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The ALMTech Project: Initial Economic Evaluation of the Potential Benefits[1,2]

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Abstract

In this paper results are reported of an initial assessment of the prospective economic benefits of a project examining the technical and economic feasibility of the use of new carcase measurement technologies for the Australian beef, sheep meat, and pig meat industries (the ALMTech project). Information provided in a report to Meat and Livestock Australia on their Objective Measurement program (the Revised OM Report) is used as input into recently updated/developed partial equilibrium models of the Australian beef and sheep meat industries to replicate the six value proposition scenarios for the beef and sheep meat industries assessed within that report. The Revised OM Report provides the starting values, and then the formal economic models are used to estimate the magnitude and distribution of gross annual benefits after the market reacts to the new information. Benefits are also estimated for the pig meat industry using a similar modelling framework. Adoption profiles from the Revised OM Report are then used to predict benefits out to 2040, R&D and user costs are estimated, all values are discounted to a common 2020 time period, and NPVs and benefit cost ratios are calculated. The estimated NPV for net benefits was $243 million, while the discounted R&D cost was $127 million. The overall Meat and Livestock Australia OM program was estimated to generate a discounted net benefit of $116 million with an estimated BCR of 1.9:1; for the ALMTech project it was $30 million with the same BCR.

Keywords: carcase measurement technologies, value of information, livestock industries, Australia

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[2] It should be noted at the start that the estimates reported here exclude any consideration of the benefits and costs from animal health related outcomes (scenario 4 in the Revised OM Report). The combined discounted gross benefits for scenario 4 for the beef and sheep meat industries are estimated to sum to close to $200 million. The estimates reported here also exclude any consideration of benefits and costs from on-farm measurement outcomes. The combined discounted gross benefits for the on-farm scenarios for the beef and sheep meat industries are estimated to sum to close to $240 million. Full details about the calculation of these two sets of benefits are given in Griffith et al. (2020).

Introduction

In the meat industries, carcase value depends on the key attributes of lean meat yield (LMY) and eating quality. At present, these attributes are poorly measured within the Australian beef, sheep meat and pork industries. Even the world leading Meat Standards Australia (MSA) system for predicting eating quality in beef uses simple manual techniques to grade carcases. The actual value of meat carcases is poorly represented throughout the value chain.

Effective measurement and transmission of meat value is essential for value chains to accurately respond to market demands and to maximise chain surplus (Mounter et al., 2016; Zhang et al., 2020a, 2020b). If the value chain is unable to accurately describe carcase/meat value, inefficiencies will result, and the transparency of relationships between the livestock producer and the processor/retailer will be eroded. There are numerous examples where measurement and feedback have been successfully implemented. For example, the European and United States pork industries measure carcase LMY and primal weight using ultrasound (Busk et al., 1999) which has led to improved LMY and increased value within belly, bacon and ham markets. Overall, objective live animal/carcase measurement in combination with appropriate information feedback has been shown to be one of the most powerful forces for changing the management decisions of livestock producers, but measurement and data feedback must capture both quantity and quality to address both efficiency and consumer concerns (Zhang et al., 2020c).

Fortunately, there have been significant developments in a range of measurement technologies. For example, Dual Energy X-Ray Absorptiometry (DEXA) (Pearce, 2009) and Computed Tomography (CT) (Bunger et al., 2011) are used to scan the whole carcase to determine LMY, and various types of probes and cameras measure a particular part of a carcase to predict overall LMY (Slanger, 1994) and meat quality (intramuscular fat, Elmasry, 2012).

A major project, *Advanced measurement technologies for globally competitive Australian meat* (or ALMTech), was funded by the Australian Government Rural R&D for Profit programme to investigate the technical and economic feasibility of the use of these new carcase measurement technologies for the Australian beef, sheep meat, and pig meat industries. The objective of this paper is to report the results of an assessment of the prospective economic benefits of the first four years of this investment. These initial estimates are to be updated at the end of the second phase of the project as more information becomes available about the accuracy, reliability and commercial usability of the various measurement technologies being investigated, and about the adoption rates for these technologies.

Broad Approach

A draft report was prepared in early 2019 that used recently updated partial equilibrium models of the Australian beef and pig meat industries (Zhang et al., 2018a,b) and a newly constructed similar model of the Australian sheep meat industry (Mounter et al., 2019), to replicate the six scenarios assessed within a report submitted to Meat and Livestock Australia (MLA) titled "Development of supply chain objective measurement strategy and value proposition to stakeholders" (the OM Report, project code MLA V.MQT.0071) (Greenleaf et al., 2017). The 2017 OM Report estimated a range of levels of gross benefits, from theoretically possible to most likely, across two future points in time, 2020 and 2030[3].

[3] It should be noted that the benefits estimated in these OM reports are what MLA calls "first round" estimates, with no account taken of any response in the market to incentives arising due to yield, cost or demand shifts. In the MLA evaluation process, "second round" effects are done separately.

The economic modelling approach, the process adopted to translate the 2017 OM Report assumptions and the results obtained were discussed at an ALMTech Economic Evaluation workshop in February 2019. It was reported at that workshop that MLA were going through a process of updating the OM Report, and it was agreed that the final evaluation (reported here) should use to the extent possible the same assumptions about the expected impact of the technologies being studied, and the levels and timing of the adoption of these technologies, as reported in the revised OM Report, when it was released.

In fact, there have been two revisions to the adoption rates and benefits associated with OM technologies. An early 2019 revision (project code MLA V.MQT.0001) estimated ***net*** rather than ***gross*** benefits, and pushed the assessment period out to 2040 (Greenleaf et al., 2019a). The adoption rates used in that 2019 report were further revised downwards following feedback from an industry workshop in June 2019, to provide the most recent results (project code MLA V.MQT.0002). This latter revision is here called the Revised OM Report, "Revision of supply chain model supporting objective measurement (OM) strategy and value proposition to stakeholders" (Greenleaf et al., 2019b).

Thus over the course of the revisions to adoption rates described in the sequence of MLA reports (project codes MLA V.MQT.0071, MLA V.MQT.0001, and MLA V.MQT.0002, respectively), benefit estimates have reduced substantially. These downward revisions were solely on the basis of revised adoption levels and timings, due to "…slower than planned adoption of DEXA measurement systems by industry across both beef and lamb [sheep meat] sectors as well as delays in rolling out feedback mechanisms and value-based pricing grids." (Greenleaf et al., 2019b, 2). Additionally, some very minor changes were made to per unit estimates of yield changes, cost savings and other technical data. It is the adoption estimates and the per unit impact measures reported in this Revised OM Report which are used as the basis for the current analysis.

The six scenarios in the original OM Report were developed to cover the range of possible uses of new information potentially available through recent advances in objective measurement technologies. Their names have been slightly altered in the current revision, but the basic ideas remain the same:

1. **Genetic trait selection for increased lean meat yield whilst maintaining or increasing eating quality -** Together Lean Meat Yield (LMY)[4] and Eating Quality (EQ) determine total carcase value. This scenario applies to 100 per cent of **lamb** production and 60 per cent of **beef** production where reliable southern environments and broad market access reward a mix of quality and yield.
2. **Genetic trait selection for increased lean meat yield and reduced dark cutters (northern beef)** - Dark cutters imposes significant discounts on beef carcases. This scenario applies primarily to 30 per cent of beef production in more unreliable northern environments where conditions make it difficult to get a return on investment in EQ in Scenario 1.
3. **Genetic trait selection for increasing marbling and improving feed conversion (feedlot cattle) -** This scenario applies to feedlot animals destined for high quality markets where marbling (MB) has greater impact on finished product value than LMY but more efficient feed conversion (negatively correlated to MB) is required for higher profitability.
4. **Improving on-farm animal health from processor feedback -** This scenario considers the value opportunity for managing animal health issues that impact both the production and processing sectors across the beef and lamb industries by animal health feedback from processors to producers.

