final report

Project Code: G.MIO.1255

Prepared by: Chris Wilcox, Russell Pattinson, Kimbal Curtis and Gwen Rees
Poimena Analysis

Date published: May 2012

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Review of existing forecasting methodologies for the Australian sheep and wool industries

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Acronyms used:

AAGIS	Australian Agricultural and Grazing Industries Survey
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
AWPFC	Australian Wool Production Forecasting Committee
AWEX	Australian Wool Exchange
AWI	Australian Wool Innovation
AWTA	Australian Wool Testing Authority
BoM	Bureau of Meteorology
ICS	Independent Commodity Services
MLA	Meat and Livestock Australia
NCWSBA	National Council of Wool Selling Brokers of Australia
NLRS	National Livestock Reporting Service
SPC	Sheep Projections Calculator
USDA	United States Department of Agriculture

1. Key Findings

- Key sheep industry forecasting organisations (MLA, AWI, ABARES) use similar data inputs (as expected) and methods, but vary in process and timeframes.
- External organisations (e.g. banks) rely heavily on industry / Government forecasts and statistics.
- Private consultants use some differing modelling approaches, notably including farmgate price relativities between wool / lamb / sheep and other enterprises and rainfall data, but these have not been tested against 'real' data as they have only been finished recently.
- The MLA sheep projections spreadsheet is a calculator rather than a demographic model and does not include distinctions between lambs and adult sheep or between breeds.
- The accuracy of forecasts is not dissimilar between MLA, ABARES and AWI for comparable variables.
- Perhaps the most important variable, sheep numbers, has poor accuracy in other than the current year (and even then not particularly good). Given the importance of sheep numbers in determining other forecast variables, this is a key source of error in the forecasts of other parameters being forecast, such as lamb slaughterings and wool production.
- The accuracy of lamb slaughter is better than for sheep numbers. However, in recent years both MLA and, to a lesser extent, ABARES have projected a strong increase in lamb slaughter numbers which has not eventuated.
- The accuracy of forecasts reduces as the timeframe of such forecasts increases - as expected.
- Forecasting accuracy for specific parameters varies - with "discretionary traded" variables (sheep slaughterings / mutton production, live exports etc) being far less accurate than 'biological outputs' (lambs produced and slaughtered, wool production)

2. Introduction

This report provides findings from Stage 2 of the project – a review and assessment of how forecasting is currently undertaken for Australia's sheep, lamb and wool industries. This stage was undertaken to understand how MLA and AWI currently prepare forecasts, assess the accuracy of such forecasts, and to examine how other organisations undertake similar functions. One outcome from this process will be to provide an initial identification of the strengths and weaknesses of such forecasting methods and to identify perceived gaps in existing methodologies.

3. Methodology

The project team reviewed the approach taken by MLA's Market Information and Analysis team, by ABARES, and by the AWI-funded Australian Wool Production Forecasting Committee. This involved interviews with key personnel, desk research and analysis and drawing on the project team's own extensive knowledge of the methods used by ABARES, AWI and MLA.

A comparison of the accuracy of forecasts provided by the three groups was evaluated as was the extent to which objective analysis is used and the role of expert judgement / experience. The MLA's existing spreadsheet model was examined and sensitivity analysis conducted, investigating all inputs and how these currently affect lamb forecasts. A rank order of these inputs in terms of their influence on the forecasts was made.

Processes used by private consultants and banks in preparing forecasts for their clients and internal needs was also examined, specifically Independent Commodities Services, ProFarmer, Rabobank and ANZ Bank.

4. Overview of current sheep and wool industry projections models and forecasting methodologies

4.1 Meat and Livestock Australia

Meat and Livestock Australia prepares forecasts of supply and demand for Australian lamb and sheepmeat twice a year. These forecasts are on a calendar year basis and provide a review of current market conditions and a five year outlook. Currently the main forecast is produced in February, with a mid-year update in July and these are communicated via the *Australian Sheep Industry Projections* reports. MLA intend to change to a financial year basis resulting in the June/July forecast becoming the major forecast, with the February release the mid-year update.

MLA's Market Information and Analysis team relies on a range of inputs in making its forecasts, including input from the Lamb Forecasting Advisory Committee. The Committee meets in March, July and November. It comprises grower, processor, stock agent, and department of primary industries representatives from all states and ABARES, AWI and NCWSBA representatives. It discusses results from the MLA/AWI producer survey and comments on seasonal conditions in each state, as well as trends in lamb markings etc in different regions. It also receives a briefing from the MLA sheep analyst on current industry supply and demand conditions as well as on the MLA's draft supply and demand forecasts.

The Committee provides advice and commentary on the draft supply forecasts to MLA but is not a decision-making committee. The MLA Market Information and Analysis team decides on the forecasts, with guidance from the Committee.

The MLA Sheep Projections Calculator (SPC) is used to consolidate all assumptions and calculate the projections that are published. There are three core equations in the MLA Sheep Projections Calculator. They calculate lambs slaughtered (LS), sheep slaughtered (SS) and closing flock number (CFN) using opening flock number and analyst inputs (assumptions). Those equations are:

$$LS = OFN \times BE\% \times IM\% \times AM\% \times LM\% \times LS\%$$

$$SS = OFN \times ST\% - LE$$

$$CFN = OFN + LM - LS - SS - LE - (D\% \times OFN)$$

where

OFN is opening flock number,
BE% is percent breeding ewes in the flock,
IM% is intended matings as a percent of breeding ewes,
AM% is actual matings as a percent of intended matings,

LM% is lambs marked as a percent of intended matings,
LS% is lambs slaughtered as a percent of lambs marked,
ST% is sheep turn off (slaughter + live export) as a percent of opening flock number,
LE is live exports,
LM is lambs marked (OFN x BE% x IM% x AM% x LM%)
D% is deaths as a percent of opening flock number.

As actual data becomes available, it replaces the assumptions. Once all data in known for a year including the closing flock number (opening flock number for the following year), deaths are calculated as the residual using:

Deaths = OFN + LM – LS – SS – LE – CFN

While the producer survey provides an indication of breed composition, the Sheep Projections Calculator does not include breed splits but this is taken into account by the MLA analysts as a subjective input into the forecasting approach.

