System changes to a lamb farm in south-west Victoria: some pre-experimental modelling

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Abstract

There is limited capital available to spend on livestock research programs. Consequently, it is important to estimate the potential economic impact of changing on-farm factors within farm systems at the outset, to identify which changes may have big payoffs and which ones look less attractive. We present the results of some pre-experimental modelling to inform on the most suitable targets for research efforts in the Victorian lamb industry. Increased stocking rate through improved weaning percentage generated the highest average annual profit after interest and tax of all the scenarios investigated, increasing average annual net profit from the base farm system by 40%. Potentially attractive innovations that allow earlier mating, increased growth rates, increased lamb feed efficiency, faster lamb turnoff, reduced animal health costs and increased ewe fleece weight did not rank as highly in terms of profit and risk as the traditional, well known innovations.

Keywords: Lamb production, system changes, economics

Introduction

In the next decade it is likely that sheep farming net returns will continue to be squeezed by rising real costs of key inputs and stable or declining prices received for product (Tocker *et al.* 2013). However, outcomes from current research and development programs have the potential to increase the productivity and profit of farms in the lamb industry for at least the next thirty-five years (Alston 2010). The intricate complexity of farming systems means there are almost unlimited opportunities to investigate interesting components of lamb production systems. With limited funds to invest, agricultural research and development agencies face the perennial problem of deciding which research projects to select. Agencies that seek to improve the welfare of farmers should fund those projects that bring about the greatest increase in farm profit. To identify which of the available set of research projects are most likely to do this, the expected net benefits to farmers of potential research projects need to be quantified. An important aspect of this work is that it must be done before the research is started, which means the value of net benefits must be estimated with limited information about what the outcomes of the research will be. Despite this limitation, we argue that more informed decisions can be made about which research projects to fund with this information than without it.

Many articles in the technical literature answer questions about how farm livestock activities might perform when changes are imposed (e.g. Salmon *et al.* 2004; Warn *et al.* 2006; Graham and Hatcher 2006, Mokany *et al.* 2009). These analyses use gross margin (Total Income – Variable Costs) to determine the performance of livestock activities and draw conclusions accordingly. However, activity gross margins are partial representations of reality and have limited ability to answer questions about which livestock activity to run in a farm business. Whole farm analysis is a more complete approach, considering cash, profit, wealth and risk aspects of the investment (Heard *et al.* 2013).

The objective of this paper is to quantify the potential net benefits to farmers for a suite of plausible research induced changes to a lamb farm system in south-west Victoria. We present the results of this pre-experimental modelling to inform scientific research efforts in the Victorian lamb industry.

Materials and Methods

The model

A whole-farm economic model was developed according to whole-farm management economic principles (e.g. Malcolm *et al*. 2005). The model comprised a series of spreadsheets which represented the physical structure, livestock activities and feedbase of a case study farm. The economic and financial performance of the farm was recorded over a 7 year planning period, using annual balance sheets, profit budgets and cash flow budgets, and subject to volatility of climatic and economic conditions. The key measure of performance used in this analysis was annual net profit after interest and tax, once the change being investigated was fully operational. This measure reflects the typical annual contribution to equity of making the change. Using this variable as the measure of performance meant that all the changes to the farm system could be compared on the same basis. A flow chart of the model is provided in the appendices (Figure 1).

The physical structure and management of the farm was represented by data which described the amount of land, labour and capital used in production. The livestock system was defined by the number and type of animals in each of up to 17 livestock classes, which were included to reflect ewes and wethers of different age groups, rams, and also different joining/lambing dates for different ewe groups The 'feedbase' of the farm referred to the area and type of pasture used to provide energy to livestock, plus whatever supplementary feed was required.

The model represented the operation of a case-study farm over a seven-year period. Each year was represented by an individual spreadsheet which contained a fortnightly livestock calendar and feed budget. The livestock calendar tracked the number of animals in each livestock class throughout the year. The revenues and costs associated with animal husbandry and livestock trading activities were also recorded in this calendar when they occurred.

The feed budget balanced energy demanded by animals with energy supplied by the feedbase. This was done using the metabolisable energy (ME) system as published in Freer *et al.* (2010). In summary, ME reflects the amount of energy available to animals from a feedstuff after accounting for losses in faeces, urine and methane. Convention is for the ME of a feedstuff to be measured in megajoules of ME per kilogram of dry matter (DM), so that feeds can be compared on a standard basis. Animal daily requirements for energy were also expressed on an ME basis for various physiological processes including maintenance, pregnancy, lactation and activity. This data was aggregated to a fortnightly frequency. The summed product of the ME requirements of animals in each class of livestock and the number of animals in each class gave the whole-farm ME demand at a fortnightly frequency.

An estimate of the amount of ME supplied by the feedbase of the farm was calculated using the Sustainable Grazing Systems (SGS) pasture model (Johnson *et al*. 2003). These estimates were based on the climate of Hamilton between 1970 and 2010. Distributions of possible pasture growth rates were constructed for each fortnight to capture the year to year variability in pasture growth, and were matched with pasture nutritive characteristics from the SGS model.

Metabolisable energy demanded by livestock and ME supplied by pastures were balanced in annual feed budgets. If ME supply was less than ME demand in a particular fortnight the difference was provided in the form of purchased supplementary feed with an energy content of 12 MJ ME/kg DM. No specific fodder conservation strategies were used in times of surplus however the calculations in the feed budget included the carryover of 67% of surplus pasture from one fortnight to the next (Moore and Zurcher 2005).