[4] We should note here that the term LMY is a proportion (per cent), whereas the modelling is attempting to estimate the value of additional saleable meat yield (SMY) in kg, ie HSCW (kg) x LMY (%). In the detailed calculations, we use the term SMY except where it is expressly associated with a proportion.

5. **Improved processor boning room efficiencies -** Initially a processor benefit of improved carcase sortation to customer specifications using accurate carcase objective measures to increase productivity of processing plants.
6. **Fabrication of purchased livestock to optimise processor sales value -** Objective measures will enable more accurate processor sales pricing decisions linking to alternative boning make schedules to extract increased value from carcases.

As per the overall objectives of the ALMTech project, benefits are also estimated where appropriate for the pig meat industry.

Three important points should be noted. First, both the analysis reported in the Revised OM Report and the analysis reported in this study are for the whole MLA Objective Measurement program of work. Thus the expected benefits for all investments in OM (not just in ALMTech) are calculated, and they are then related to all of the costs incurred in these investments. Subsequently, we have to apportion shares of benefits to different projects, such as ALMTech. The easiest way to do this is by cost share, with an underlying assumption that all the investments are equally efficient.

Second, Scenario 4 above (animal health benefits) has been recently excluded by MLA from contributing to OM as there was no direct attribution possible to ALMTech/OM funding – this work is being done as part of another program within MLA. The scenarios for animal health benefits were actually done and included in earlier drafts (Griffith et al., 2020), but they are excluded from the calculations reported here.

Third, on-farm measurement technologies are a part of the ALMTech project, but until recently were not part of MLA's OM program. Progress has been slower in that component of the work than in the within-plant component. Again, estimates of the benefits of on-farm measurements were attempted based on preliminary information and included in Griffith et al. (2020), but have been excluded from this paper. Those benefits will be reconsidered when the technology is more reliable.

The Revised (2019) OM Report as the Base Case

The Revised OM Report presented their results using the four figures reported in Appendix 1 (Figures A.1 to A.4). These estimates were simply at points in time – separately there was information on adoption and impact by year.

Figures A.1 and A.2 report estimated ***most likely*** annual ***gross*** benefits by benefit scenario, for beef and sheep meat respectively, while Figures A.3 and A.4 report estimated ***most likely*** annual ***net*** benefits by benefit scenario, for beef and sheep meat respectively. The original OM Report (Greenleaf et al., 2017) reported only gross benefit figures, while the two 2019 revisions reported net benefit figures. Comparing Figures A.1 and A.3, and Figures A.2 and A.4, it is evident that for the 2023 estimates across all scenarios, the aggregated user costs taken into account are $1.592 million per year for beef and $4.205 million for sheep meat; while for the 2040 estimates the aggregated user costs are $2.298 million for beef and $5.333 million for sheep meat. These estimates relate to the implementation and operating costs for OM by processors, producers and other users, as well as the amortised costs of the capital expenditure at commercial prices for these technologies. These estimates will be useful later when we discuss net present values.

To maintain a like-for-like comparison with the economic modelling results reported below, it is the ***gross*** benefits that are of interest. Since MLA/Greenleaf now report net benefits, we would have preferred to do the same here, and as mentioned in the following section, that is standard practice in RD&E evaluation studies in agriculture using partial equilibrium models. However, the theoretical concepts underlying these models rely strictly on changes in average ***variable*** costs as the measure of the initial shock or disequilibrium, the so-called k-shift. That is because shifts in supply curves are equivalent to shifts in marginal cost curves which are based on average variable cost curves. The costs included in the MLA/Greenleaf analysis are a combination of user variable costs and amortised capital or fixed costs. We have chosen to estimate gross benefits first, then deduct both these amalgamated user costs and R&D costs when calculating return on investment metrics. As the models are linear in proportional change terms, the net benefit is identical whichever way it is calculated.

While it is expected that the second-round values coming out of the partial equilibrium models will be less than the first round estimates shown in the Figures in Appendix 1, it is useful to compare the two sets of estimates for orders of magnitude. So the particular values in Figures A.1 and A.2 that we are interested in are the column headed "likely benefit (2023) re-forecast – 2019" in the beef results ($33.081 million, and its components (minus the $13.675 million for Scenario 4)), and "likely benefit (2023) re-forecast – 2019" in the sheep meat results ($13.094 million, and its components (minus the $7.769 million for Scenario 4)).

The Equilibrium Displacement Modelling Approach

Equilibrium Displacement Modelling (EDM) is a comparative static approach commonly used to evaluate RD&E investments (Piggott, 1992). It is based on well-known microeconomic theory. The industry of interest is represented by a system of demand and supply relationships, price transmission relationships and market clearing conditions, and is calibrated with actual historical data on prices and quantities. EDMs require only base equilibrium price and quantity data before any exogenous changes occur, reflecting a "representative" period of time, and market elasticity parameters to quantify the responsiveness of producers and consumers to changes in market prices. These can be taken from previously published results so do not need to be statistically estimated every time the model is run.

The impact of any exogenous change to the system, such as a new technology, is modelled as a shift in a supply curve or a demand curve from the assumed base situation (either the current year, or some representative year). These shifts can occur anywhere in the model, from shifts in farm supply through to shifts in retail demand. They are typically represented as 'tx' for shifts in supply curves, and 'nx' for shifts in demand curves, where the x refers to a specific variable in the model. From the resulting estimated changes in all market prices and quantities, changes in producer surplus and consumer surplus can be calculated as measures of the gross benefit or cost to the industry from the exogenous change. The elapsed time reflects the length of time required for all the suppliers and purchasers represented in the model to fully adjust to the new market conditions. Typically, a "medium term" time horizon is specified (3-5 years), determined by the values of the assumed elasticity variables which measure the pressures for such adjustment.

EDMs have been constructed for the cattle and beef industries (Zhao et al., 2001a, 2001b, 2003), the sheep and wool industries (Mounter et al., 2008a, 2008b, 2009), and the pig industry (Mounter et al., 2005a, 2005b), as well as for many other industries. The three models used here have been formally updated in recent years (Griffith, 2009c; Griffith et al., 2010; Zhang et al., 2018a,b; Mounter et al., 2019).

In this project, the relevant equilibrium price and quantity data, and the relevant elasticity estimates, are embedded in the specification of these models. The set of initial disequilibria that are being assessed are taken from the Revised OM Report, but these impact measures have to be converted to upwards or downwards proportional shifts in supply or demand curves ('t' or 'n' values) as required by the specification of the industry models. That is done in the following sections.