Other inputs used by the MLA analysts include:

- NLRS yardings by state
- ABS - sheep and lamb slaughterings by month, opening sheep numbers, live sheep exports, meat export data, lamb markings
- MLA/AWI sheep meat and wool (producer) survey (mail-out and internet survey conducted by Axiom),
- ABARES - sheep and wool production and price forecasts
- BoM - recent weather and seasonal outlooks
- Assumptions about trends in prices for sheep and lambs

Outputs from the process include forecasts (at a national level) for:

- Opening sheep numbers
- Lamb slaughterings annually and a chart of quarterly lamb slaughterings
- Sheep slaughterings annually and a chart of quarterly sheep slaughterings
- Lamb meat production and mutton production (annual), using predicted carcass weights
- Live sheep exports
- Domestic utilisation and meat exports

4.2 ABARES

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) produces forecasts for a range of agricultural products, including livestock products, broadacre crops and horticulture. Forecasts for the sheep industry are separated into wool and “sheep meat”, which includes lamb, mutton and live sheep exports.

The ABARES forecasts are produced quarterly in the publication *Agricultural Commodities* (formerly *Australian Commodities*). The March forecast includes a 5 year medium term “Outlook”, which constitutes a one-year forecast and projections for the rest of the forecast period. The other quarterly forecast releases during the year are only for the next financial year.

ABARES sheep industry forecasts and projections begin with the ABARES demographic flock model. This model is a 'balance sheet' approach using ABS sheep flock, sheep slaughter and sheep meat production and exports data and ABARES AAGIS survey data (for wool cut per head). ABARES analyst(s) modify assumptions in this model and then using the model and other inputs produce forecasts for commodity production, exports and prices.

Input to the forecasting process comes from:

- ABARES survey and macroeconomic units – AAGIS survey data and reports, macroeconomic assumptions (exchange rates, economy-wide economic outlook, GDP growth rates)
- AWTA Ltd - test data (bales, volumes and wool characteristics (e.g. micron profiles))
- AWEX – price data, sale offerings and comparative brand analyses
- AWI - production models, producer survey (in conjunction with MLA)
- AWPFC – wool production forecast (the ABARES wool analyst is a member of the AWPFC)
- MLA - forecasts, livestock sales data, producer survey, MLA Lamb Production Forecasting Advisory Committee (the ABARES sheep meat analyst is a member)
- ABS - sheep industry data (opening sheep numbers, slaughterings, live exports etc)
- BoM - recent weather and seasonal outlooks
- International data sources (USDA, US Office of Textiles and Apparel, Beef & Lamb NZ, Capewools SA, China Statistical Yearbook, EUROSTAT, Argentine Wool Federation, Uruguayan Wool Secretariat)
- Advice from brokers, growers, private treaty merchants, representatives from state departments of agriculture and the AWTA

Outputs from the process include forecasts (at a national level) for:

- Greasy wool production
- Number of sheep shorn
- Greasy fleece weights
- Wool (via Eastern Market Indicator), saleyard sheep and saleyard lamb average yearly prices
- Lamb and sheep slaughter, production and exports
- Live Sheep exports
- Closing sheep numbers
- Gross value of wool and sheep meat production and live sheep exports

Commentary is provided in the *Agricultural Commodities* report on key assumptions behind the forecast and reasons for any production increase / decrease compared to the previous / subsequent year. Important risks for the forecast are identified and analysed.

As with the MLA approach, breed splits are not explicitly incorporated into the ABARES balance sheet model, although ABARES analysts take this into account in their subjective assessments.

4.3 Australian Wool Production Forecasting Committee

The Australian Wool Production Forecasting Committee (AWPFC) has a similar purpose but quite different process to MLA's Lamb Forecasting Advisory Committee. The key differences are:

- AWPFC is a decision making (not advisory) group
- AWPFC receives input from separate State-based committees

The AWPFC usually meets quarterly and distributes updated forecasts within two days of meeting. Such forecasts (supported by a press release and detailed report) are usually the subject of considerable media interest. The scope of such forecasts is relatively short term - 18 months or less (i.e. updates of current seasonal forecasts, with a forecast for the forthcoming season undertaken in the period February to April prior.

Input to the AWPFC national committee comes from:

- AWTA Ltd - test data (bales, volumes and wool characteristics (e.g. micron profiles)
- AWEX - sale offerings and comparative brand analyses
- AWI - production models, producer survey (in conjunction with MLA)
- MLA - forecasts, livestock sales data, producer survey
- ABARES - sheep and wool production and price forecasts
- ABS - sheep industry data (opening sheep numbers, slaughterings, live exports etc)
- BoM - recent weather and short term forecasts (3 monthly)
- Advice from the six state committees
- Advice from brokers, growers, private treaty merchants, representatives from state departments of agriculture and the Australian Wool Testing Authority on both state and national committees

Outputs from the process include forecasts (at national and state levels) for:

- Greasy shorn wool production
- Number of sheep shorn
- Greasy fleece weights

Estimates of wool quality (in particular fibre diameter) are provided for the wool clip as a whole. Commentary is also provided on the reasons for any production increase / decrease compared to the previous / subsequent year.

Until recently, the AWPFC, as part of its analysis, estimated opening sheep numbers to provide a guide to sheep shorn numbers. This was based on a relatively simple 'balance sheet' of estimates of lambs marked, lamb and sheep disposal and deaths. The MLA forecasts of opening sheep numbers are now used by the AWPFC as a basis for its estimate of the numbers of sheep shorn. A recent analysis by AWI found that the AWPFC's forecast of shorn wool production was strongly correlated to the opening sheep numbers.

The AWPFC only considers wool production and, to some extent, wool supply (from held stocks). It does not consider the demand situation and outlook for the industry.