Importantly, risk was represented in the model. Specifically, stochastic simulation was performed using @Risk, an add-in to Microsoft Excel, which allows probability distributions to be defined for variables of interest using Monte Carlo sampling (Palisade 2009). To do this, risk variables are represented in the model using probability distributions rather than single values. By sampling many times from the distributions of possible values that risk variable may take, distributions of expected farm profit (rather than single values) were calculated using this model. Variation in the distribution of farm profit is a measure of risk. The key inputs to each system for which probability distributions were defined are presented in Table 1 of the appendices.

Multivariate stepwise regression was used to determine the contribution of each uncertain variable to the estimated total variability of annual net profit after interest and tax for each scenario. The derived coefficients (generated using @Risk) represent the normalised regression coefficients associated with each input, indicating the change in output associated with each unit standard deviation change in input (Palisade 2009).

The spreadsheets which represent each year of operation of the farm were linked to allow dynamic effects of changes to the livestock system or the feedbase to be represented. For example, sowing a new pasture in year 2 altered the feedbase of the farm in year 2 and in subsequent years. Similarly, the effect of risky variables could also have dynamic impacts. For example, a poor season of pasture growth in year 3 reduced the amount of feed available to livestock in both years 3 and 4 because less surplus feed would be available to be carried over from spring of year 3 to summer of year 4.

Labour, animal husbandry, supplementary feed and sale costs were all constructed to vary in proportion to the number of ewes and lambs carried.

Finally, in addition to the annual variation in production parameters described in Table 1, a Poisson distribution was also included in the model to represent the occurrence of particularly ‘poor’ seasons. Specifically, these seasons occurred one year in every seven (on average), and when they occurred, the weaning rate of 2+ year old ewes decreased from 148% to 132%, the weaning rate from 1 year old ewes decreased from 71% to 56%, the annual mortality rate was increased from 3% to 6%, the proportion of heavy lambs (defined below) decreased from 30% to 20% and the proportion of light lambs that made 50 kg decreased from 70% to 50%.

The case study farm

The case study farm used for this work is a 1,000 hectare lamb farm in south-west Victoria. The farm business is currently performing well, as demonstrated by its high annual profit (Figure 2, Table 4) and return on capital relative to other specialist lamb producing farms (Caboche and Thompson 2013; Waterman and Creese 2013). The soil types are characterised as 80% red loam clay and 20% self-mulching black flats. The feed supply of the farm comprises 800 hectares of a high-performance ryegrass and clover pasture, and 200 hectares of a lucerne and plantain mix. The entire farm is fenced into 10-hectare paddocks and a rotational grazing system is used.

The livestock system of the farm consists of 10,000 first-cross ewes joined to Dorset rams to produce prime lambs at an average weaning rate of 130% (148% for 2+ year old ewes, 71% for 1 year old ewes). Ewes weigh approximately 70-75kg at maturity and are purchased at 10 months of age, joined at 12 months and retained for 5 years. The average annual stocking rate is calculated to be approximately 25 dry sheep equivalents (DSE) per hectare (DSE is a standard measure used to compare the feed requirements of different classes of stock. One DSE is the amount of feed required by a two year old 45 kg Merino sheep to maintain it’s weight).

All ewes are joined over six-weeks from mid-February until the end of March. Lambing occurs in mid-July to the end of August and weaning occurs in mid-December. At weaning the composition of lambs by weight is typically approximately 30% at 50kg, 50% at 40kg and 20% at 30kg. In a poor year these proportions become approximately 20% at 50kg, 50% at 40kg and 30% at 30kg.

Lambs are sold at 50kg liveweight so lambs that have reached this weight at the time of weaning are classed as ‘heavy’ and sold. Those that have not reached 50kg by weaning are classed as ‘light’ and are retained on the lucerne and plantain pasture over summer. Light lambs are sold in mid-March, by which time 70% have typically reached 50kg liveweight and the remaining 30% have reached 40kg. In a ‘poor’ year, these proportions are 50% each. A summary of the base farm system is provided in Table 2 of the appendices.

In the model, the total ME demand of lambs did not change from ‘average’ to ‘poor’ years, despite the weighted average liveweight gain of lambs being less in poor years. This assumption was included to try and capture situations when environmental conditions particularly affected production in a negative way. Such situations may include periods of cold, wet weather which would slow the growth of lambs. Equations required to estimate ME requirements in cold conditions require data such as windspeed, whether lambs are wet or dry and fleece length, and our model is not sufficiently sophisticated to handle this level of detail. Therefore, we assumed lambs would require the same amount of ME in normal and ‘poor’ years, but the average liveweight of lambs sold was assumed to be higher in good years.

The balance of ME demand and supply of the farm was validated based on historical records and discussions with the operator of the case-study farm. Pasture growth figures were adjusted to reflect on-farm supplementary feeding practices in both normal and ‘poor’ years.

