days of age would be sent for slaughter, as they were sure to make the grade, and would subsequently earn a premium of 13¢ per kg carcase weight[84]. Animals that failed to meet this criterion would be kept and sold at a later stage as young cattle of medium growth, thus forgoing the MSA-grading process, and would not earn a premium. A genetic trend for 600-Day Weight in the southern (British and European) breeds of 2.25 kg/year was derived from the ABRI data; this was used in the model for development of genetic merit in the herd and the value to the producer evaluated in the years 2000 to 2012.

Appendix Table 5.6. Merit of animals in improved herd versus animals without genetic improvement, expressed in kg

Year	Average Merit of the Sire Team	Average Merit of Cows in the Herd	Average Merit of Animals Assessed (2 year lag to matings)
1999[85]	7.38	1.63	1.74
2000	9.63	2.67	2.98
2001	11.88	3.94	4.5
2002	14.13	5.3	6.15
2003	16.38	6.74	7.91
2004	18.63	8.27	9.71
2005	20.88	9.89	11.56
2006	23.13	11.59	13.45
2007	25.38	13.36	15.39
2008	27.63	15.19	17.36
2009	29.88	17.07	19.37
2010	32.13	19.01	21.41
2011	34.38	20.98	23.48
2012	36.63	22.98	25.57

The proportion of animals that are slaughtered at 600 days of age and MSA-graded was calculated using a normal distribution of live weight. The year 1999 was set as the starting year and the distribution mean at 498.74kg (including 497kg average Australian live weight[86] and 1.74kg that individuals in this specific herd were superior to average animals (see Appendix Table 5.6), with a coefficient of variation of 10%. Tracking the changes within the distribution over the years was enabled by changing the mean according to the flow of genetic merit through the herd, based on the genetic trend. The additional 1.74kg over the average in 1999 was subsequently replaced with the respective value (based on the contribution of the genetic trend to the weight of the slaughtered individuals) in the years 2000 to 2012. In order to ensure that the model was close to reality, a second threshold was installed, of 538kg live weight (280kg carcase weight), at which point the dressing percentage of an animal would rise from 50% to 52%. This was calculated based on the same normal distribution. The results of these calculations are presented in Appendix Table 5.7.

[84] Based on the average 2013 premium [MSA Annual Outcomes Report 2013]

[85] The year 1999 was included in this part of the analysis to allow for a realistic view on additional animals passing the threshold in the year 2000.

[86] Based on the 1999 average carcase weight of Australian adult cattle slaughtered of 248.5 kg [Thomas, MLA] and a dressing percentage of 50%

Appendix Table 5.7. Live weight, proportion of animals graded and reaching a higher killing-out percentage (KO%) in each year

Year	Average Live Weight (kg)	Percentage of Animals passing the MSA threshold of 520kg LW	Percentage of Animals passing the KO% change threshold of 538kg LW	Percentage of MSA-graded carcasses with higher KO%
1999	498.74	33.50%	21.60%	64.40%
2000	499.98	34.40%	22.30%	64.90%
2001	501.5	35.60%	23.30%	65.50%
2002	503.15	36.90%	24.40%	66.20%
2003	504.91	38.30%	25.60%	67.00%
2004	506.71	39.70%	26.80%	67.70%
2005	508.56	41.10%	28.10%	68.40%
2006	510.45	42.60%	29.50%	69.20%
2007	512.38	44.10%	30.90%	70.00%
2008	514.36	45.60%	32.30%	70.80%
2009	516.37	47.20%	33.80%	71.50%
2010	518.41	48.80%	35.30%	72.30%
2011	520.47	50.40%	36.80%	73.10%
2012	522.57	52.00%	38.40%	73.90%

These proportions where then applied to the number of 600-day old animals slaughtered in each year[87] from 2000 to 2012.

The additional value realised by the producer through the on-going introduction of improved genetics into the herd is reflected in the additional tonnage of MSA-graded beef (valued at $0.13/kg) generated. This is comprised of two components. Firstly, there is the additional carcase weight of the number of animals that already made the cut in previous years, and secondly there is the carcase weight of the additional animals that pass the live weight threshold at 600 days of age in every year. A breakdown is presented in Appendix Table 5.9.

[87] Since the model herd was assumed to be self-replacing with a constant calving percentage and replacement rate, the number of animals eligible for assessment at 600 days of age was constant at 1100

Appendix Table 5.8. Additional carcase weight generated through genetic improvement between 2000 and 2012 in a herd of 2,000 cows initially producing 358 MSA-graded animals in 1984.