It should be noted that these industry models, being 'representations of reality', do not attempt to replicate all of the various markets for Australian beef, sheep meat and pig meat, whether segmented by quality differentials, end use or location. However, a partial segmentation is provided: for beef, grain-fed is different from grass-fed, and there are separate domestic and export demands for each; for sheep meat, lamb is different from mutton, and there are separate domestic and export demands for each; and for pig meat, fresh pork is different from processed pig meat, and there are separate domestic, export and import demands. All of these separate market segments have their own demand elasticities.

Beef Industry Model, Input Data and Results

Full details of this model including the specified price and quantity data and elasticity values, are available in the published paper (Zhang et al., 2018a).

Beef industry scenarios remodelled

The following base data were taken from ABARES for 2015/16 (ABARES, 2018):

- Number of cattle and calves slaughtered: 8,796,000
- Average weight: 279 kg
- Production (cwt): 2,069,000 tonnes

The following assumptions were taken from the original or the revised OM Report:

- Saleable meat yield percentage: 0.687 (also see Griffith and Thompson, 2012)
- Saleable meat produced: 1,421,000 tonnes
- Value of saleable meat: $8.48/kg
- Weight of saleable meat per carcase: 153 kg
- Average value of saleable meat /head: $1297

Scenario 1a. Genetic trait selection for increased lean meat yield whilst maintaining or increasing eating quality (southern beef) - This scenario applies to 60 per cent of beef production where reliable southern environments and broad market access reward a mix of quality and yield.

The theoretical maximum rate of increase in SMY is defined as 2 per cent over a generation, or 0.4 per cent per year. The assumed rate of SMY increase used in the calculations reflects differences in measurement accuracy between existing (30 per cent) and objective (88 per cent) methods. The Revised OM Report states that the estimated value of SMY improvement is $8.3 million in 2040 (their Table 3) from an estimated 2 million head, or about $4.15 per head. The Report also states that the maximum value of increased SMY in beef is $10.91/head in 2040, so based on the assumed 60 per cent herd coverage, the assumed adoption rate must be about 37.5 per cent. No estimate is provided for 2023, but using the gross benefit estimate in Table 1 ($4.446 million), and the number of animals covered in 2023 as shown in their Figure 5, 865,000, results in an estimated per head benefit of $5.14.

In terms of the eating quality component, the Revised OM Report states that existing subjective-based MSA measures are assumed until 2030, and that OM technologies for eating quality measurement will be available after that. In the longer term, "For Scenario 1a, it is anticipated that the current (or typical average) eating quality standard will be slightly increased while the SMY is increased." "Slightly" is undefined. However Table 3 of that Report states that the 2040 benefit of the eating quality component is $4.0 million per year. With an assumed coverage of 1,845,000 head (their Figure 5), the per-head value is therefore $2.17, after 2030.

We now have to translate these estimated effects into inputs that the selected modelling framework can use, that is the "k" shifts. With an assumed own price elasticity of supply of 0.9 for the Australian beef industry, an increase of 0.08 per cent per year in SMY (on the quantity axis) (from their Table 2) is equivalent to a decrease in cost of 0.09 per cent on the price axis. The assumed herd coverage and adoption rates are already incorporated into the yield figure, so the shift variable, applied to capture the more productive supply of beef due to an increase in SMY is 0.09 per cent. In proportional terms the SMY effect is represented in the model as t1=-0.0009.[5]

In the short term no account needs to be taken of the eating quality component. However post 2030, the estimated maximum value of increased MSA throughput is $2.17/head, or an increase of 0.0020 per cent at wholesale values. The eating quality impact is represented in the model as an increase in WTP for domestic grainfed beef. If this was to be formally modelled sometime in the future and accounting for the adoption rates and industry shares, in proportional terms this would be represented in the model as nqnd=0.000027.

Scenario 2. Genetic trait selection for increased lean meat yield and reduced dark cutters (northern beef) - This scenario applies primarily to 30 per cent of beef production in more unreliable northern environments where conditions make it difficult to get a return on investment in eating quality in Scenario 1.

For this scenario, in 2023 adoption is 12.5 per cent across 30 per cent of output (based on Figure 7), or 328,500 animals. The estimated gross benefit is $1.934 million (Table 1), which gives a per head estimate of $5.89/head. In 2040, the estimated gross benefit is $4.796 million across approximately 680,000 animals, or a per head benefit of $7.05. Adoption rises to about 25 per cent in 2040.

In proportional terms the short run SMY impact is represented in the model as t1=-0.00015, following the same logic as for scenario 1a.

In terms of meat colour, the Report states that the value of minimising meat colour discounts is equivalent to a cost reduction of $4.17/head slaughtered. The cost saving of reduced meat colour discounts is 1.9 per cent of the stated beef processing cost of $220/head. With an assumed 12.5 per cent adoption across the assumed 30 per cent of output, in proportional terms this is represented in the model as typ=-0.0007.

Scenario 3. Genetic trait selection for increasing marbling and improving feed conversion (feedlot cattle) - This scenario applies to feedlot animals destined for high quality markets where marbling (MB) has greater impact on finished product value than LMY but more efficient feed conversion (negatively correlated to MB) is required for higher profitability.

In 2023, this scenario is estimated to deliver $6.934 million in gross benefits, over approximately 120,000 animals. Thus adoption is assumed to be just 13.5 per cent across 10 per cent of throughput (feedlot output). The per-head benefit is $58. In 2040, this scenario is estimated to deliver $12.168 million in gross benefits, over approximately 210,000 animals, or $58/head.

[5] The specific 't' and 'n' shift variables are defined in the academic paper. The t's are exogenous supply curve shifts and the n's are exogenous demand curve shifts, with the additional numbers or letters describing the particular supply or demand curve where the disequilibria occurs. In the beef model, x1 is the supply of weaner cattle, so tx1 is an upwards (+) or downwards (-) shift in the supply curve for weaner cattle. Productivity improvements are measured as downward shifts in supply curves, so the sign is (-).

In terms of weight gain, the original OM Report quotes figures based on existing industry practice of 3.3-3.5 per cent average annual rate of gain while simultaneously selecting for marbling. At the then price of $5.60/kg, this is stated to be worth $56/head, or for the industry $4.925 million at the specified adoption levels. However in the Revised OM Report, no separate figures for the value of additional weight gain are reported.

In terms of marbling, the impact comes about because of the quality increase due to higher marble scores, and the increased WTP by final consumers for this higher quality. The original OM Report estimated this increase in value to be $50.95/head of fed cattle slaughtered, while in the Revised OM report the estimate was between $75 and $96/head.

The marbling impact is represented in the model as an increase in WTP for marbled beef, which is primarily the export market for grainfed beef. This is $85/$1297 (valued at the wholesale level), or 5.8 per cent, but before accuracy and magnitude of change effects. Again accounting for the very low adoption rates and industry shares, in proportional terms this is represented in the model as nqne=0.00027.

Around $25/head of the total scenario benefit is accounted for by the marbling, so the balance of the $58/head is due to weight gain. The weight gain impact is represented in the model as a reduction in the per kg cost of producing marbled cattle. This is now $33/$1297, or 2.5 per cent. Accounting for the very low adoption rates and industry shares, in proportional terms this is represented in the model as typ=-0.00034.

***Scenario 5. Improved processor boning room efficiencies* -** Initially a processor benefit of improved carcase sortation to customer specifications using accurate carcase objective measures to increase productivity of processing plants.