For the purposes of this work, sixteen potential changes to the case study farm production system were compared. The changes (from here on referred to as ‘scenarios’) were:

1. Increased stocking rate
2. Increased stocking rate through improved weaning percentage
3. Increased weaning rate with maintained stocking rate
4. Increased proportion of ‘light’ lambs reaching 50 kg sale weight
5. Increased ewe feed efficiency
6. Increased lamb feed efficiency and faster turnoff
7. Increased ewe and lamb feed efficiency with faster lamb turnoff
8. Reduced ewe mortality
9. Increase in ewe longevity (and average mortality)
10. Decreased ewe mortality plus increased ewe longevity
11. Increased lamb growth rate and faster turnoff

12. Reduced flock health costs
13. Increased fleece weight
14. Increased fleece weight plus increased wool price
15. Purchase ewe replacements at 10 months, join at 2 y.o., unchanged ewe prices
16. Purchase ewe replacements at 10 months, join at 2 y.o., lower ewe prices

For each scenario, quantitative changes made to the base farm system were nominated by researchers at the Red Meat Innovation Centre at Hamilton, and reflect conceivable targets that may be possible from new technologies.

Capital expenditures on sheep purchases were included in the model, as were costs associated with additional labour, supplementary feed, animal health and selling costs, in proportion to increasing or decreasing sheep numbers relative to the base farm system. The costs of changing the system to achieve the improved performance – the development costs for each scenario – were not included, because the relationship between marginal capital invested to make the change and how the improved performance may be achieved was not known. In undertaking this modelling, only the primary effects of adopting a change were tested – secondary effects were not included. For example, the change in annual net profit after interest and tax from increasing the stocking rate was assessed without considering possible side effects such as a decrease in fleece weight and/or decrease in fibre diameter. A summary of production changes made to the base farm for each scenario is presented in Table 3 of the appendices.

Results

Annual farm net profit and risk for each scenario, ranked from lowest to highest in terms of average profit, is presented in boxplots in Figure 2. This expected extra profit does not include an allowance for the depreciated extra capital that would be required to make the change, but does include other extra variable costs (as described above). The average and standard deviation of annual net profit for each of the scenarios is provided in Table 4 of the appendices, and an overview of the direction of changes to revenues and costs of each scenario relative to the base farm is provided in Table 5. For each scenario, the percentage change in annual net profit and standard deviation of net profit relative to the base farm system is also shown (Table 4).

All but one of the sixteen changes tested increased average annual net profit relative to the base farm system (Figure 2, Table 4). 'Purchasing ewe replacements at 10 months to join at 2 y.o., unchanged ewe prices' (Scenario 15) returned a lower average annual net profit than the base farm system (-7%). In this scenario, it was assumed that although replacement ewes would still be purchased at normal market rates at 10 months of age, they would not be joined until 2 years of age. In this situation, annual metabolisable energy requirements of the whole flock would be reduced, allowing stocking rate to be lifted from 10 to 10.4 ewes per hectare without increasing supplementary feed costs. This age group would not be culled in their first year, thus reducing the number of replacement ewes purchased. However, a smaller proportion of the total ewe flock would be joined each year, and therefore fewer lambs would be weaned and sold. Overall, the value of the reduction in lambs sold was greater than the reduction in the cost of replacement ewes, thus whole farm profit was lower. If these replacement ewes could be purchased at $40/head less than market rates (Scenario 16), average annual net profit was predicted to improve relative to the base farm system (+9%).

Improving the feed conversion efficiency of animals in the system had mixed effects on average annual net profit. In Scenario 6, it was assumed that 'feed efficient' lambs would require 80% of the metabolisable energy requirements of an 'average' lamb. Under these conditions, lambs could be expected to reach target liveweights about 1 month earlier, and thus sale dates for each group of lambs were assumed to be about 1 month earlier (Table 3). With no other changes, this scenario generated a small increase in average annual net profit compared to the base farm system (+3%), principally because of a reduction in supplementary feed costs.

In Scenario 5, it was assumed that 'feed efficient' ewes would require 80% of the metabolisable energy requirements of an 'average' animal. This in turn would allow stocking rate to be increased by 20% without an increase in feed demand (Table 3). Labour costs were increased by 10% to account for increased stocking rate. In contrast to Scenario 6, increasing ewe feed efficiency by 20% had a substantial positive effect (+33%) on average annual net profit. While labour, supplementary feed, animal husbandry and sale costs all increased (Table 5), the value of extra lambs and wool sold more than offset these additional costs.

In Scenario 7, it was assumed that the feed efficiency of both ewes and lambs were improved – essentially Scenarios 5 and 6 combined. This had an even more marked effect on average annual net profit (+38%), ranking second highest of all scenarios tested (Figure 2, Table 4). Increasing ewe stocking rate without a concurrent requirement for additional supplementary feed meant that the farming system could generate more lambs and wool, thus increasing gross income. Increased lamb production and decreased age to turnoff would ensure that more feed is available for other livestock classes at key times of the year, reducing the reliance on supplementary feed.

The impact of increasing the proportion of ‘light’ lambs reaching 50kg sale weight was also investigated (Scenario 4). In this scenario, total revenue from the sale of lambs increased marginally, having a small positive impact on average annual net profit (+9%).

Purchasing replacement ewes represents a significant cost to this business. The impact of reducing ewe mortality and/or increasing ewe longevity was tested (Scenarios 8-10). Reducing ewe mortality (Scenario 8) decreased the number of replacement ewes required to be reared or purchased and led to a small increase in the number of cull animals sold. Relative to the base farm system, this scenario generated a small increase in supplementary feed requirements, because of the timing of purchasing replacement stock. Overall, reducing ewe mortality had only a small positive influence on average annual net profit (+6%, Figure 2, Table 4).