4.4 Banks and private consultants

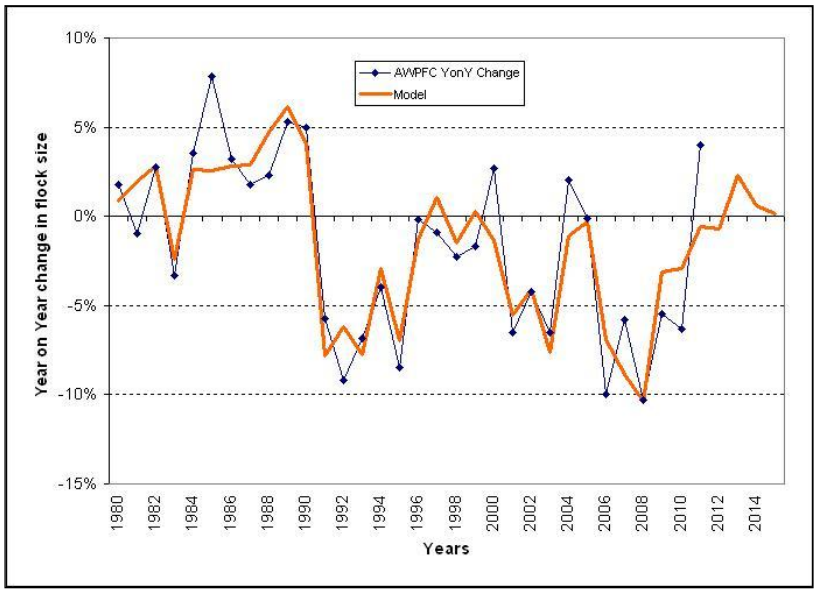
4.4.1 Independent Commodity Services

Independent Commodity Services (ICS) specialises in analysing the Australian wool market, looking at both price and supply trends, and forecasts both prices and production for their commercial clients. Andrew Woods is the principal and has long experience in analysing the Australian wool industry. His focus is on wool production for private clients, notably brokers and exporters, but recently started to develop models for sheepmeats.

ICS has a collection of regression models which predict sheep numbers, wool production (by micron category), wool prices and sheep meat prices. The trends in sheep numbers and micron category production volumes are dependent on decisions made at the farm level in response to wool prices and competing commodity prices. Seasonal conditions generally play a shorter term role, which is captured using rainfall data. ICS notes that the period between 2001 and 2009 proves the exception to the rule in that this extended dry period helped drive sheep numbers to very low levels.

The models do not mimic the flock structure but rely on historical trends (based on databases which go back to the early 1980s) to inform the regression equations. The models are also not linked together and are used and developed as needs require, with an independent consultant overseeing their statistical veracity.

The outputs from the models are based on percentage change, not an absolute value. For example, the sheep flock model predicts the change in opening sheep numbers from the year before. The chart below from ICS shows how its current sheep number model has tracked the actual changes in sheep numbers over the past thirty years (I assume ICS happy to have this in our report?). The ICS sheep model has only been operating since November 2011, so it has not been 'tested' in real life. This will be done in coming months as sheep numbers for end 2011/12 become known. Interestingly the ICS model currently predicts that sheep numbers will not rise this coming season. NOTE: MLA's current forecast is for sheep numbers to increase by around 4 per cent from 74.3 million at 30th June 2011 to 77.4 million at 30th June 2012.



4.4.2 ProFarmer

ProFarmer provides price and supply forecasts and advice to farmer and grower clients. Its focus is on cropping but they also look at wool. Malcolm Bartholomaeus is an agricultural economist with long experience in analysing and commenting on the Australian grain and wool industries, having written and published the "Callum Downs" newsletter until NZX purchased Callum Downs in 2010. NZX had previously purchased ProFarmer in 2008. Gavin Warburton is a very experienced modeller of grain crop forecasting.

ProFarmer does not forecast wool production or sheep numbers, rather relying on the 'official' forecast of wool production to develop an understanding of whether growers are running down wool stocks or building them up. This is used to consider price trends and future directions.

For their cropping advisory service, ProFarmer provides grain production forecasts. These forecasts are based on results from a survey of 1500 grain growers in the grain belt (accounting for 10% of Australia's winter crop planted). The survey asks about land use for pasture as well as cropping to assess year-on-year shifts between cropping area and pasture. The survey results are used together with a model which includes rainfall to predict grain production. The model is based on work done by Reg French in the 1970s and 1980 and is a correlation of rainfall with yield using an historical data series of rainfall from 1600 reporting sites around the grain belt of Australia. They input the monthly data for these 1600 sites as the season unfolds to predict that year's grain production. Both national and state results are provided.

ProFarmer believes that a similar approach could be used for wool production i.e. by modelling pasture growth from rainfall data and then relating that to wool production. Reg French also developed a model of pasture growth and wool production based on rainfall data. The model was based on the wheat-sheep zone, but could be developed further for the high rainfall zone. It would not be useful for the pastoral zone.

ProFarmer argues that in the high rainfall zone, sheep numbers do not change very rapidly, so it is about fleece weights. In the wheat-sheep zone there is some stocking/destocking, but fleece weights are as, if not more, important. In the pastoral zone the issue is about stocking / destocking depending on seasonal conditions and prices.

4.4.3 Banks

Rabobank's Agri-Commodity Markets Research Group conducts periodic analysis of the global animal protein markets as well as the Australian, New Zealand and global wool market. The former includes an assessment and forecast of global sheep numbers as well as selected countries. The wool report (one has just been released) does not include forecasts of sheep numbers. However, the Global Head of the Group, Luke Chandler, said that Rabobank's animal protein analyst, Wendy Boss, left at the end of last year and they are still recruiting. As a result, they do not have anybody who knows what is done for forecasting sheep and lamb production. He noted that Wendy came to Rabobank from MLA, so she was probably using similar techniques to what MLA does.

The **ANZ Bank's agribusiness commodities group** includes a member of staff (Paul Deane) who previously was an economist for The Woolmark Company and also acted as convenor of the AWPFC. As a result, the ANZ is very aware of the forecasting processes undertaken by both the wool and sheep industries. As only two staff are employed to provide analysis and internal advice, covering both national and international agricultural commodities, they rely heavily on forecasts

coming from both industry (AWI, MLA) and Government (ABARES). Such forecasts are largely fed into broader considerations of trade and policy issues (commodity prices, export levels, exchange rates etc). They do not have their own demographic / production models but adjust industry and Government forecasts with their own information and expertise

5. Assessment of forecasting accuracy

The project team analysed the accuracy of forecasts of several key sheep and wool industry outputs from Meat and Livestock Australia, the Australian Wool Production Forecasting Committee and ABARES.

The table on the following page compares the forecasting accuracy for several sheep and wool industry outputs for which independent objective statistics are available: sheep numbers (as at 30th June of each year); lamb slaughterings; sheep slaughterings; lamb meat production; mutton production; average carcass weight for lambs and sheep (for which the actuals are based on the ABS statistics on numbers slaughtered and meat produced); live sheep exports; and wool production.

There are a number of inputs to the forecasting processes that are more subjective (including lamb marking % and the number of lambs marked each year; sheep deaths; average fleece weights; and the number of sheep shorn) for which firm statistics are not generally available. For this reason, we did not report the forecast 'accuracy' of these inputs.