The original OM Report states that the net impact estimated in some plants is an increase in productivity of 1.1 per cent per person per day. This was calculated to be a reduction in beef processing costs due to better sorting to market outlets of $2.43 per head, on a $220/head cost. Over the 8,796,000 head slaughtered, this adds up to $21.4m. However the saving would only apply to 5 per cent of throughput in 2023, so the expected likely cost savings would be $1.070m. The Revised OM Report estimates a benefit from this scenario of $0.24m. In 2040 the estimated coverage rises to 60 per cent of processing volume.

The cost saving per head on the current processing cost figure is equivalent to a 1.1 per cent saving in beef processing costs. At the assumed adoption rate, in proportional terms this assumption is represented in the model as typ=-0.00055.

***Scenario 6. Fabrication of purchased livestock to optimise processor sales value* -** Objective measures will enable more accurate processor sales pricing decisions linking to alternative boning make schedules to extract increased value from carcases.

The original report states that better fabrication processes would increase the yield of saleable beef by 1 per cent. The additional 14,200 tonnes of saleable beef would be valued at $120.5 million. However, this would only apply to 5 per cent of throughput in 2023, so the estimated value of the likely extra quantity is $6.025 million. The report provides an estimate of $5.853 million. Adoption is expected to trend up to 60 per cent by 2040.

With a farm supply elasticity of 0.9, the 1 per cent increase in yield is equivalent to a downward reduction in cost/kg of 1.1 per cent. At the assumed adoption rate, in proportional terms this assumption is represented in the model as typ=-0.00055.

All scenarios combined

The combined assumptions for 2023 are represented in the model as tx1=-0.00105, typ=-0.00214, and nqne=0.00027.

Beef industry results

The full set of results of these beef model simulations are shown in Table 1.

The combined annual benefit from all scenarios is calculated to be $5.82 million for 2023. Given the economic characteristics of the Australian beef industry (slightly inelastic supply of beef and domestic demand, relatively elastic export demand for beef, and very elastic supply functions for other inputs into processing, retailing and exporting), the second-round estimates reported here are, as expected, substantially lower than the first round estimates calculated in the Revised OM Report for the same time period and adoption profiles. Some of the discrepancy could also be put down to differences in underlying price and quantity data, although every effort was made to get as close as possible to the Revised OM Report assumptions.

One of the key findings from the economic modelling is that processors receive very little of the longer term benefits of these new technologies, even though that sector is where some of the initial investment occurs (the typ shifters shown in Table 1). Input supply elasticities are assumed to be quite elastic (that is, businesses can secure as much labour and capital as they require at the going market rate). All intermediary input suppliers together only receive between 9 and 20 per cent of the benefits, depending on where the cost saving occurs. For the combined scenario, livestock producers receive about 40 per cent, domestic and overseas consumers together receive more than 50 per cent, and all input suppliers together (processors, feedlotters, retailers and exporters) receive less than 10 per cent. These shares correspond to the hypothetical simulations done as part of the model validation exercise (Zhang et al., 2018) and also accord well with the expected patterns from prior research, reported at least 20 years ago (Zhao et al., 2001a,b; Zhao et al., 2003).

Sheep Meat Industry Model, Input Data and Results

As for the beef model, full details of the sheep meat model are available in the academic paper (Mounter et al., 2019).

Sheep Meat Industry Scenarios Remodelled

As for the beef simulations, the following base data were taken from ABARES (2018) for 2015/16

- Number of lambs slaughtered: 22,050,000
- Number of older sheep slaughtered: 8,510,000
- Average weight of lamb: 22.0 kg
- Average weight of older sheep: 25 kg
- Production of lamb (cwt): 485,000 tonnes
- Production of mutton (cwt): 213,000 tonnes

Table 1. Economic surplus changes (in $million per year) and percentage shares of total surplus changes (in per cent) to various beef industry groups, 2023

Industry Group	**Scenario 1 tx1=-0.0009**		**Scenario 2 tx1=-0.00015 typ=-0.00070**		**Scenario 3 typ=-0.00034 nqne=0.00027**		**Scenario 5 typ=-0.00055**		**Scenario 6 typ=-0.00055**		**All scenarios together***	
	$m		$m		$m		$m	per	$m		$m	
Weaner producers	per cent		per cent		per cent		cent		per cent		per cent	
Grass-finishers	1.23	33.3	0.83	25.1	0.24	28.9	0.49	25.7	0.49	25.7	1.83	32.6
Backgrounders	0.17		0.15		0.05		0.10		0.10		0.28	
Farmers	0.08		0.07		0.02		0.04		0.04		0.13	
	1.48	**40.1**	**1.05**	**31.7**	**0.31**	**37.4**	**0.63**	**33.0**	**0.63**	**33.0**	**2.24**	**39.5**
Feedgrain growers												
Feedlotters	0.14		0.12		0.04		0.08		0.08		0.22	
Processors	0.00		0.00		0.00		0.00		0.00		0.01	
Domestic retailers	0.01		0.06		0.01		0.05		0.05		0.04	
Other input suppliers	0.18		0.51		0.03		0.10		0.10		0.28	
	0.33	**8.9**	**0.69**	**20.8**	**0.08**	**9.6**	**0.23**	**12.0**	**0.23**	**12.0**	**0.55**	**9.2**
Overseas Consumers												
	0.52	**14.1**	**0.45**	**13.6**	**0.13**	**15.7**	**0.29**	**15.2**	**0.29**	**15.2**	**0.82**	**14.1**
Domestic Consumers												
	1.34	**36.3**	**1.12**	**33.8**	**0.31**	**37.4**	**0.75**	**39.3**	**0.75**	**39.3**	**2.12**	**36.6**
Total Surplus												
	3.69	**100**	**3.31**	**100**	**0.83**	**100**	**1.91**	**100**	**1.91**	**100**	**5.82**	**100**

Note: Percentage shares of total benefits are not calculated where the monetary value is very small. Further, all results are rounded and some small input suppliers are not reported, so subtotals may not be exact. * Excludes Scenario 4.

Assumptions from the OM Report

- Saleable meat yield percentage: 0.55
- Saleable meat produced: 266,750 tonnes
- Value of saleable meat, lamb: $11.36/kg
- Value of saleable meat, mutton: $4.52/kg
- Weight of saleable meat per carcase: 12.1 kg
- Average value of saleable meat /head, lamb: $137.46
- Average value of saleable meat /head, mutton: $54.69

***Scenario 1b. Genetic trait selection for increased lean meat yield whilst maintaining or increasing eating quality* -** This scenario applies to 100 per cent of lamb production and 35 per cent of mutton where reliable southern environments and broad market access reward a mix of quality and yield.

For lamb, the theoretical maximum rate of increase in SMY is defined as 2 per cent over a generation, or 0.5 per cent per year, while for mutton it is 0.3 per cent per year. The assumed rate of SMY increase used in the calculations reflects differences in measurement accuracy between existing (30 per cent) and objective (88 per cent) methods. The Revised OM Report states that the estimated value of SMY improvement is $5.3 million in 2040 (Table 2) from an estimated 10 million head of lamb and mutton, or about $0.46 per head. Given the potential numbers of lamb and sheep, and the assumed flock coverage, the assumed adoption rate must be about 40 per cent across both types. No estimate is provided for 2023, with the assumed improvement not commencing until 2024.