The effect of increased ewe longevity was considered (Scenario 9). In the base farm system, productive ewes were kept until approximately 5.5 years of age, after being joined 5 times over their lifetime. In this scenario, it was assumed that ewes were kept until 7.5 years of age, joined 7 times over their productive lifetime. Average annual cull rate for the flock was accordingly reduced from 20% per age group to 14% per age group. Increasing ewe longevity had a stronger positive impact on average annual net profit than reducing ewe mortality (+12% compared with the base farm system, Table 4). This was primarily caused by a reduced requirement for replacement ewes in each year.

In Scenario 10, the effect of decreased ewe mortality coupled with increased ewe longevity on farm profitability was considered. In this scenario, ewe mortality was reduced to 1% in ‘good’ years and 3% in ‘poor’ years. Labour costs were increased by 10% to account for possible costs associated with this change. Productive ewes were kept until 7.5 years of age, and all else was held constant. The combination of decreased ewe mortality plus increased ewe longevity had a strong positive effect (+18%) on average annual net profit (Table 4, Figure 2).

The effect of improvements in fleece weight, reductions in fibre diameter (as price received for wool) or a combination of both increased fleece weight and increased wool price on farm profitability was investigated (Scenarios 13 and 14). Improving fleece weight by 20% or fleece price by 20% had a positive (+7%, Table 4) influence on average annual net profit. Increasing both fleece weight and wool price by 20% had a more marked positive effect (+17%, Table 4).

Increasing stocking rate from 10 to 12 ewes per hectare (Scenario 1), with concurrent increases in supplementary feed, husbandry, labour and sale costs, increased average annual net profit by 29%, but also generated the greatest standard deviation of net profit of all scenarios tested (Table 4). Increased stocking rate through improved weaning percentage (Scenario 2) generated the highest average annual net profit after interest and tax of all the scenarios investigated, increasing average annual net profit from the base farm system by 40% (Table 4). In this scenario, it was assumed that weaning rate could be increased without changing ewe numbers, essentially increasing stocking rate per hectare. While labour, supplementary feed and sale costs increased in proportion to the additional lambs, the increase in revenues from lamb sales more than made up for the increase in costs. Increasing weaning rate had a more beneficial effect on the risk-return profile of the farm than increasing stocking rate from 10 to 12 ewes (Scenario 1) as it generated a greater increase in livestock trading profit without running any more ewes. This reduced exposure to variation in replacement ewe prices, seasonal conditions and interest rates, reducing risk to the farm business.

The contribution of key uncertain variables to estimated variability in annual net profit after interest and tax was estimated for each scenario (Table 6). The occurrence of a one in seven year ‘poor’ season had the greatest impact on variability in profit for all of the scenarios tested. In most cases, variation in replacement ewe prices had the second greatest influence over variability in profit, followed by lamb prices (c/kg CW). Variability in mutton and wool prices had less impact on variability in profit for these scenarios.

Discussion

The main determinants of profit and risk for this farm are the value of lamb sold and cost of replacement ewes. Thus, changes to the farm system which had the greatest effect on these two variables were expected to have the greatest effect on farm profit and risk.

This expectation was borne out in the results – increasing the stocking rate and the weaning rate caused the greatest increase in farm profit because these changes caused the greatest increase in the value of lambs sold. This is in agreement with McEachern and Sackett (2008) who reported that the increase in stocking rate that occurs when the weaning rate is increased generates a significant part of the overall benefit of the change. Scenarios where ewe mortality was decreased and ewe longevity was increased also cause relatively large increases in farm profit because this reduced the annual depreciation cost of flock capital, the largest single cost of the sheep enterprise.

This pre-experimental analysis was a 'first-look' analysis - changes to the farm system were evaluated in a partial sense - as if they were the only change being made. The effects of the change on the farm business were calculated in the steady state for a single year of a seven year planning period once the change being investigated was fully operational. The change in annual net profit (surplus) generated by each change was estimated as annual extra revenue minus annual extra costs, including extra feed and labour costs and the annual opportunity cost of extra capital invested in changed stock capital. The estimated annual surplus for each innovation represents an amount that would be available to cover the undefined extra annual costs of capital invested, and any extra operating costs that may be incurred to achieve the changed state of affairs, with the remainder available to add to the wealth of the farm owner.

Technical information describing the costs and benefits of the change are critical inputs to this method of comparing technologies. However, in this analysis, while the main benefits of the change are clear – for example, increasing the weaning rate resulted in more lambs being sold, and hence more livestock trading revenue – for some of the changes, not all of the costs of establishing the changed system are known. For example, consider increasing weaning rate. If the weaning rate is increased, in the analysis the number of lambs on the farm increases, whole-farm annual energy demand increases, and consequently the average supplementary feed cost increases. With more lambs weaned and sold, total animal husbandry and sale costs also increase. However, the costs of the changes that actually make the increased weaning rate possible are not included in this analysis, because the changes to achieve this goal are not explicitly defined. Suppose, to increase the weaning rate, costs may be incurred for known changes such as using extra labour to more closely monitor sheep, to purchase a supplement, to create a sheltered lambing area, to obtain better lambing genetics, or some other change yet to be researched. These costs are unlikely to be zero – however they are currently unknown, and therefore are not included in the analysis.