Year	Number of MSA-graded animals slaughtered		Additional carcase weight generated (kg)	
	Base annual production from 2,000 cows	Animals added to the base in this year	On the base number of animals	On the additional animals added to base
2000	455	12	304	3,200
2001	470	15	384	3,972
2002	487	17	430	4,341
2003	505	18	476	4,677
2004	523	19	505	4,823
2005	543	19	537	4,979
2006	562	20	569	5,123
2007	582	20	603	5,257
2008	602	20	637	5,377
2009	623	21	671	5,480
2010	644	21	704	5,561
2011	665	21	737	5,621
2012	686	21	769	5,660

Since more animals out of the MSA lot pass the threshold of 538kg live weight in every year and are therefore have a higher killing-out percentage, the additional carcase weight per animal graded accumulates faster over the years as a greater proportion of the herd meets grading criteria due to the impact from the improved genetics brought in.

The amount of additional carcase weight accumulated between 2000 and 2012 is **70.9** tonnes. When valued at $0.13 per kg, this represents a cumulative additional gain through genetic improvement of **$9,212**[88].

Estimating value at an industry level

To estimate the value of using genetically-improved bulls in an entire industry sector, the model was extrapolated to the level of the Southern beef sector. Evaluation of sire production capacity of the British and Continental European herds on BREEDPLAN showed that a use of improved bulls in the entire Southern beef herd would be possible. A more realistic view is given by assuming a 90% adoption rate; to this end the model is expanded on 90% of the cows mated in Southern beef. The results are presented in Appendix Table 5.9.

[88] Note that this analysis is retrospective and thus applies the premium to every year without discounting.

Appendix Table 5.9. Estimate of the additional carcase weight generated in Southern beef herd between 2000 and 2012[89]

Year	No. of Cows mated	Number of MSA-graded animals slaughtered		Additional carcase weight generated (kg)	
		Base annual production from the herd	Animals added to the base in this year	On the base number of animals	On the additional animals added to base
2000	2,998,197	681,534	42,638	405,577	10,935,824
2001	3,016,938	709,080	27,547	532,286	7,088,386
2002	3,050,372	742,575	33,495	599,719	8,649,619
2003	3,076,832	776,773	34,198	671,025	8,864,775
2004	3,205,533	838,971	62,198	718,528	16,184,787
2005	2,926,140	793,730	-45,241	753,312	0
2006	3,165,835	889,664	95,934	771,394	25,162,662
2007	2,703,076	786,598	-103,067	781,806	0
2008	2,520,192	758,997	-27,601	770,029	0
2009	2,458,997	765,937	6,940	784,469	1,843,047
2010	2,471,472	795,588	29,651	804,236	7,908,049
2011	2,557,897	850,247	54,659	846,676	14,640,350
2012	2,782,384	954,138	103,890	915,108	27,946,861

The additional carcase weight accumulated in British breeds between 2000 and 2012 due to introduction of 26% genetically improved bulls into the sire team in every year amounts to **92,317** tonnes. When valued at 28¢ per kilogram, this equates to **$12 Million**[90].

Lamb production in Victoria

The Victorian prime lamb sheep (breeding/finishing) sector (crossbred sheep for lamb production) is a good example of technology uptake where the use of rams from LAMBPLAN-recorded flocks provides the basis for some assessments of impact.

Background - Sheep industry in Victoria

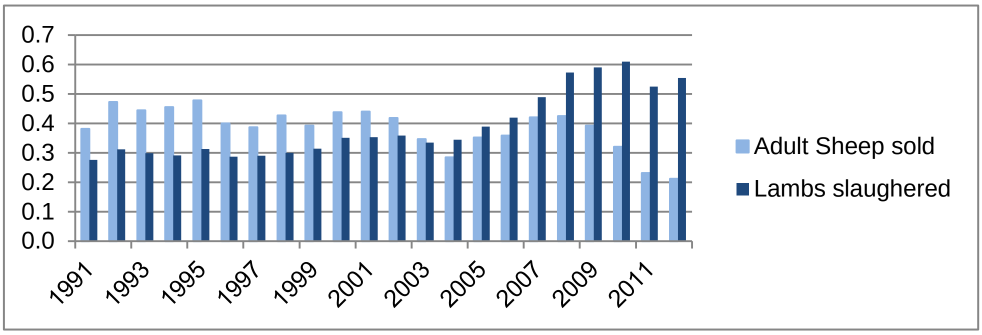
Even though most sheep in Australia around the year 1800 were meat breeds, Merinos came to dominate the sheep industry by 1900, which made wool the main focus and marginalized lamb production. However in contrast Victoria specialized in lamb production relatively early.

Decreasing wool prices coupled with a lower domestic demand for lamb and mutton led to a long-term decline in Australian sheep and sheep farm numbers starting from the early 1970s. A structural change resulted (see Analysis of Industry Productivity), with a change within the Merino-based flocks away from wethers (and ewes) as wool-producers towards ewes to produce lambs. These ewes were often bred to maternal sires (e.g. Border Leicester) to produce first-cross ewes (that still produce reasonably fine wool) that can then be bred to terminal sires to produce high-quality lambs. This flock restructuring process and the shift

[89] In 2005, 2007 and 2008, the number graded was lower than the year before. In these cases, the difference was factored into calculation of additional kg on the base number of animals and the number of new animals graded was assumed to be nil. In these years, no additional carcase weight was generated by adding new animals to the base.