In terms of the eating quality component, no benefits have been included as eating quality in lamb is said to be at a good standard already and there are no pricing systems in the sheep industry that support a further increase in value for an increasing level of eating quality.

In the short term, this scenario does not have to be modelled.

***Scenario 5. Improved processor boning room efficiencies* -** Initially a processor benefit of improved carcase sortation to customer specifications using accurate carcase objective measures to increase productivity of processing plants.

The report states that the reduction in processing costs due to better sorting to market outlets is equivalent to a 1.1 per cent saving. In 2023 the saving would only apply to 5 per cent of throughput, generating benefits of less than $1 million per year, but would rise to 60 per cent by 2040.

In proportional terms this assumption is represented in the model as t3=-0.00055.

***Scenario 6. Fabrication of purchased livestock to optimise processor sales value* -** Objective measures will enable more accurate processor sales pricing decisions linking to alternative boning make schedules to extract increased value from carcases.

The original report stated that the reduction in lamb processing costs due to better fabrication is $0.12/kg of saleable meat valued at $7.50/kg. With the new value of $11.36/kg, this saving is now $2.18 per head or $47.96 million across the 22 million lambs slaughtered. At 5 per cent adoption, the estimated value to industry would be $2.40 million, still less than the quoted gross benefit of $4.629 million. Given the assumptions of the model, the savings in fabrication costs is equivalent to a saving in lamb processing costs of 1.6 per cent. At an adoption rate of 5 per cent of throughput in 2023, in proportional terms this assumption is represented in the model as t3=-0.0008. Adoption is predicted to rise to 60 per cent by 2040.

All scenarios combined

The combined assumptions are represented in the model as t3=-0.00135.

Sheep meat industry results

The results of these simulations are shown in Table 2.

For the combined scenario 5 and 6, the annual gross benefit for 2023 is estimated to be only $0.210 million. The estimated shift in the supply of processing services is only a little over 0.1 per cent, and the value added in that sector is relatively low.

In the economic modelling, all input suppliers into lamb and mutton transformation (lamb and mutton processors, retailers and exporters) receive around 14 per cent of the benefits, but this is quite imprecise given the rounding that has occurred. Sheep meat producers receive 43 per cent, and conversely, domestic and overseas consumers together receive about the same. Again, these shares correspond to the hypothetical simulations done as part of the model validation exercise (Mounter et al., 2019) and also accord well with the expected patterns from prior research.

Further, as noted already, some sectors lose from these sheep meat scenarios. Lamb producers, processors, exporters, retailers and domestic and foreign lamb consumers gain from these lamb-only cost savings, but all participants in the mutton and live sheep sectors lose.

Pig Meat Industry Model, Input Data and Results

As for the beef and sheep meat models, full details of the pig meat model are available in the published paper (Zhang et al., 2018b).

Pig meat industry scenarios modelled

We did not have access to a set of reports like the MLA OM Reports that provided detailed discussion of alternate scenarios and how businesses would go about adopting OM technologies. In lieu, we discussed the possible use of the technologies with several senior people in industry organisations.

We first asked the question: how would the new technologies be implemented at the level of the market where they are applied, that is, on farm or on the slaughter floor or in further processing?

Their response was that the implementation of these technologies would be mostly on the slaughter floor (at least 50 per cent) particularly the larger export plants, with a flow down to the boning room (although this will take longer as most boning rooms are not currently set up for this technology, and need more automation first) and further processing, then flowing down again from there to some on-farm measures. This would mostly be through a technology such as Pork Scan, or a similar theoretical technology.

In the opinion of these industry leaders, a technology that produced an eating quality measure is further off, but the implementation here would be the sorting of carcases into premium lines for export markets such as China or other Asian markets. The best eating quality carcases could be removed from the line and sorted into high value export cuts.

Table 2. Economic surplus changes (in $million) and percentage shares of total surplus changes (in per cent) to various sheep meat industry groups

Industry Group	Scenario 5 t_3=-0.00055		Scenario 6 t_3=-0.0008		All scenarios Combined*	
	$m	per cent	$m	per cent	$m	per cent
Lamb farmers	0.03	33.3	0.06	50.0	0.09	42.9
Mutton farmers	-0.00		-0.00		-0.00	
Live sheep farmers	-0.00		-0.00		-0.00	
Farmers subtotal	**0.03**	**33.3**	**0.06**	**50.0**	**0.09**	**42.9**
Lamb processors	0.01		0.01		0.01	
Mutton processors	-0.00		-0.00		-0.00	
Lamb exporters	0.00		0.00		0.00	
Mutton exporters	-0.00		-0.00		-0.00	
Live sheep exporters	-0.00		-0.00		-0.00	
Lamb retailers	0.01		0.01		0.02	
Mutton retailers	-0.00		-0.00		-0.00	
Other input suppliers subtotal	**0.01**	**11.1**	**0.02**	**16.7**	**0.03**	**14.3**
Overseas lamb consumers:	0.01		0.01		0.02	
Overseas mutton consumers	-0.00		-0.00		-0.00	
Domestic lamb consumers	0.04		0.03		0.07	
Domestic mutton consumers	0.01		0.00		0.01	
Live sheep consumers	0.00		0.00		0.00	
Consumers subtotal	**0.05**	**55.6**	**0.04**	**33.3**	**0.09**	**42.9**
Total Surplus	**0.09**	**100**	**0.12**	**100**	**0.21**	**100**

Note: Percentage shares of total benefits are not calculated where the monetary value is very small or where a loss is incurred. As a result, subtotals may not be exact. * Excludes Scenario 4.

We then asked how the new technologies would change the costs of performing the functions at those market levels, or if that is not available, what are the expected changes in yields?

Their response was that changes in costs are not really where they see a benefit, at least initially. Yield change would be limited to reducing the variation currently seen, with a flow down effect of better on farm decisions. Currently plants are reliant on throughput, and any additional cost even with a long term prospect of benefit is an issue. The benefits are also not really expected to be in increased yields, but more in identifying the correct value for the best carcases, which at the moment can be guess work. Currently with P2 as the only measure being inconsistent with the quality of the entire carcase, they are rewarding many carcases without the right specifications on belly for example. Being able to properly assess the best overall carcases would have great benefit in rewarding the right producers, which would have huge flow on effects to on-farm management and nutritional strategies, even into genetics with better understanding on what gives the best overall carcase value. So the accuracy of carcase evaluation is better, and while total value does not increase, the accuracy of payment and reward is enhanced. There was no discussion around driving genetic gain for pork (EQ vs LMY), as for beef and lamb, from OM and better pricing signals.

Finally we sought views on adoption, and asked the question: what proportion of the industry would take up these technologies, and over what time frame?

These industry leaders reinforced the point that it would be the supply chains driving uptake, as the pork industry deals in whole carcase sales, not primals. Initial uptake would be roughly 50 per cent of total production, over around 2-4 years for this to be complete.

In the absence of any formal industry data or reports similar to the Revised OM Report, we have assumed that the benefits can be captured by applying similar assumptions as for scenario 5 and scenario 6 for sheep meat.