More generally, in modelling such as this, all the extra costs of achieving the improved performance of the system, the extra costs of running the animal activity and the extra costs of changes to the farm to make the changed performance of the activity possible may not be known. Thus an estimate of net benefit generated by a given change is made up of extra returns minus identified extra costs, but this net benefit may still have to also cover some currently undefined and uncounted capital and operating costs associated with the change in the steady state. Furthermore, the estimates do not include any development costs which may be incurred prior to reaching the steady state. Research such as this presents a guide to the relative attractiveness of different targets rather than the innovation per se. Changes to farm systems which are not profitable in the medium term are unlikely to be adopted; hence the focus of a 'first look' analysis such as this one should be on the steady state. However, it is important to recognise that once *all* costs associated with making these changes are taken into account, some of them may not actually increase overall farm profit.

Conclusion

This paper reports the economic viability of 16 different farm scenarios identified by researchers and sheep farmers as likely good investment opportunities on-farm over the next decade. Several different farm scenarios confirm that common sense and intuition of experienced researchers and farmers will increase the farm's economic viability; however, other findings are less obvious. Potentially attractive innovations such as earlier mating, increasing growth rates, increasing lamb feed efficiency, faster lamb turnoff, reducing animal health costs, increasing ewe fleece weight, did not rank as highly in terms of profit and risk as the traditional, well known innovations to do with increasing stocking rate and ewe feed efficiency and reproductive performance. That said, nearly all changes increased farm profit relative to the 'base case' farm system.

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Appendices

Figure 1. Flowchart outlining the operating process for the whole farm economic model

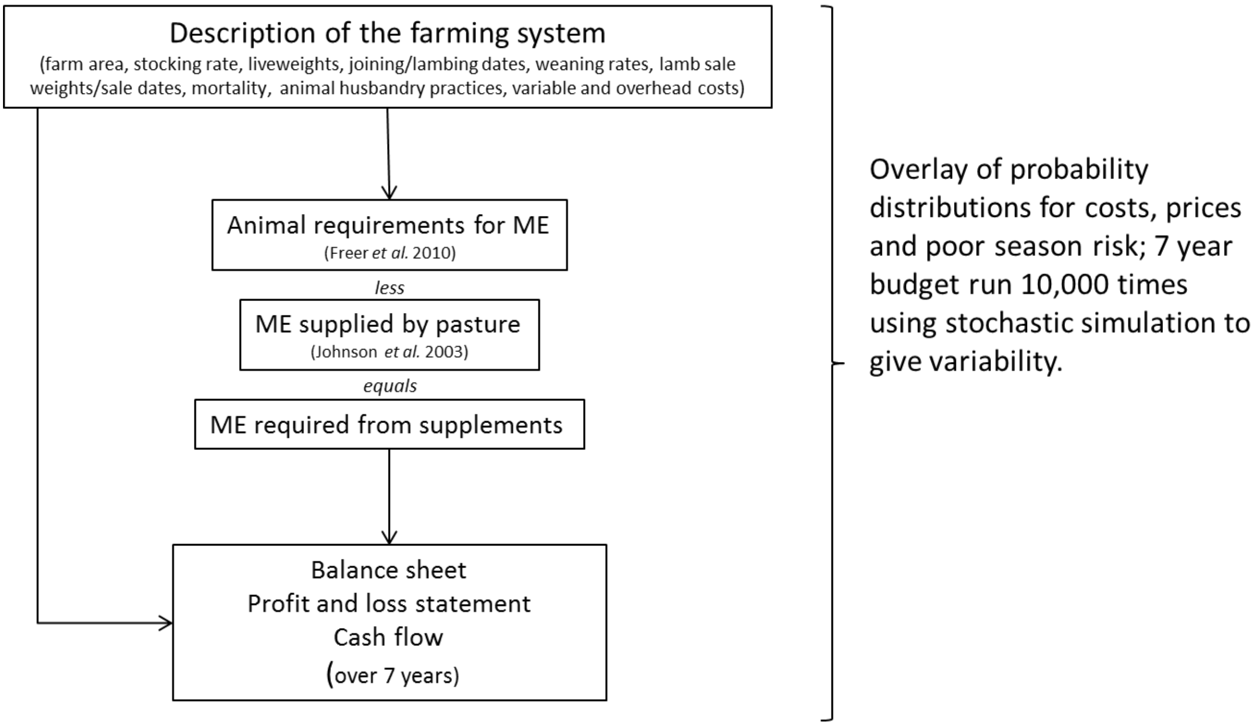

Figure 2. Box and whisker plots indicating the 5th (lower whisker), 25th-75th (box) and 95th (upper whisker) percentiles for annual net profit after interest and tax for each of the scenarios tested. The numbers below the scenario title on the x-axis refer to the number of the scenario within this paper.