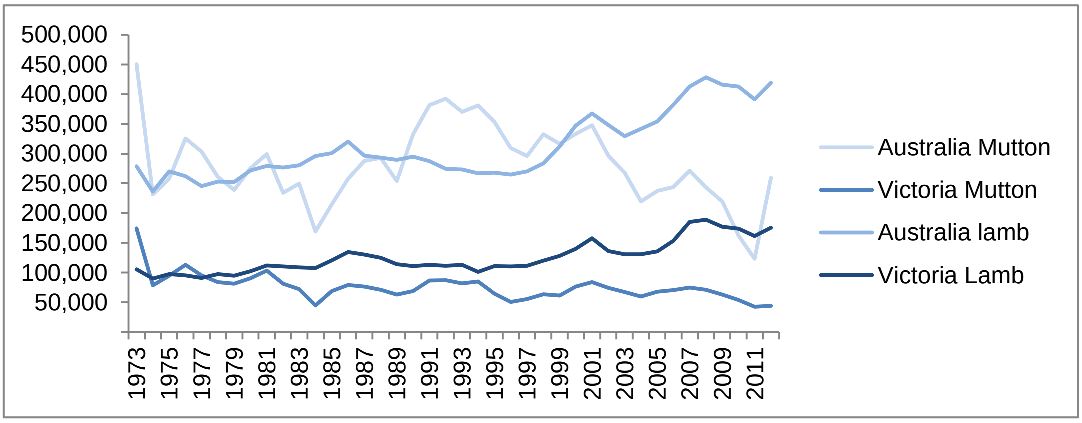
[90] Note that this analysis is retrospective and thus applies the premium to every year without discounting.

from slaughtering adult sheep (culls from the wool producing flock) to slaughter lamb production is illustrated in Figure 2 (note that slaughter lamb production per ewe increases).



Appendix Figure 5.2. Production per mated ewe across years between 1991 and 2012 in Australia

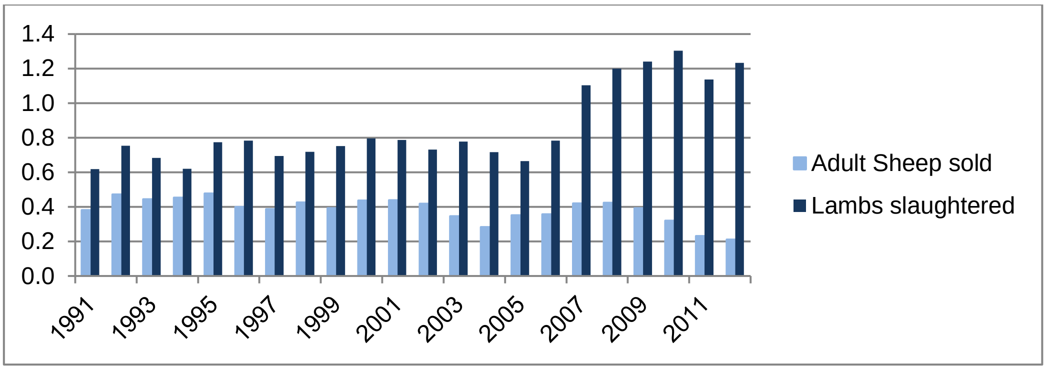
While Victoria did not avoid the general decline in sheep numbers (from 33.7 in 1971 to 13.7 million in 2012), the industry did not experience the structural changes to the same extent as the other states. As far back as 1940's, Victoria was a major producer of lamb with an emphasis on the export of meat. Although the Victorian flock made up only 16% of the Australian flock in 1944, 57% of lamb exports came from Victoria. This is reflected in the production of mutton and lamb in Australia and Victoria since 1973 (Appendix Figure 5.3). There was a peak in Australian mutton production in the early 1990s yet this is not evident in Victorian mutton production.



Appendix Figure 5.3. Production of mutton and lamb in Australia and Victoria (tonnes of carcase weight) between 1973 and 2012

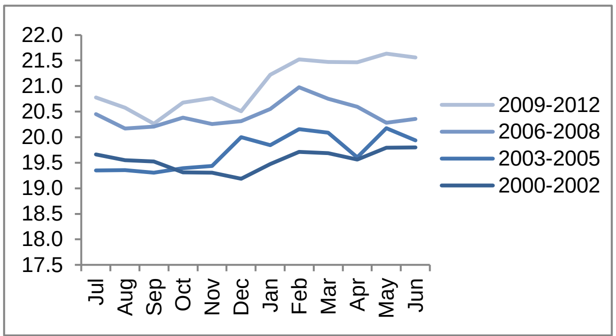
Changes in productivity from 2000 to 2012