***Scenario 5. Improved processor boning room efficiencies* -** Initially a processor benefit of improved carcase sortation to customer specifications using accurate carcase objective measures to increase productivity of processing plants.

As for sheep meat, we assume that a reduction in processing costs due to better sorting to market outlets is equivalent to a 1.1 per cent saving. Given the responses described above and our knowledge of the structure of the industry, we assume in 2023 the saving would apply to 50 per cent of throughput, and would rise to 90 per cent by 2040.

In proportional terms this assumption for 2023 is represented in the model as t3=-0.0055.

***Scenario 6. Fabrication of purchased livestock to optimise processor sales value* -** Objective measures will enable more accurate processor sales pricing decisions linking to alternative boning make schedules to extract increased value from carcases.

The 2017 OM Report stated that the reduction in lamb processing costs due to better fabrication is $0.12/kg of saleable meat when valued at $7.50/kg. We assume the same proportional saving here. Thus, the savings in fabrication costs is equivalent to a saving in pork processing costs of 1.6 per cent. Again, at an adoption rate of 50 per cent of throughput in 2023, in proportional terms this assumption is represented in the model as t3=-0.008.

Adoption is assumed to rise to 90 per cent by 2040.

Both scenarios combined

The combined assumptions are represented in the model as t3=-0.0135.

Pig meat results

The results of these simulations are reported in Table 3. The gross annual benefit across both pig meat scenarios estimated using the economic model is $3.16 million.

Across the scenarios, pig meat producers receive just 8.5 per cent of total benefits, domestic consumers receive 78.6 per cent, and all input suppliers into pig meat transformation (primary and secondary processors, retailers and exporters) and overseas consumers receive the remaining 13 per cent of the benefits. Again, these shares correspond to the hypothetical simulations done as part of the model validation exercise (Zhang et al., 2018b) and also accord well with the expected patterns from prior research.

Table 3. Economic surplus changes ($ million) and percentage shares of total surplus changes (per cent) to pig producers and domestic pig meat consumers from selected scenarios, 2023

Change in economic surplus to	Scenario 5 T3=-0.0055		Scenario 6 T3=-0.0080		Both Scenarios Combined T3=-0.0135	
	$m	per cent	$m	per cent	$m	per cent
Pig Producers	0.11	8.5	0.16	8.5	1.35	8.5
Domestic Consumers	1.01	78.6	1.46	78.6	9.52	78.6
Total Surplus	1.29	100	1.87	100	3.16	100

Note: in this case the combined scenario measures the same disequilibria as the component scenarios, so the total estimated gross benefit is simply the addition of each of the component scenarios.

The Whole Program

Here we combine the beef, sheep meat, and pig meat estimates for 2023 as summarised in Tables 1, 2 and 3. They are shown in Table 4.

Table 4. Estimated gross annual benefits ($ million), by scenario and industry, 2023

Industry	Scenario					
	1	2	3	5	6	Combined
Beef	3.69	3.31	0.83	1.91	1.91	5.82
Sheep meat	-	-	-	0.09	0.12	0.21
Pig meat	-	-	-	1.29	1.87	3.16
Total	3.69	3.31	0.83	3.29	3.90	9.19

For the year 2023, a total annual gross benefit of just over $9 million is estimated. Around $5.8 million (or 63 per cent) is attributable to the beef industry, about $0.2 million (or 2 per cent) to the sheep meat industry and about $3.2 million (just on 34 per cent) to the pig meat industry.

In terms of scenarios, scenario 3 (Genetic trait selection for increasing marbling and improving feed conversion in feedlot cattle) makes only a minor contribution, but all other scenarios offer annual benefits in the order of $3.3-3.9 million.

It is worth noting that removing scenario 4 (Improving on-farm animal health from processor feedback) from the analysis has resulted in a substantial reduction of the total annual benefit. As reported in Griffith et al. (2020), the most likely benefit for 2023 for scenario 4 would have been $8.43 million for sheep meat and $4.91 million for beef, for a total gross benefit of over $13 million.

Long Run Impacts and Net Benefit Measures

Here we take the combined beef, sheep meat, and pig meat estimates for annual benefits (as shown in Table 4) and extrapolate them annually out to 2040. This is done using the explicit animal numbers and adoption assumptions described in the Revised OM Report, and our related assumptions for the pig meat scenarios.

For the beef and sheep meat industry benefits, the estimated values were entered into an Excel spreadsheet. First, the animal numbers from each of the graphs in the Revised OM Report were entered out to 2040. MLA also provided a table of these values from the Revised OM report study which were used to double check the various numbers. Per animal gross benefits for 2023 for each scenario were then calculated from the aggregate gross benefits and the relevant starting animal number, and then these unit values were successively multiplied by the rising numbers of animals in the relevant adoption profile. In all cases, increasing genetic merit (scenarios 1-3) and increasing processing efficiencies (scenarios 5 and 6) were accounted for. Values for 2020 to 2022 were added to reflect the information about adoption trajectories. The annual benefits for each year for each scenario were then summed vertically to give a total gross benefit, and these totals were then summed over the 2020-2040 period. For the beef industry, aggregated gross benefits over the period 2020-2040 are $320 million, or $163 million when discounted at 5 per cent.

Aggregated user costs for beef were taken from Appendix Table A.1 to calculate a measure of net present value. Aggregated costs over the period 2022-2040 are $36 million, or $23 million when discounted at 5 per cent. Aggregated net benefits over the period 2023-2040 are therefore $285 million, or $142 million when discounted at 5 per cent. This value was confirmed by subtracting the discounted costs ($23 million) from the discounted benefits ($162 million). Thus the NPV for the beef industry scenarios is $142 million, prior to accounting for R&D costs.

Using similar information for the sheep meat industry, aggregated gross benefits over the period 2021-2040 are $119 million, or $59 million when discounted at 5 per cent. Aggregated costs over the period 2023-2040 are $13 million (from Appendix Table A.2), or $7 million when discounted at 5 per cent. Aggregated net benefits over the period 2023-2040 are $106 million, or $52 million when discounted. This value was confirmed by subtracting the discounted costs ($7 million) from the discounted benefits ($59 million). Thus the NPV for the sheep meat industry scenarios is $52 million, prior to accounting for R&D costs.

The combined beef and sheep meat NPV of net benefits is therefore $194 million, prior to accounting for R&D costs[6].

[6] As noted previously, this analysis excludes any potential benefits and any potential costs from Scenario 4 in the Revised OM Report, which relates to improvements in animal health. The combined discounted gross benefits for scenario 4 for the beef and sheep meat industries are estimated to sum to close to $200 million. The analysis also excludes any potential benefits from on-farm measurement technologies. The combined

For the pig meat industry, aggregated gross benefits over the period 2023-2040 are $89 million, or $49 million when discounted at 5 per cent. Cost information provided by industry was approximately $72,000 per year, accounting (as in the Revised OM Report) for amortised capital costs and ongoing repairs and maintenance. These costs summed to $1.5 million over the period 2020-2040, or $923,000 when discounted at 5 per cent.

Thus the sum of net benefits for the pig meat industry scenarios is $88 million or $49 million when discounted, prior to accounting for R&D costs.

Aggregating across the three industries gives a total discounted net benefit value of $243 million, prior to accounting for R&D costs.