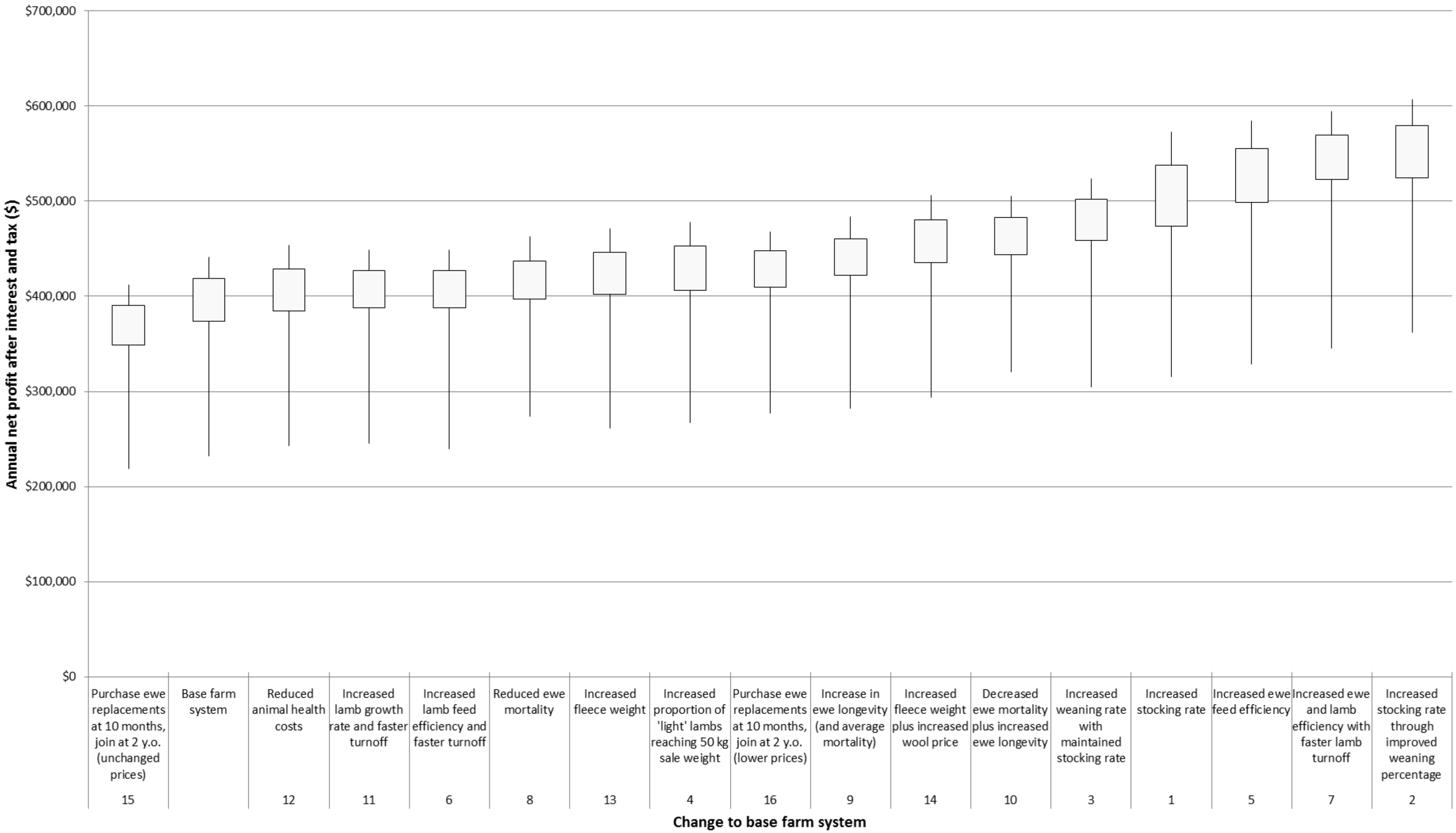

Table 1. Details of probability distributions used in the model.

	Distribution type	minimum	most likely	maximum	shift
Lamb Prices: c/kg CW	Pert	350	430	440	5
Replacement Ewe Prices: $/head	Pert	90	120	200	0
Mutton Prices: c/kg CW	Pert	60	100	120	0
Wool Prices: c/kg clean	Pert	303	357	375	0
Replacement Ram Prices : $/head	Pert	750	800	850	0
Supplementary Feed Prices : $/tonne	Pert	120	180	220	0
Fertiliser Prices: (% change)	Pert	0.9	1	1.1	0
Fuel Prices: (% change)	Pert	0.85	1	1.15	0
Interest rates: % - term loan	Pert	0.085	0.095	0.105	0
Interest rates: % - overdraft	Pert	0.1	0.11	0.12	0
Interest rates: % - lease	Pert	0.08	0.09	0.1	0
Poor season event risk	Poisson	0	0.143	1	0

PERT distributions were used to represent continuous random variables. These are variables that can take any value within a range – for example the sale weight of lambs. PERT distributions are continuous, and are defined by stating the minimum, maximum and mean values the variable is expected to take. This is more readily done using case-study farm data than stating the mean, standard deviation and skewness parameters as is required to define other continuous probability distribution types.

Poisson distributions are used to represent discrete random variables. These are variables that occur a particular number of times within a given period. Poisson distributions are discrete, and are defined by the single parameter λ, which is the mean number of times the event is expected to occur in the relevant period. Using this distribution, we can represent the random occurrence of events such as poor seasonal conditions in some years of the modelling period.

Table 2. Details of the physical characteristics and operating system of the base case study farm.