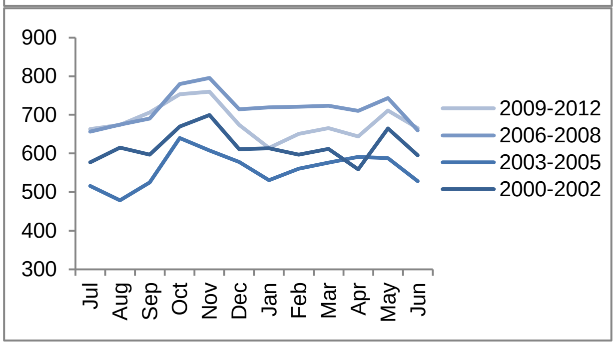
In this prime lamb industry, where an estimated 70% of all sheep are kept with a focus on lamb production, the contribution of structural change to per ewe productivity is small. Moreover, the fundamental decision to mate Merino ewes to Maternal sires and establish a crossbred flock to produce high-quality lambs will only have had limited impact in an industry that was already based on meat production. However the evidence from Figure 2 is that the number of lambs slaughtered per mated ewe increased markedly over the years. However given the rapid change between 2006 and 2007 in the apparent production per ewe mated (Appendix Figure 5.4) and the fact that lambs slaughtered per ewe exceeds 110%, there must be an external factor impacting. This is likely to be transport of lambs from out-of-state to Victoria for slaughter.



Appendix Figure 5.4. Production per mated ewe between 2000 and 2012 in Victoria[91]

In addition to producing more lambs per ewe, the lamb carcase weight increased over time[92]. While initially (in the 1970's), this might have been due to a later age at slaughter (turn-off), an analysis of slaughter data shows that this is no longer the case. While the average carcase weight is still increasing, the distribution of lambs slaughtered within the course of a year has not changed (Appendix Figure 5.5). Hence it is a reasonable to deduce that the rise in average carcase weight is not the result of slaughter at a later turn-off age.





[91] 1.2 lambs slaughtered per ewe is a number that would be impossible to achieve under the lambing percentages stated by the MLA lamb survey (112% for Non-Merino), even in an industry with focus on prime lamb production. This number can be explained by excess lambs being brought into Victoria for slaughter, mostly from New South Wales. Since proportions of lambs born and raised in Victoria and others can only be speculated on and the rise in lambs per ewe itself is not a subject of this case study, no further investigation into the matter was undertaken. The core trend would still be the same, as the numbers of lambs produced in all three states have been relatively stable over the years (Appendix Table 5.12).

[92] An important driver in the lamb industry has been the demand for larger, leaner carcases. This became first apparent in the mid 1970's, with consumer research in the UK (an important export market for Australian lamb), that was later confirmed by consumer satisfaction surveys carried out domestically. Ironically, this led to problems in the 1970's when premiums were put in place as incentives for producers to grow larger lambs. [Source: "We love our lamb – Australian lamb marketing from paddock to plate" – Lamb Industry Steering Committee] Unfortunately, heavier lambs of the same genetics are fatter. This in turn did not meet the customer requirements and resulted in a lower consumer acceptance of lamb. Consequently, the quest for larger carcases with good carcase quality has been a major driver for genetic improvement.

Appendix Figure 5.5. A] Average lamb carcase weight (kg) from 2000 to 2012. **B]** Number of lambs slaughtered ('000 head) per month between 2000 and 2012 in Victoria.

Total numbers vary in between years; the comparatively low number of lambs slaughtered in between 2004 and 2006[93] is notable. Nevertheless, the change from 2000 to 2012 represents an increase in total turn-off numbers (1.08 Million additional lambs) and in carcase weight (19.6 kg to 21.3 kg). As a consequence, the overall production of lamb increased by about 35,000 tonnes (from 140,000 tonnes to 175,000 tonnes) (Appendix Table 5.10)

Appendix Table 5.10. Lamb slaughter in Victoria 2000 to 2012

Year	Lambs slaughtered ('000 head)	Average carcase weight (kg)	Lamb production (tonnes CW)
2000	7,144	19.63	140,214
2001	8,090	19.52	157,898
2002	6,997	19.48	136,324
2003	6,905	18.93	130,699
2004	6,471	20.21	130,772
2005	6,787	20.03	135,947
2006	7,614	20.15	153,448
2007	9,100	20.32	184,912
2008	9,059	20.87	189,077
2009	8,719	20.30	177,018
2010	8,231	21.10	173,662
2011	7,553	21.40	161,641
2012	8,223	21.31	175,246

Given the history of prime lamb production and the current status of processing plants in Victoria[94], it is reasonable to assume that these changes are strongly influenced by changes in terminal and maternal breeds.