Table 1: Comparisons of Forecasting Accuracy of Different Organisations (%)

Output	Organisation	Number of years from forecast			
		Immediate year	1 year	3 years	5 years
closing sheep numbers	MLA (a)	9%	17%	38%	33%
	ABARES (b)	6%	16%	37%	50%
	AWPFC (c)	6%	na	na	na
lamb slaughter	MLA		9%	9%	7%
	ABARES		6%	7%	9%
	AWPFC		na	na	na
lamb meat production	MLA		7%	6%	11%
	ABARES		4%	6%	9%
	AWPFC		na	na	na
lamb carcass weight	MLA		2%	4%	4%
	ABARES		3%	3%	3%
	AWPFC		na	na	na
sheep slaughter	MLA		27%	23%	56%
	ABARES		30%	33%	50%
	AWPFC		na	na	na
mutton production	MLA		23%	17%	48%
	ABARES		28%	27%	46%
	AWPFC		na	na	na
sheep carcass weight	MLA		3%	4%	4%
	ABARES		4%	5%	6%
	AWPFC		na	na	na
live sheep exports	MLA		9%	28%	53%
	ABARES		15%	24%	45%
	AWPFC		na	na	na
shorn wool production	MLA		na	na	na
	ABARES		6%	25%	45%
	AWPFC		5%	na	na

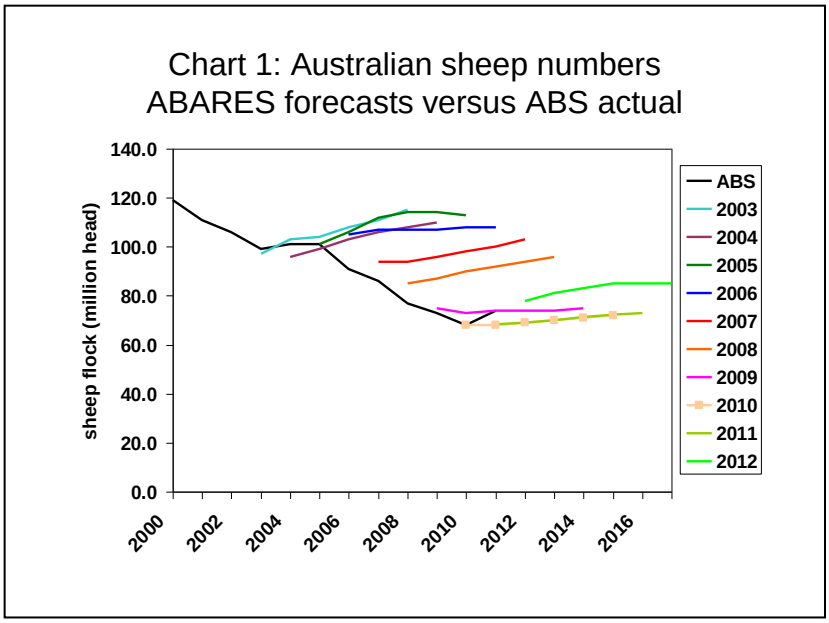
Notes
The forecasting accuracies reported are the average of the individual forecasting accuracies of the last 5 years (ended 2011). The forecasting accuracy is the absolute relative forecast error calculated using the equation abs(Forecast – Actual) / Actual.
(a) - MLA forecasts are for the calendar year forecasts made in February of each year. For sheep numbers the MLA forecasts show an estimate as at 30th June for that year (ie the end of the current financial year) and then projections for each subsequent four years. The accuracy % in the 5 Years column for sheep numbers for MLA is for the four years of projections. For other outputs, the forecast accuracy is for the calendar years and therefore there are five years of forecasts.
(b) - ABARES forecasts are made in March and its forecasts have an estimate for each output at the end of the current financial year and then a projection for five years after that. The accuracy % in the 5 Years column for all outputs is for the five projection years, not including the estimate for sheep numbers at the end of the current financial year.
(C) -The AWPFC forecasts are those made in March/April for the subsequent financial year only. The opening sheep numbers estimate is for the coming financial year (i.e. 3 months into the future, not 15 months into the future as for the MLA and ABARES forecasts.

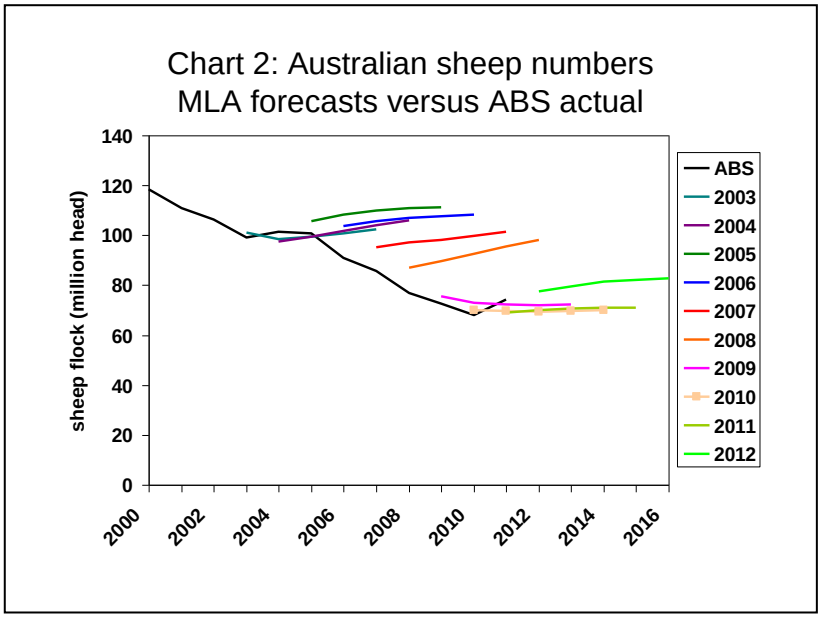
There are several observations from this analysis:

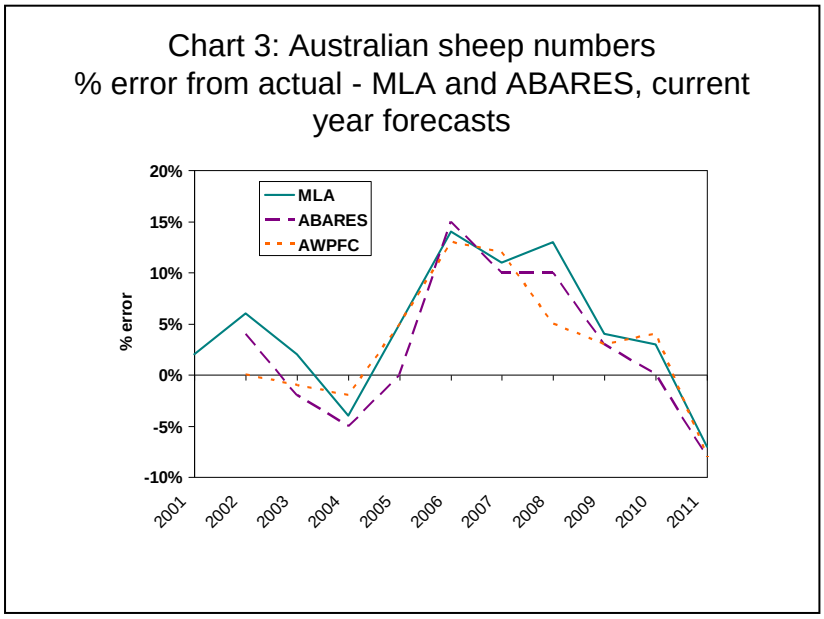
- Opening/closing sheep numbers forecasts have a relatively high error rate in the near and the longer term for all organisations. Even for the current year, the error is between 6% and 9% on average. In part this is due to changes in the ABS estimates of sheep numbers for the previous year. All organisations have the ABS preliminary estimate of previous year closing sheep numbers on which to base their forecasts with the final ABS estimates released in May/June after all three organisations have prepared their forecasts. Analysis shows that there has been an average 2% absolute difference between the preliminary and final ABS estimates in the past 11 years.
- The error rates for lamb slaughter and lamb meat forecasts are much lower, notably for the short term (i.e. one year) but also for the forecasts to five years. ABARES short term forecasts are a little more accurate than MLA (see further commentary below).
- Forecasts of annual sheep slaughter and, subsequently, mutton production have a high error rate in both the short and long term forecasts.
- The error rates for shorn wool production are relatively low in the short term for both ABARES and the AWPFC, but still above average 3% accuracy rate.

The table of average absolute errors mask variations in the percentage error rate for some of the key outputs.

For sheep numbers, both MLA and ABARES projected a solid recovery in sheep numbers for much of the 2000s which did not eventuate (see Charts 1 and 2). As a result, both MLA and ABARES forecasted higher sheep numbers than actual, even over the shorter term throughout this period (Chart 3). Chart 3 also shows the error rate for the AWPFC.





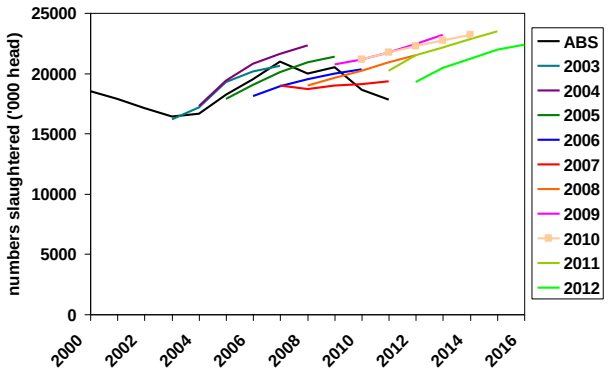


More recently the sheep number forecasts have been more conservative, predicting only modest increase in sheep numbers. The ABS' preliminary estimate of opening sheep numbers for the 2011/12 of 74.2 million head was much higher than both the estimate for a year earlier and the predictions by MLA, ABARES and the AWPFC.

In contrast to the relatively high error rate for opening sheep numbers, the error rate for forecasts of the number of lamb slaughtered is relatively low for both MLA and ABARES. The rates are, however, above the rate desired by MLA of an average of 3% with a maximum variation of 7% in

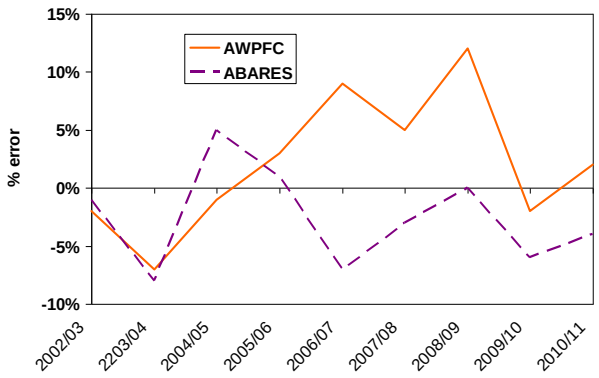
any one year. One reason for the lower error rate is that the annual number of lambs slaughtered has been relatively stable. Chart 4 shows the trends in the number of lambs slaughtered and the MLA forecasts over the past decade. An important point to note from this chart is that MLA's forecasts since 2009 have been for a strong increase in the numbers of lambs slaughtered which has not eventuated as producers rebuild their flocks. Chart 6 in Appendix I shows ABARES' projections of lamb slaughter numbers against the actual. ABARES has also predicted a strong rise in lamb slaughtering, although to a lesser degree than MLA.

Chart 4: Australian lamb slaughter
MLA forecasts versus ABS actual



As noted above, the average absolute accuracy of wool production forecasts is relatively good, but there have been some significant variations from year to year for both the AWPFC and ABARES (chart 5). As the chart shows, AWPFC has been optimistic in a number of years while ABARES has been more pessimistic.

Chart 5: Australian shorn wool production
% error from actual - AWPFC and ABARES, one year forecasts



Note: MLA is for calendar year and ABARES is financial year

The other charts in Appendix I provide the variations in error rates for lamb slaughterings and sheep slaughterings by ABARES and MLA over the past ten years.

The accuracy of the opening sheep number forecasts is very important to the forecasts for lamb slaughterings, sheep slaughterings and wool production. A sensitivity analysis conducted as part of this project on the MLA's Sheep Projections Calculator shows that opening sheep numbers is one of the most important inputs to predictions of lamb slaughterings and sheep slaughterings. It shows that, for example, a 10% increase in opening sheep numbers for 2011/12 results in an 8.5% increase in the number of lambs slaughtered in subsequent years. Appendix II gives the report on this sensitivity analysis.