Base farm system information		
Total farm area	1000 ha	
latitude (º, - in S)	-35	
Steepness	Gentle	
Soil	80% red loam clay, 20% self-mulching black flats	
Breed of maternal ewes		Border Leicester x Merino
Number of 2+ y.o. ewes		7,200
Number of rising 1 y.o. ewes		2,800
Standard reference weight (ewes)		70.0 kg
Clean fleece weight (ewes)		4.0 kg
Fibre diameter		32.0 microns
Ram breed		Dorset
Number of rams		100
Standard reference weight (rams)		100 kg
Clean fleece weight (rams)		3.0 kg
Fibre diameter		32.0 microns
Death rate	average year	3%
	'bad' year	6%
Cull rates	2 + y.o. ewes	20%
	1 y.o ewes	20%
Management Policy : ewe management		
Stocking rate		10 ewes/ha
Shearing date		15-Dec
Replacement rule	Purchase :	ewes 2 Jan age 10 mo. LW 55 kg
	Sell cast for age:	stock aged 5-6 years on 15-Dec
Reproduction		
First join at		1 year
Mating date		mid Feb start
Birth date		mid July start
Castration		yes
Weaning date		15-Dec
One ram per		100 ewes
Keep rams for		3.0 years
Sell young ewes		when they reach 50 kg
Sell young wethers		when they reach 50 kg

Weaning rates	Mature ewes	average year	148%
		'poor' year	132%
	1 y.o. ewes	average year	71%
		'poor' year	56%
Number of lambs sold		**sale date**	
	Heavy (50 kg)	15-Dec	3,900
	Lights (50 kg)	15-Mar	6,370
	Lights (40 kg)	15-Mar	2,730

Table 3. Summary of production changes made to the model for each scenario tested. Cells highlighted in grey identify the changes made in each scenario relative to the base farm system.

	ewes/ha	Weaning rate 2+ y.o. ewes	Weaning rate 1 y.o. ewes	% heavy lambs 'good' year	% heavy lambs 'bad' year	% light lambs to 50 kg ('good' year)	% light lambs to 50 kg ('bad year')	Factor for ewe efficiency	Factor for lamb efficiency	Mortality 'good year'	Mortality 'bad' year	% culled per year 2+ y.o. ewes	% culled per year 1 y.o ewes	Factor for animal health costs	Factor for clean fleece weight	Factor for clean wool price
Base farm system	10	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	20%	1.0	1.0	1.0
1. Increased stocking rate	12	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	20%	1.0	1.0	1.0
2. Increased stocking rate through improved weaning percentage	10	178%	85%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	20%	1.0	1.0	1.0
3. Increased weaning rate with maintained stocking rate	9	178%	85%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	20%	1.0	1.0	1.0
4. Increased proportion of 'light' lambs reaching 50 kg sale weight	10	148%	71%	30% (15-Dec)	20% (15-Dec)	100% (15-Mar)	80% (15-Mar)	1.0	1.0	3%	6%	20%	20%	1.0	1.0	1.0
5. Increased ewe feed efficiency	12	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	0.8	1.0	3%	6%	20%	20%	1.0	1.0	1.0
6. Increased lamb feed efficiency and faster turnoff	10	148%	71%	30% (19-Nov)	20% (19-Nov)	70% (2-Feb)	50% (2-Feb)	1.0	0.8	3%	6%	20%	20%	1.0	1.0	1.0
7. Increased ewe and lamb efficiency with faster lamb turnoff	12	148%	71%	30% (19-Nov)	20% (19-Nov)	70% (2-Feb)	50% (2-Feb)	0.8	0.8	3%	6%	20%	20%	1.0	1.0	1.0
8. Reduced ewe mortality	10	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	1%	3%	20%	20%	1.0	1.0	1.0
9. Increase in ewe longevity (and average mortality)	10	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	14%	14%	1.0	1.0	1.0
10. Decreased ewe mortality plus increased ewe longevity	10	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	1%	3%	14%	14%	1.0	1.0	1.0
11. Increased lamb growth rate and faster turnoff	10	148%	71%	30% (19-Nov)	20% (19-Nov)	70% (2-Feb)	50% (2-Feb)	1.0	1.0	3%	6%	20%	20%	1.0	1.0	1.0
12. Reduced animal health costs	10	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	20%	0.8	1.0	1.0
13. Increased fleece weight	10	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	20%	1.0	1.2	1.0
14. Increased fleece weight plus increased wool price	10	148%	71%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	20%	1.0	1.2	1.2
15. Purchase ewe replacements at 10 months, join at 2 y.o. unchanged prices	10.4	148%	0%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	0%	1.0	1.0	1.0
16. Purchase ewe replacements at 10 months, join at 2 y.o. lower prices	10.4	148%	0%	30% (15-Dec)	20% (15-Dec)	70% (15-Mar)	50% (15-Mar)	1.0	1.0	3%	6%	20%	0%	1.0	1.0	1.0

Table 4. Average annual and standard deviation of net profit, the percentage change from the results of the base farm, and coefficient of variation for each of the scenarios.