Estimation of the impact of genetics on the Victorian lamb productivity

A proportion of the gain in productivity between 2000 and 2012 can be attributed to the increase in ewe productivity (Figure 4) where the number of lambs slaughtered per ewe mated ewe rose from 0.8 to 1.2. The underlying changes are due to three different developments - genetic improvement in the maternal traits (number of lambs weaned per ewe), changes in ewe management, and the confounding effect of shifting sheep from interstate for slaughter.

Since it is impossible to separate these factors, a standardized approach to the estimation of

[93] Between 2003 and 2006, Victoria was hit by the full impact of the drought in south-eastern Australia, with rainfall reaching an on-record rank 2 low in the second half of 2006 [Australian Bureau of Meteorology]

[94] The focus on prime lamb is also reflected in the number of processors and abattoirs accredited under both AUS-MEAT (Authority for Uniform Specification – meat) and MSA (Meat Standards Australia). Both schemes work on a species basis. Of 33 processors accredited under AUS-MEAT in Victoria, 76% are licensed for sheep, the same proportion as for beef (in Queensland, out of 29, only 31% are accredited for sheep). Under MSA on the other hand, 44% of Victorian abattoirs are licensed for sheep only, with 40% of the remaining licensed for both beef and sheep. [AUS-MEAT Accreditation Listing – AUS-meat; MSA licensed Plants – MLA]

the value of genetic improvement has been applied. The number of lambs slaughtered in 2000 (7.144 million) was taken as the standard number of lambs through to 2012. Analysis (Appendix Figure 5.5B) has shown that there has been no apparent change in age at slaughter. Hence this increase in average carcase weight is an expression of improvement in growth rate, and therefore carcase weight due to higher growth rate can be used to estimate the value of genetic improvement to prime lamb producers.

The value of carcase weight was based on a rolling 3-year average carcase weight[95] applied to the 7.144 mn lambs (Appendix Table 5.11), and the increase in total carcase production derived. The calculation requires an estimate of feed costs.[96] Hence the value of the extra carcase production is generated using the standardized economic value (margin) of $2,328 per tonne of carcase weight, or that based on actual prices.

Appendix Table 5.11. Estimated impact in terms of total value added for the Victorian lamb crop due to the increase in carcase weight per lamb between 2000 and 2012 without allowing for any increase in lamb numbers (calculated at 7.144 million lambs slaughtered in 2000).

Year	Carcase weight (CW) parameters			Value of increase in carcase production ($ millions)			
	Rolling 3 year average CW (kg)[97]	Total carcase production (tonnes)	Carcase production increase (tonnes)	Standardised prices[98]		Actual prices[99]	
				Value	Present value[100]	Value	Present value
2000	19.44	138,855	-	-	-	-	-
2001	19.54	139,616	761	1.77	2.45	1.05	1.45
2002	19.31	137,956	-899	-2.09	-2.81	-1.56	-2.10
2003	19.54	139,599	744	1.73	2.26	1.58	2.06
2004	19.72	140,905	2,050	4.77	6.04	4.63	5.87
2005	20.13	143,825	5,239	11.57	14.23	11.82	14.54
2006	20.17	144,094	5,239	12.20	14.57	11.28	13.47
2007	20.45	146,099	7,244	16.86	19.55	15.07	17.47
2008	20.50	146,453	7,598	17.69	19.91	16.89	19.01
2009	20.76	148,306	9,451	22.00	24.04	23.59	25.78
2010	20.93	149,561	10,706	24.92	26.44	31.38	33.29
2011	21.27	151,964	13,109	30.52	31.44	39.75	40.94
2012	21.20	151,481	12,626	29.39	29.39	36.42	36.42
Estimate of net total value added ($ millions)				**$171**	**$188**	**$192**	**$208**

[95] This is considered more stable than the price observed in each year.

[96] In a pastoral system, feed costs can be regarded as an opportunity cost and are therefore a function of the value of the product produced using that feed; the Economic Value for carcase weight includes a feed cost component which is a function of the price per kg of carcase.

[97] The regression of carcase weight on year from 1991 to 2012 was CW = 0.165*year + 17.38 (Year 1, 1991; 2000: 19.03kg); the rate of increase in carcase weight (0.165 kg per year) is similar to that calculated here for a shorter period on a 3-year rolling average (0.147 kg/ year)

[98] Economic Value based on an average price for lamb between 2000 and 2012

[99] Economic Values base on 3-year rolling average prices for lamb between 2000 and 2012

[100] Present value in 2012 is calculated based on a net interest rate of 3% per annum