6. Concluding comments

There are significant commonalities in the methodology used by the two main public forecasters of Australian sheep and wool industry. Both MLA and ABARES use a 'balance sheet' approach to estimating opening sheep numbers, a crucial element in forecasting lamb slaughterings, sheep slaughterings, live exports and wool production. The AWPFC had previously adopted a similar approach.

This method requires considerable assessment and judgment by experienced industry analysts to infer estimates for other critical inputs (such as lamb marking rates, the proportion of breeding ewes in the flock, the number of lambs and sheep sent for slaughter (as opposed to being retained), and proportion for the live export market, the numbers of sheep shorn and average fleece weights. In both the sheepmeat and wool forecasting there is also considerable input from 'on-the-ground' industry participants to provide guidance on these inputs, which is supplemented by surveys of producers in the sheep and wool industries. This has considerable strengths in ensuring that forecasts are grounded in actual industry experience.

However, none of these organisations use models which could include price relativities between wool, lamb / sheep, and other competing farming enterprises, or to account for seasonal conditions. This approach however is undertaken for wool industry clients by a private consultant and is also used in the cropping industry. It should be considered to supplement the existing methodology.

One focus for further development is on improving the accuracy of forecasts of opening sheep numbers. This element results in a relatively high % error rate and has a significant influence on the key forecasts of lamb production, mutton production and wool production.

MLA's Sheep Projections spreadsheet is in essence a calculator to determine sheep numbers. It does not include separate demographic elements such as age or breed. For example, it makes no distinction between adult sheep and lambs. Both sheep age and breed should be considered in development of the model.

Appendix I: Variations in short-term error rates

Chart 6: Australian lamb slaughter
ABARES forecasts versus ABS actual

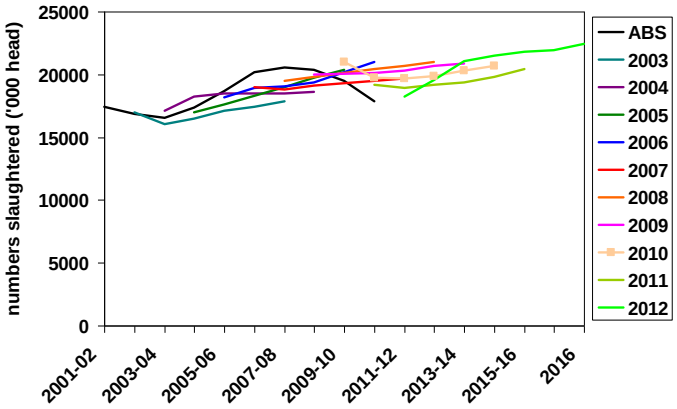
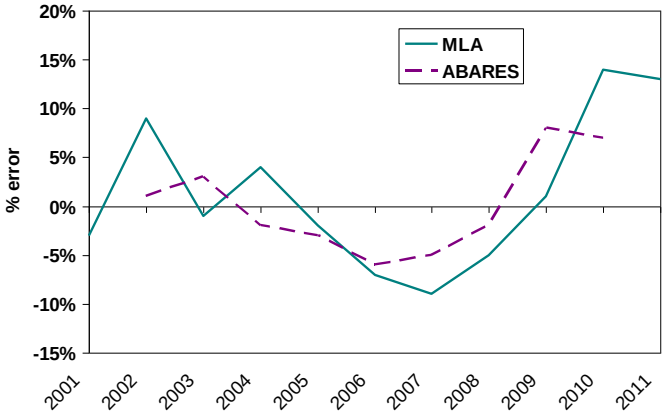
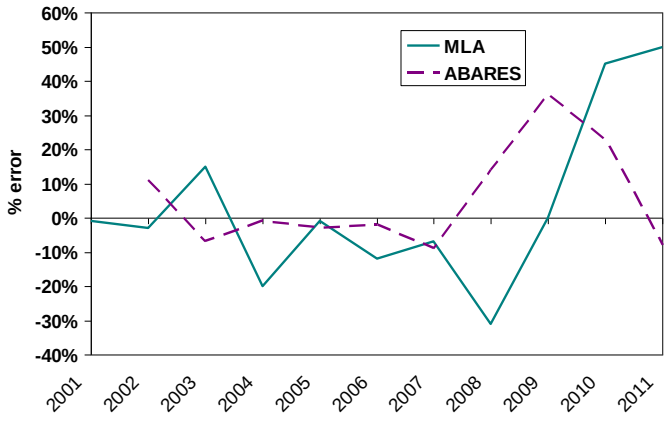


Chart 7: Australian lamb slaughterings
% error from actual - MLA and ABARES, one year forecasts



Note: MLA is for calendar year and ABARES is financial year (2002=2002/03)

Chart 8: Australian sheep slaughterings
% error from actual - MLA and ABARES, one year forecasts



Note: MLA is for calendar year and ABARES is financial year

Appendix II: Sensitivity analysis conducted on MLA Sheep Projections calculator

Background

MLA uses a Sheep Projections Calculator (SPC) to make forecasts of lamb and sheep turnoff, opening flock numbers, lamb production, etc. The SPC is a Microsoft Excel workbook that reconciles sheep numbers, marking rates, sheep turnoff and deaths. The three main worksheets for the operation of the SPC are *HistoryFinYear*, *AssumptionsFinYear* and *ProjectionsFinYear*.

- The *HistoryFinYear* worksheet is a tabulation of known historical data.
- The *AssumptionsFinYear* worksheet contains columns for past years (all data known), transition years (partial data is available) and forecast years (no actual values known). The purpose of this worksheet is to assemble known data and collate inputs (assumptions) for future years. The inputs are provided by the analyst.
- The *ProjectionsFinYear* worksheet uses the assumptions provided to forecast future sheep numbers, slaughter and death rates. The forecasts are based on a simple reconciliation of lambs marked, sheep and lambs turned off and deaths.

For the version of the SPC provided, 2006-07 through 2009-10 were history years with all data known, 2010-11 through 2012-13 are transition years with partial data, and 2013-14 through 2016-17 are forecast years.

This combination of worksheets is supported by look up functions between worksheets that make it relatively simple to update the calculator as new data is received, or as the forecast period changes.

A sensitivity analysis was conducted on the SPC to identify the relative importance of the inputs to the key outputs.

Method

The sensitivity analysis was conducted by recording the impact on each output of individually changing every input that affects that output by -10%, -5%, +5% and +10%, and comparing the results to the output (base value) calculated using the original input values. By using five levels (-10%, -5%, 0%, +5%, +10%), the analysis also gives an indication of the linearity of the relationship between input and output.