To calculate ROI measures, we now have to deduct the R&D costs of the beef, sheep meat and pig meat industries. Actual R&D costs for beef and sheep meat were provided by MLA for the period 2016-2020 as well as commitments to 2025. These costs were first converted to real 2020 value by applying official CPI figures, and then past values were compounded forward to 2020 using the same 5 per cent value as used to discount future values back to 2020. The total value of these investments in 2020 $ values was $127 million.

Actual R&D costs for pig meat were provided by APL for the period 2017-2020. As with the MLA costs, these were first converted to real 2020 values, and then compounded forward to 2020 using the same 5 per cent value as used to discount future values back to 2020. The total value of these investments in 2020 $ values was $289,000.

The results are reported in Table 5. Across all industries, the estimated NPV is $116 million and the estimated BCR is almost 2:1.

Table 5. ROI measures, all OM investments

All Industries	Present value net benefits ($m)	Present value R&D Costs ($m)	Net present value	BCR
Total	243	127	116	1.9:1

These values are quite consistent with the returns from other large R&D programs such as Cooperative Research Centres (Farquharson et al., 2003; Griffith et al., 2006; Jones et al., 2006; Griffith, 2009b; Griffith and Burrow, 2014), especially given that two potentially large but quite uncertain benefit streams have been excluded from the analysis. Adding the estimated $240 million of on-farm benefits (Griffith et al., 2020) would increase the BCR to almost 4:1, and adding the almost $200 million of benefits relating to scenario 4 would increase it to almost 5.5:1.

The final task is to apportion benefits to the ALMTech program. There are a number of different options, but the simplest way is to assume all investment $ have equal research efficiency. Therefore we take the actual R&D costs for the ALMTech program for the period 2016-2020 and transform them in the same way we have transformed MLA and APL costs into real 2020 values.

discounted gross benefits for the on-farm scenarios for the beef and sheep meat industries are estimated to sum to close to $240 million (see Griffith et al., 2020).

This results in a total value of $15.9 million in 2020 $ values. Comparing this value with the equivalent value for the whole OM program ($127 million) generates a cost ratio of 0.125. Applying this ratio to the total discounted net benefit ($510 million) generates a discounted value of the ALMTech Program I of some $30 million. This return has the same benefit cost ratio of 1.9:1 as that on the total investment.

Summary

The broad objective of the analysis reported here was to provide a first estimate for the most likely value of the project, *Advanced measurement technologies for globally competitive Australian meat*, to the Australian beef, sheep meat, and pig meat industries. These initial estimates are to be updated as more information becomes available about the accuracy, reliability and commercial usability of the various measurement technologies being investigated, and about the adoption rates for these technologies.

A rigorous process was followed to collect and use the best available industry information on potential cost savings, yield changes and demand enhancements, and adoption profiles, across a range of scenarios, which were then used as inputs into EDMs of the beef, sheep meat and pig meat industries. Using the benefit estimates provided by simulating the models, and estimates of both user costs and R&D investment costs, NPVs and benefit cost ratios were calculated. The results were reported in Table 5 above. Across all industries, the estimated NPV is $116 million and the estimated BCR is almost 2:1. Thus, even with early estimates of relatively minor changes in costs and yields, and low and slow adoption profiles, these investments are predicted to return significant value to the Australian meat industries.

In this report we have not undertaken a formal sensitivity analysis. The input data used were sourced from a number of different and in some cases inconsistent sources. However we have followed the cautious, "most likely" assumptions in the Revised OM Report, and where we have had to make additional assumptions, these too have been made in a cautious, most likely fashion. In particular we have omitted from this analysis potential benefits from on-farm measurement technologies due to uncertainty about the technical feasibility at the time of the analysis. We have also omitted any potential benefits arising from better disease surveillance and management, due to uncertainty about the R&D funding attribution. Both of these areas are obvious avenues for more detailed work in the next round of evaluations for this project.

We acknowledge that there are still many unknowns associated with the performance and implementation of these OM technologies, and that as better information becomes available, the assumptions used in this report can be revised and the results updated. This will also allow a more formalised approach to sensitivity analysis in the future.

The series of MLA-funded OM reports pay particular attention to the supporting structures required to facilitate industry uptake and so capture as many of the potential benefits available as possible. From an economics perspective, three of these elements are worthy of emphasis:

- New IT systems that will support information sharing and new payment systems required to incentivise changes in production practices and quality of outputs;
- A willingness and ability of processors to move to new value-based pricing payment systems for OTH purchases, given current supply side constraints; and
- Cultural change required across industry for new payment methods to become effective.

The willingness to pay by end users for better information which enables better decisions can only be captured if there are suitable incentive systems in place to facilitate these better decisions. New information has to be measured, recorded, and shared to those who have the most use of it (Zhang et al., 2020a,b,c). Value based payment and marketing systems have to be implemented in parallel to the implementation of the new measurement and recording technologies to enable the potential benefits to be captured.

Looking ahead, a system has now been developed to calculate ROI measures for investments such as ALMTech. Future research will include updating the gross benefit estimates over the course of the project as more information becomes available about the accuracy, reliability and commercial usability of the various measurement technologies being investigated.

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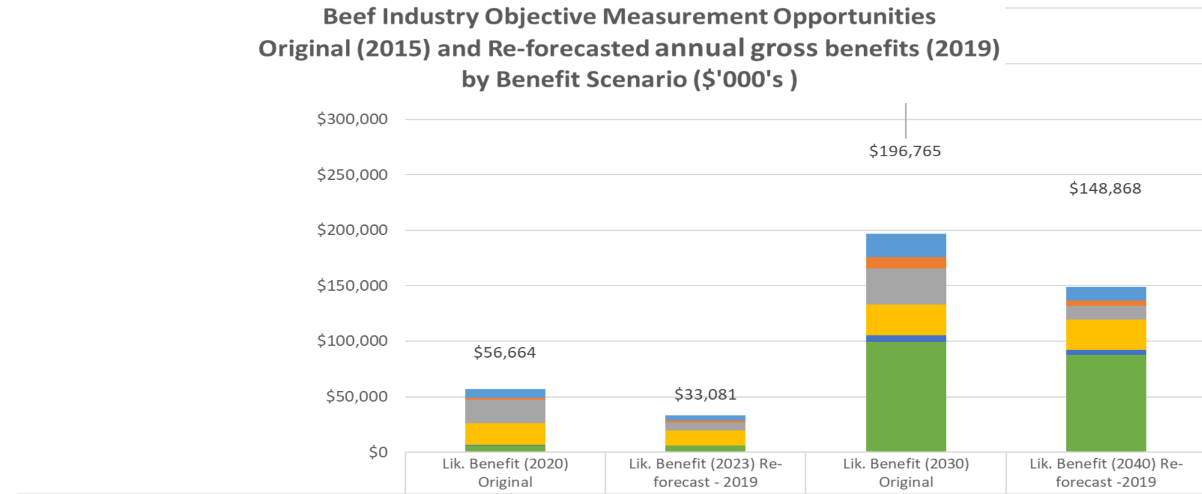
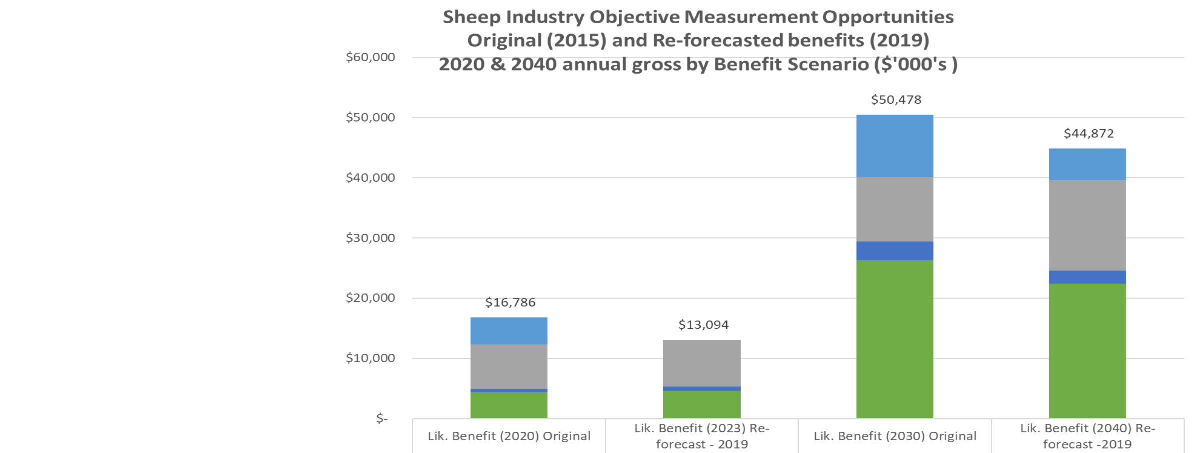
Appendix 1. Revised OM Report base data