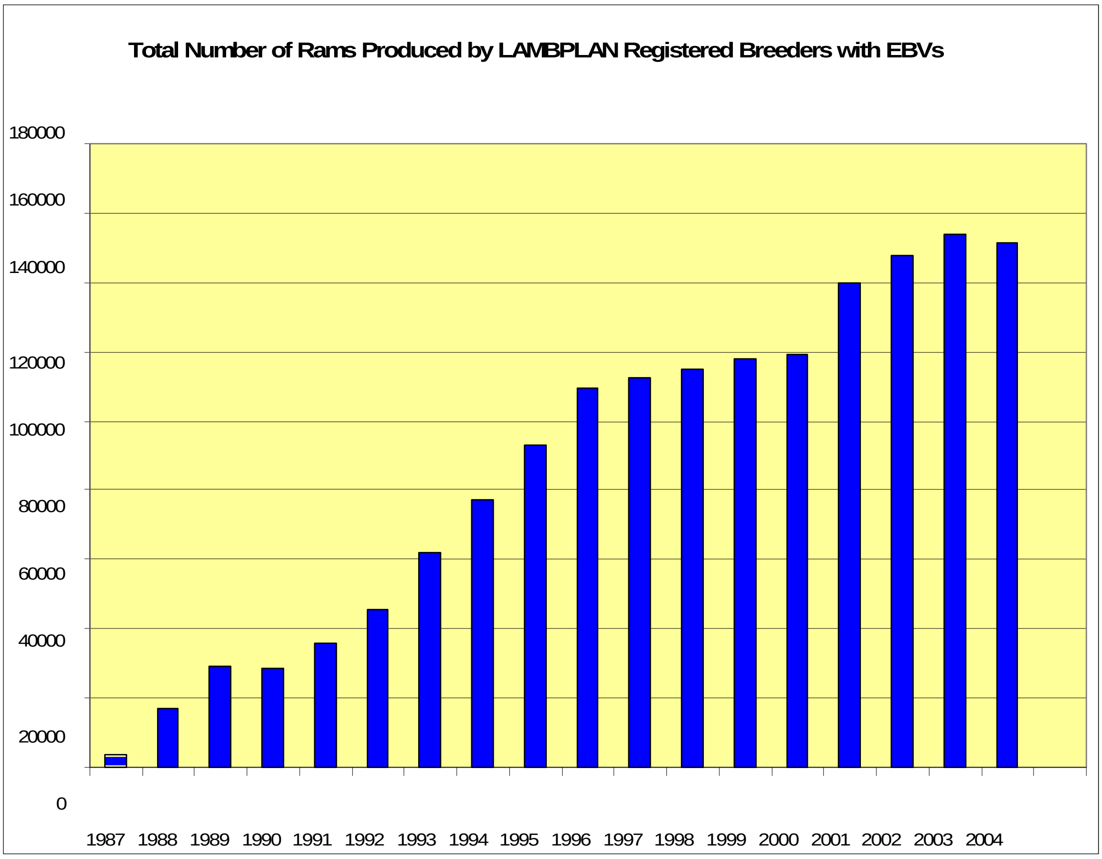
Thus the total additional value generated in this scenario is $171 million ($188 mn present value) between 2000 and 2012. However, this is at the level of the producer only and does not include any other value generated further down the supply chain.

Appendix Table 5.12. Lambs produced for slaughter in Victoria, New South Wales and South Australia.

Year	Lambs available for slaughter (assuming 25% Ewes) Replaced in Million Head			Lambs slaughtered in Victoria in Million Head
	Victoria	New South Wales	South Australia	
2000	3.79	6.35	2.65	7.14
2001	4.77	7.86	2.19	8.09
2002	4.32	6.64	2.11	7.00
2003	3.90	4.59	2.76	6.90
2004	4.09	4.22	2.48	6.47
2005	4.76	4.46	2.26	6.79
2006	5.20	4.65	2.14	7.61
2007	4.23	4.88	2.31	9.10
2008	3.55	5.33	2.08	9.06
2009	3.50	5.64	2.11	8.72
2010	3.39	6.46	2.24	8.23
2011	3.92	7.14	2.90	7.55
2012	3.98	7.23	3.11	8.22

Appendix 6. LAMBPLAN (2006)

Russell Barnett, Australian Venture Consultants Pty Ltd (2006, SHGEN.114); LAMBPLAN: National system for describing the genetic worth of animals in the Australian sheep meat industry. Review of Adoption by the Australian Meat Sheep Breeding Industry



Appendix Figure 6.1 (Barnett 2006). Total number of rams with EBVs produced by LAMBPLAN-registered flocks

Reach of LAMBPLAN in the Commercial Production Sector

Extract from Barnett (p 35): It is difficult to estimate the reach of animals produced from LAMBPLAN registered breeders with any degree of accuracy, particularly in the case of the progeny of maternal sires. In the case of terminal sires we can make an indicative estimate. For example, from simple deduction we can estimate that the 70,000 sires sold from flocks using LAMBPLAN in 2004 produced approximately 45 percent of all lambs produced in the Australian sheep industry and 55 percent of the total lambs produced for slaughter by the Australian sheep industry in 2004. This basic calculation is demonstrated in Table 4 below. Although this estimation is only indicative, it does demonstrate the order of magnitude affect that LAMBPLAN is having on the genetic base of the Australian flock. The impact is further evidenced by the results of the Terminal Sire Central Progeny Tests (see Chapters 5 and 6) and the relationship between adoption of LAMBPLAN and improved average carcase weights (see Chapter 5).