Scenario	Average annual net profit	% change from base farm	Standard deviation	% change from base farm	Coefficient of Variation %
Base farm system	$384,000		$58,000		15.1
1. Increased stocking rate	$494,000	29	$72,000	24	14.6
2. Increased stocking rate through improved weaning percentage	$539,000	40	$67,000	16	12.4
3. Increased weaning rate with maintained stocking rate	$467,000	22	$59,000	2	12.6
4. Increased proportion of 'light' lambs reaching 50 kg sale weight	$418,000	9	$58,000	0	13.9
5. Increased ewe feed efficiency	$512,000	33	$68,000	17	13.3
6. Increased lamb feed efficiency and faster turnoff	$395,000	3	$54,000	-6	13.7
7. Increased ewe and lamb efficiency with faster lamb turnoff	$531,000	38	$65,000	12	12.2
8. Reduced ewe mortality	$408,000	6	$52,000	-8	12.7
9. Increase in ewe longevity (and average mortality)	$430,000	12	$55,000	-2	12.8
10. Decreased ewe mortality plus increased ewe longevity	$454,000	18	$51,000	-10	11.2
11. Increased lamb growth rate and faster turnoff	$395,000	3	$56,000	-4	14.2
12. Reduced animal health costs	$394,000	3	$58,000	0	14.7
13. Increased fleece weight	$412,000	7	$59,000	1	14.3
14. Increased fleece weight plus increased wool price	$448,000	17	$59,000	1	13.2
15. Purchase ewe replacements at 10 months, join at 2 y.o. (unchanged prices)	$359,000	-7	$53,000	-9	14.8
16. Purchase ewe replacements at 10 months, join at 2 y.o. (lower prices)	$418,000	9	$52,000	-10	12.4

Table 5. Overview of the direction of changes to revenues and costs of each scenario relative to the base farm.

	Revenues		Costs					
	Livestock trading profit	Revenue from wool sales	Extra capital borrowed	Annual labour costs	Supplementary feed costs	Animal husbandry costs	Sale costs	Replacement ewe costs
Base farm system			-	$100,000				-
1. Increased stocking rate	↑	↑	$234,000	↑	↑	↑	↑	↑
2. Increased stocking rate through improved weaning percentage	↑	↑	-	↑	↑	↑	↑	-
3. Increased weaning rate with maintained stocking rate	↑	↓	-	↑	↑	↑	↑	-
4. Increased proportion of 'light' lambs reaching 50 kg sale weight	↑	-	-	-	↑	-	-	-
5. Increased ewe feed efficiency	↑	↑	$234,000	↑	↑	↑	↑	↑
6. Increased lamb feed efficiency and faster turnoff	-	-	-	-	↓	-	-	-
7. Increased ewe and lamb efficiency with faster lamb turnoff	↑	↑	$234,000	↑	↓	↑	↑	↑
8. Reduced ewe mortality	↑	-	-	↑	↑	-	-	↓
9. Increase in ewe longevity (and average mortality)	↑	-	-	-	-	-	-	↓
10. Decreased ewe mortality plus increased ewe longevity	↑	-	-	↑	-	-	-	↓
11. Increased lamb growth rate and faster turnoff	↑	-	-	-	↓	-	-	-
12. Reduced animal health costs	-	-	-	-	-	↓	-	-

13. Increased fleece weight	-	↑	-	-	-	-	-	-
14. Increased fleece weight plus increased wool price	-	↑	-	-	-	-	-	-
15. Purchase ewe replacements at 10 months, join at 2 y.o. (unchanged prices)	↓	↑	-	-	↓	-	↓	↓
16. Purchase ewe replacements at 10 months, join at 2 y.o. (lower prices)	↑	↑	-	-	↓	-	↓	↓

Table 6. Regression coefficients for key variables influencing annual net profit after interest and tax for each of the scenarios.

	'Poor' season event risk	Replacement ewe price ($/hd)	Lamb price (c/kg CW)	Mutton price (c/kg CW)	Wool price (c/kg greasy)	Better perennial ryegrass	Interest rate % (term loan)
Base farm system	-0.80	-0.57	0.48	0.11	0.10		
1. Increased stocking rate	-0.76	-0.55	0.46			0.16	
2. Increased stocking rate through improved weaning percentage	-0.80	-0.49	0.49	0.10		0.12	
3. Increased weaning rate with maintained stocking rate	-0.82	-0.50	0.50	0.10	0.09		
4. Increased proportion of 'light' lambs reaching 50 kg sale weight	-0.79	-0.57	0.50	0.12		0.10	
5. Increased ewe feed efficiency	-0.75	-0.54	0.47	0.12		0.11	
6. Increased lamb feed efficiency and faster turnoff	-0.77	-0.57	0.50	0.13			-0.10
7. Increased ewe and lamb efficiency with faster lamb turnoff	-0.78	-0.57	0.50	0.13	0.10		
8. Reduced ewe mortality	-0.79	-0.55	0.53	0.12	0.10		
9. Increase in ewe longevity (and average mortality)	-0.82	-0.41	0.50		0.10		-0.10
10. Decreased ewe mortality plus increased ewe longevity	-0.80		0.25		0.11	0.12	
11. Increased lamb growth rate and faster turnoff	-0.82	-0.56	0.48	0.14	0.11		
12. Reduced animal health	-0.79	-0.53	0.45	0.14	0.11		

costs							
13. Increased fleece weight	-0.79	-0.53	0.45	0.14	0.12		
14. Increased fleece weight plus increased wool price	-0.79	-0.52	0.44	0.14	0.14		
15. Purchase ewe replacements at 10 months, join at 2 y.o. (unchanged prices)	-0.76	-0.44	0.48	0.12			-0.13
16. Purchase ewe replacements at 10 months, join at 2 y.o. (lower prices)	-0.75		0.19	0.12			