The outputs analysed were opening flock number, lamb slaughter and sheep slaughter. These were recorded for the final transition year (2012-13), and each of the four forecast years (2013-14 to 2016-17).

Prior to conducting the analysis, the SPC was simplified to just the *ProjectionsFinYear* worksheet by converting all links to other worksheets to their current values. This has the effect of explicitly setting the inputs from the history and assumptions worksheets on the *ProjectionsFinYear* worksheet.

Results

For each forecast period, and each input, there was a linear relationship between the five levels of that input and the resulting output values. Therefore only the changes in an output due to a +10% change in each input are reported.

The tables below show the percent change in lambs slaughtered (Table 1), sheep slaughtered (Table 2) and opening flock number (Table 3) for a +10% change in the listed input parameters. Only input parameters that changed the output by more than 2% are listed.

Table 1 Impact on lamb slaughter of a 10 percent increase in each of the input parameters. Results presented for three periods and for impacts greater than two percent

Results for lamb slaughter in 2012-13 (base value 20.16 million)

Input parameter	*Impact on lamb slaughter, 2012-13*
Intended matings as a per cent of breeding ewes, 2012-13	10.0%
Lambs marked as a percent of actual matings, 2012-13	10.0%
Lambs slaughtered as a percent of lambs marked, 2012-13	10.0%
Actual matings as a percent of intended matings, 2012-13	10.0%
Breeding ewes as a percent of opening numbers, 2012-13	10.0%
Opening flock number, 2011-12	8.5%
Actual matings as a percent of intended matings, 2011-12	3.2%
Opening number of breeding ewes, 2011-12	3.2%
Intended matings as a per cent of breeding ewes, 2011-12	3.2%
Lambs marked as a percent of actual matings, 2011-12	3.2%
Percent of total lambs slaughtered in Jul-Sep quarter, 2012-13	2.7%
Percent of total lambs slaughtered in Apr-Jun quarter, 2012-13	2.4%
Percent of total lambs slaughtered in Jan-Mar quarter, 2012-13	2.4%
Percent of total lambs slaughtered in Jul-Sep quarter, 2012-13	2.4%

Results for lamb slaughter in 2014-15 (base value 21.75 million)

Input parameter	*Impact on lamb slaughter, 2014-15*
Intended matings as a per cent of breeding ewes, 2014-15	10.0%
Lambs slaughtered as a percent of lambs marked, 2014-15	10.0%
Actual matings as a percent of intended matings, 2014-15	10.0%
Lambs marked as a percent of actual matings, 2014-15	10.0%
Breeding ewes as a percent of opening numbers, 2014-15	10.0%
Opening flock number, 2011-12	8.5%
Lambs marked as a percent of actual matings, 2011-12	3.2%
Actual matings as a percent of intended matings, 2011-12	3.2%
Intended matings as a per cent of breeding ewes, 2011-12	3.2%
Opening number of breeding ewes, 2011-12	3.2%
Lambs slaughtered as a percent of lambs marked, 2013-14	–2.6%
Lambs slaughtered as a percent of lambs marked, 2012-13	–2.5%

Results for lamb slaughter in 2016-17 (base value 22.60 million)

Input parameter	*Impact on lamb slaughter, 2016-17*
Intended matings as a per cent of breeding ewes, 2016-17	10.0%
Lambs slaughtered as a percent of lambs marked, 2016-17	10.0%
Actual matings as a percent of intended matings, 2016-17	10.0%
Lambs marked as a percent of actual matings, 2016-17	10.0%
Breeding ewes as a percent of opening numbers, 2016-17	10.0%
Opening flock number, 2011-12	8.5%
Intended matings as a per cent of breeding ewes, 2011-12	3.2%
Lambs marked as a percent of actual matings, 2011-12	3.2%
Actual matings as a percent of intended matings, 2011-12	3.2%
Opening number of breeding ewes, 2011-12	3.2%
Lambs slaughtered as a percent of lambs marked, 2015-16	–2.7%
Lambs slaughtered as a percent of lambs marked, 2014-15	–2.6%
Lambs slaughtered as a percent of lambs marked, 2013-14	–2.6%
Lambs slaughtered as a percent of lambs marked, 2012-13	–2.5%

Table 2 Impact on sheep slaughter of a 10 percent increase in each of the input parameters. Results presented for three periods and for impacts greater than two percent

Results for sheep slaughter in 2012-13 (base value 5.62 million)

Input parameter	*Impact on sheep slaughter, 2012-13*
Sheep turnoff as a percent of opening flock number, 2012-13	15.2%
Opening flock number, 2011-12	13.0%
Live exports, 2012-13	–5.2%
Opening number of breeding ewes, 2011-12	4.8%
Intended matings as a per cent of breeding ewes, 2011-12	4.8%
Lambs marked as a percent of actual matings, 2011-12	4.8%
Actual matings as a percent of intended matings, 2011-12	4.8%
Percent of total sheep slaughtered in Oct-Dec quarter, 2012-13	2.9%
Percent of total sheep slaughtered in Jan-Mar quarter, 2012-13	2.9%

Results for sheep slaughter in 2014-15 (base value 7.56 million)

Input parameter	*Impact on sheep slaughter, 2014-15*
Sheep turnoff as a percent of opening flock number, 2014-15	14.0%
Opening flock number, 2011-12	12.0%
Actual matings as a percent of intended matings, 2011-12	4.5%
Intended matings as a per cent of breeding ewes, 2011-12	4.5%
Lambs marked as a percent of actual matings, 2011-12	4.5%
Opening number of breeding ewes, 2011-12	4.5%
Live exports, 2014-15	–4.0%
Lambs slaughtered as a percent of lambs marked, 2013-14	–3.6%
Lambs slaughtered as a percent of lambs marked, 2012-13	–3.5%
Lambs marked as a percent of actual matings, 2013-14	2.6%
Actual matings as a percent of intended matings, 2013-14	2.6%
Intended matings as a per cent of breeding ewes, 2013-14	2.6%
Breeding ewes as a percent of opening numbers, 2013-14	2.6%
Actual matings as a percent of intended matings, 2012-13	2.6%
Breeding ewes as a percent of opening numbers, 2012-13	2.6%
Lambs marked as a percent of actual matings, 2012-13	2.6%
Intended matings as a per cent of breeding ewes, 2012-13	2.6%

Results for sheep slaughter in 2016-17 (base value 8.32 million)