Variable	Value
Number of LAMBPLAN rams sold in 2004	70,000
Estimated number of joinings per ram[101]	110
Estimated Lambing Rate[102]	93%
Estimated marking rate[103]	125%
Total Number of Lambs Produced by LAMBPLAN Rams	10.1 million
Total Number of Lambs Marked in 2004 (not including Merino lambs retained)	22.2 million
Percentage of Total (non-Merino) Lambs Produced by LAMBPLAN Rams in 2004	**45 %**
Total number of lambs slaughtered in 2004 (not including Merino lambs)	15.7 million
Estimate of percentage of slaughter (non-Merino) lambs produced by LAMBPLAN rams	**55%**

[101] Brown, S. (2002), 'LAMBPLAN for Commercial Lamb Producers', *Farmnote,* AGWA, Perth

[102] Hooper, S., Blias, A. & Ashton, D. (2003), *Australian Prime Lamb Industry,* ABARE, Canberra

[103] Brown, S. (2002), 'LAMBPLAN for Commercial Lamb Producers', *Farmnote,* AGWA, Perth

Appendix 7. Northern Australia perspectives

Data sources

Research opportunities for sustainable productivity improvement in the northern beef industry: A scoping study (Report to MLA 2013, B.BSC.0107; Leigh Hunt, Andrew Ash, Neil MacLeod, Cam McDonald, Joe Scanlan, Lindsay Bell, Robyn Cowley, Ian Watson and John McIvor) - Contribution of genetic gains to the increase in Productivity – ex page 31

Consultations with industry representatives and the scientific community revealed a variety of potential development opportunities suggesting productivity benefits for the northern beef industry. However, this was accompanied by a prevailing view that there are no 'silver bullets' for quickly, or cheaply, placing the industry onto a firmer economic footing. Many suggestions related to improving the fundamental aspects of cattle production (e.g. livestock reproduction and growth). While there was some commonality in issues amongst regions, this was not always the case, and within regions not all producers agreed on what were feasible development options. The issues that were most commonly raised by producers included:

- better pastures (especially to provide more protein in the late dry season)
- improved breeder genetics (especially in relation to re-conception rates)
- faster growth rates (through improved genetics and pastures)
- improved pasture utilisation through better grazing distribution
- reduced labour costs through the development of remote technologies
- more effective options for managing weeds, pests and diseases.

The need for increased adoption of existing best practices was also frequently mentioned. A lack of viable alternative markets and processing facilities in northern Australia were often nominated as major impediments to the further development of the industry, but these issues were considered to be beyond the control of producers themselves. Despite the concept of mosaic irrigated agriculture being widely discussed by policy makers and some investors in the context of the development of northern Australia (e.g. Chilcott 2009), this was rarely advanced as a serious option by beef producers. However, when suggested many saw its potential for increasing animal growth rates and helping to meet market specifications for sale animals.

Ex page 32

Better breeder genetics	Improved breeder conception rates at moderate body condition scores and whilst lactating, resulting in improved calving, branding and weaning percentages
Better genetics for growing	Improved efficiency of energy use

Appendix 3, P 141, Table 2. Estimated adult equivalents in each region and the contribution this makes to the northern beef herd. (Meta-analysis of beef production on improved forages in northern beef industry, December 2011, Prepared by Lindsay Bell, CSIRO, Toowoomba)

Region	**Estimated AE**	**% of herd**	**Areas included** †
Katherine/Kimberley	841	7.6	511, 713, 714
Pilbara/Central Aust.	538	4.9	512, 711
Barkly/NW Qld	1146	10.4	311b, 313d,712
Western Qld	1633	14.8	312, 314
North Qld	2303	20.9	311a,313a-c, 313e, 332
Central, southern & south-east Qld	4556	41.4	321,322,331

Appendix 8: Consultation

Consultation

NABRC – Rockhamption

AGCC – Webinar

Sheep Genetics Committee

Geoff Daniels – Growth Farms

Terry Longhurst, MLA

David Campbell, ACIL Allen

Geoff Lindon, AWI

John Thompson, UNE (emeritus)

Julius van der Werf, UNE

Sam Clarke, UNE

Stephen Lee, University of Adelaide

Alex Ball, MLA

Deon Goosen, ABRI

Steve Skinner, ABRI

Sam Gill, SGA

Hutton Oddy, NSW Dept of AG

Rob Banks, AGBU

Dave Johnson, AGBU

Daniel Brown, AGBU

Peter Parnell, Angus Association

Wayne Hall, MLA

James Rowe, Sheep CRC

Discussions undertaken August 2013 by Amer, Lindner et al

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MLA and AWI sheep meat and wool survey “lamb survey”2010, 2012, extract from MLA database on 11/02/2014 by Rebecca Matthews, MLA

Cattle-calves slaughtered 1972-2013, extract from the ABS series 7218.0.55.001 Livestock and Meat, Australia, on 20/02/2014 by Gertje Petersen, Abacusbio Ltd

Sheep-Lamb slaughterings meat produced monthly 1972-2013, extract form the ABS Series 7218.0.55.001 Livestock and Meat, Australia on 19/02/2014 by Greg Martin, IDA Economics

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Appendix 10. Application of Genomic Technologies

Peter Fennessy & Peter Amer, AbacusBio Limited Updated August 2013

Background

Genomic technologies are being applied in a number of livestock industries throughout the world, but it is in dairy cattle that by far the greatest penetration has been achieved.