Input parameter	*Impact on sheep slaughter, 2016-17*
Sheep turnoff as a percent of opening flock number, 2016-17	14.0%
Opening flock number, 2011-12	11.9%
Lambs marked as a percent of actual matings, 2011-12	4.4%
Opening number of breeding ewes, 2011-12	4.4%
Intended matings as a per cent of breeding ewes, 2011-12	4.4%
Actual matings as a percent of intended matings, 2011-12	4.4%
Live exports, 2016-17	–4.0%
Lambs slaughtered as a percent of lambs marked, 2015-16	–3.8%
Lambs slaughtered as a percent of lambs marked, 2014-15	–3.7%
Lambs slaughtered as a percent of lambs marked, 2013-14	–3.6%
Lambs slaughtered as a percent of lambs marked, 2012-13	–3.5%
Lambs marked as a percent of actual matings, 2015-16	2.6%
Actual matings as a percent of intended matings, 2015-16	2.6%
Breeding ewes as a percent of opening numbers, 2015-16	2.6%
Intended matings as a per cent of breeding ewes, 2015-16	2.6%
Lambs marked as a percent of actual matings, 2014-15	2.6%
Intended matings as a per cent of breeding ewes, 2014-15	2.6%
Actual matings as a percent of intended matings, 2014-15	2.6%
Breeding ewes as a percent of opening numbers, 2014-15	2.6%
Intended matings as a per cent of breeding ewes, 2013-14	2.6%
Actual matings as a percent of intended matings, 2013-14	2.6%
Breeding ewes as a percent of opening numbers, 2013-14	2.6%
Lambs marked as a percent of actual matings, 2013-14	2.6%
Actual matings as a percent of intended matings, 2012-13	2.6%
Lambs marked as a percent of actual matings, 2012-13	2.6%
Intended matings as a per cent of breeding ewes, 2012-13	2.6%
Breeding ewes as a percent of opening numbers, 2012-13	2.6%

Table 3 Impact on opening flock number of a 10 percent increase in each of the input parameters. Results presented for three periods and for impacts greater than two percent

Results for opening flock number in 2012-13 (base value 77.7 million)

Input parameter	*Impact on opening flock number, 2012-13*
Opening flock number, 2011-12	8.5%
Actual matings as a percent of intended matings, 2011-12	3.2%
Intended matings as a per cent of breeding ewes, 2011-12	3.2%
Lambs marked as a percent of actual matings, 2011-12	3.2%
Opening number of breeding ewes, 2011-12	3.2%

Results for opening flock number in 2014-15 (base value 81.6 million)

Input parameter	*Impact on opening flock number, 2014-15*
Opening flock number, 2011-12	8.5%
Actual matings as a percent of intended matings, 2011-12	3.2%
Intended matings as a per cent of breeding ewes, 2011-12	3.2%
Lambs marked as a percent of actual matings, 2011-12	3.2%
Opening number of breeding ewes, 2011-12	3.2%
Lambs slaughtered as a percent of lambs marked, 2013-14	–2.6%
Lambs slaughtered as a percent of lambs marked, 2012-13	–2.5%

Results for opening flock number in 2016-17 (base value 83.0 million)

Input parameter	*Impact on opening flock number, 2016-17*
Opening flock number, 2011-12	8.5%
Intended matings as a per cent of breeding ewes, 2011-12	3.2%
Lambs marked as a percent of actual matings, 2011-12	3.2%
Opening number of breeding ewes, 2011-12	3.2%
Actual matings as a percent of intended matings, 2011-12	3.2%
Lambs slaughtered as a percent of lambs marked, 2015-16	–2.7%
Lambs slaughtered as a percent of lambs marked, 2014-15	–2.6%
Lambs slaughtered as a percent of lambs marked, 2013-14	–2.6%
Lambs slaughtered as a percent of lambs marked, 2012-13	–2.5%

Discussion

Lamb slaughter

Lambs slaughtered is directly related to five inputs in the SPC – breeding ewes as a percent of opening flock number (BE%), intended matings as a percent of breeding ewes (IM%), actual matings as a percent of intended matings (AM%), lambs marked as a percent of actual matings (LM%), and lambs slaughtered as a percent of lambs marked (LS%). A change in any of these five parameters gives an equivalent percent change in lambs slaughtered. This results from the equation for lambs slaughtered (LS) where the same result is achieved by adjusting any of the independent variables (by the same percent):

$$LS = OFN \; x \; BE\% \; x \; IM\% \; x \; AM\% \; x \; LM\% \; x \; LS\%$$

where OFN is opening flock number. Opening flock number is the next most important input. A change of +10 percent in OFN results in an increase in lamb slaughter from the base value by 8.5 percent. [Only OFN for 2011-12 is included in the inputs analysed because the OFN in all later years is dependent on other values.]

Sheep slaughter

The main inputs impacting on sheep slaughter are sheep turn off as a percent of opening flock number (in the slaughter year) and opening flock number in 2011-12.

For both these inputs, this analysis showed the percent change in sheep slaughter is greater than the change applied to the input. This is a result of the allocation of extra opening numbers or a higher turnoff to sheep slaughter without changing the live export number. This can be seen from the equation for sheep slaughter:

$$SS = OFN \; x \; ST\% - LE$$

where SS is sheep slaughter, ST% is sheep turn off as a percent of opening number and LE is live exports.

Opening flock number

Changes to opening flock number itself have the greatest impact on future opening flock numbers. An increase in flock size of 10% increases future flock size by around 8.5 percent.

Inputs that drive reproductive performance (actual matings as a percent of intended matings, intended matings as a percent of breeding ewe numbers and lambs marked as a percent of actual matings) have a high impact on future opening flock number. In later periods (e.g. 2014-15 and 2016-17), lambs slaughtered as a percent of lambs marked directly impact on opening flock number. A 10 percent increase in lambs slaughtered reduces opening flock number by around 2.5 percent.

Summary

From this analysis, the inputs that have the greatest impact on the key outputs to be forecast are:

Lamb slaughter:

- Intended matings as a percent of breeding ewes
  Lambs marked as a percent of actual matings
  Lambs slaughtered as a percent of lambs marked
  Actual matings as a percent of intended matings
  Breeding ewes as a percent of opening numbers
- Opening flock number

Sheep slaughter

- Sheep turn off as a percent of opening flock number
- Opening flock number

Opening flock number (2012-13 onwards)

- Opening flock number, 2011-12