There is a huge amount of effort going into genomic selection globally, but there is little evidence of any substantive utility yet, outside of dairy breeding schemes. Current estimates of accuracies in beef cattle are well below those for dairy cattle (discussed further below).

The reality is that genomic predictions of merit (genomic breeding values, GBVs) are completely dependent on the quality of the training set. In particular, the genetic relatedness of the training set to the individuals for which the GBVs are to be estimated is an important factor that was overlooked in many early attempts at application. It is still an unknown as to how large the training population size must be for accurate genomic prediction, and there is still some debate as to whether the prediction formulae of how genomic selection improves with an increased training population size are actually appropriate. However, in general, it is widely accepted that genomic selection works best with large training populations and selection candidates that are reasonably closely-related to animals in the training population. For example in an analysis of the accuracies of GBVs in Hereford cattle using US or international training populations, it is clear the predictions for non-US animals were less accurate than those obtained for US Herefords; among the non-US animals, genomic predictions were more accurate for Canadian animals reflecting the greater usage of US Herefords in Canada compared with the Argentinian and Uruguayan Hereford populations[1].

There is some indication that genomic prediction methods are working reasonably well in Black Angus in the US but these predictions do not appear to transfer to Australian Angus (see current estimates of accuracies for Angus cattle in Swan AA *et al*[2]), or to Red Angus. Several beef breed associations in the

USA are progressing with genomic initiatives, although the approach of companies such as Zoetis (previously Pfizer) has shifted away from developing a "global key" marketed as having wide and generic predictive ability towards working with industry partners to develop predictors that add value in the target population.

How does genomic selection work?

The general consensus from the recent literature[3] is that genomic selection utilises relationship data so that it actually represents a more sophisticated and ‘accurate’ pedigree than recorded pedigree for two reasons:

- recorded pedigree is prone to human error, and
- the genomic relationship accounts for Mendelian sampling which occurs at each conception.

The initial thinking around the likely mechanism driving predictive ability with high density marker panels and relationships was that it reflected population-wide association between markers and causative genes through linkage disequilibrium (LD). However increasingly, the contribution of LD to the predictive ability of genomic selection is regarded as minor with current approaches to genomic selection. Hence as noted above, the genetic relatedness of the training set to the individuals in which the GBVs are to be estimated is critical. Therefore this essentially precludes the use of across-breed genomic selection approaches. It is conceivable, however, that accuracies will increase with improved quality of phenotypes and both improved understanding and estimation of the contribution of linkage disequilibrium (LD) to the accuracy. It should be noted that the accuracies recorded for dairy cows are far higher than those recorded for beef cattle or sheep. There are three reasons:

- the pedigree structure within the various dairy breeds (and especially the Holstein-Friesian or HF),
- the population structure, and
- phenotype quality.

In terms of pedigree structure, the HF population features well-defined, deep pedigrees characterised by multi-generation sire lines and dam-sire lines that facilitate accurate detection of Mendelian inheritance of alleles and especially haplotype blocks across generations. Sensitivity to the depth of pedigree can be assessed through the impact of the progressive elimination of ancestral generations on the power of the analysis using gBLUP approaches where the genomic relationship matrix is substituted for the pedigree relationship.

The population structure or population heterogeneity has a major influence. The effective population size of the international HF population is very small; thus the haplotypes are relatively large (extensive LD) and the small population size also facilitates definition of the LD structure of the population (with relatively few SNPs). However it is these haplotype blocks which themselves are important in defining the actual Mendelian sampling.

The quality of phenotypes is also important. The definition of phenotypes for dairy bulls is exceptional as it is based on the (sire)-daughter data; that is the phenotype is effectively a weighted value based on daughter records rather than on the individual itself.

However while the accuracies in dairy cattle are far higher than those in beef (exceeding 0.6 for dairy production traits, noting that the square of accuracy represents reliability), there are issues with bias which means that genomic breeding values are subject to problems which must be dealt with when presenting results to industry stakeholders with high stakes in the outputs of genetic evaluation. Some of this bias may be due to epistatic effects (interaction between genes).

In summary, while the prospects for the application of genomic selection are good, there is a strong case to review the breeding structures to ensure that genomic selection yields real value.

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