Figure A.1. Likely gross beef industry value created from OM by benefit scenario (2015 vs 2019 re-forecast)



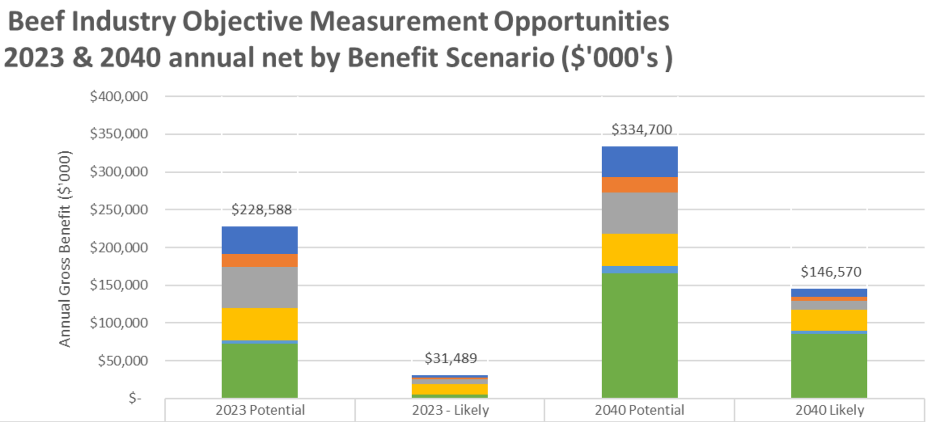
	Lik. Benefit (2020) Original	Lik. Benefit (2023) Re-forecast - 2019	Lik. Benefit (2030) Original	Lik. Benefit (2040) Re-forecast -2019
1a - Genetic trait selection for increased LMY while maintaining or increasing eating quality	$7,236	$4,446	$21,057	$12,326
2 - Genetic trait selection for increased LMY & reduced dark cutting (northern beef)	$2,196	$1,934	$10,099	$4,796
3 - Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle)	$21,334	$6,934	$32,546	$12,168
4 - Improving on-farm animal health from processor feedback	$19,326	$13,675	$27,915	$27,124
5 - Improved processor boning room efficiencies	$372	$240	$5,949	$4,807
6 - Fabrication of purchased livestock to optimise processor sales value	$6,200	$5,853	$99,199	$87,647
Cumulative total of Benefit Scenarios	$56,664	$33,081	$196,765	$148,868

Figure A.2. Likely gross sheep industry value created from OM by benefit scenario (2015 vs 2019 re-forecast)



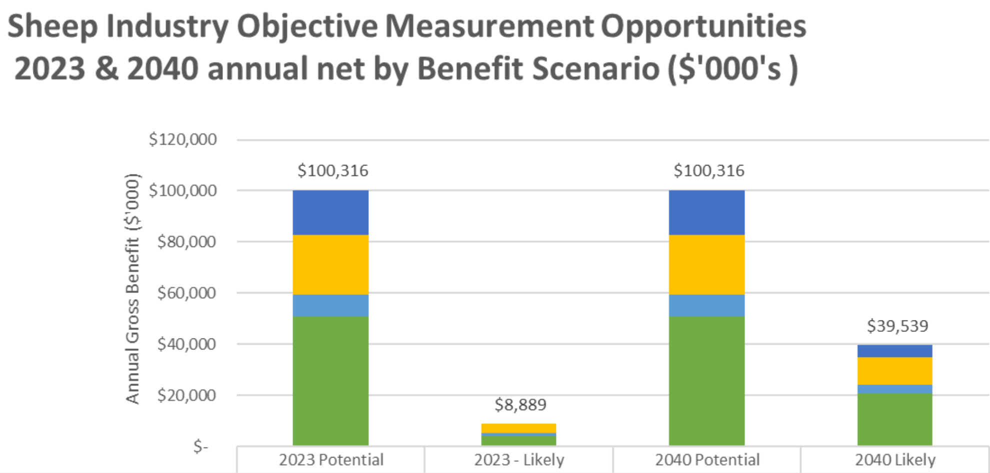
	Lik. Benefit (2020) Original	Lik. Benefit (2023) Re-forecast - 2019	Lik. Benefit (2030) Original	Lik. Benefit (2040) Re-forecast -2019
1b - Genetic trait selection for increased LMY while maintaining eating quality (Sheep)	$4,503	$-	$10,389	$5,287
2 - Genetic trait selection for increased LMY & reduced dark cutting	$0	$0	$0	$0
3 - Genetic trait selection for increased marbling & improved feed conversion	$0	$0	$0	$0
4 - Improving on-farm animal health from processor feedback	$7,377	$7,769	$10,655	$14,993
5 - Improved processor boning room efficiencies	$516	$695	$3,095	$2,170
6 - Fabrication of purchased livestock to optimise processor sales value	$4,390	$4,629	$26,338	$22,423
Cumulative total of Benefit Scenarios	$16,786	$13,094	$50,478	$44,872

Figure A.3. Likely net beef industry value created from OM by benefit scenario relative to potential opportunity (2019 re-forecast)



	2023 Potential	2023 - Likely	2040 Potential	2040 Likely
Cumulative total of Benefit Scenarios	$228,588	$31,489	$334,700	$146,570
1a - Genetic trait selection for increased LMY while maintaining or increasing eating quality	$37,168	$3,946	$42,106	$12,326
2 - Genetic trait selection for increased LMY & reduced dark cutting (northern beef)	$16,704	$1,805	$19,878	$4,796
3 - Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle)	$54,522	$6,888	$54,522	$12,168
4 - Improving on-farm animal health from processor feedback	$42,946	$13,675	$42,946	$27,124
5 - Improved processor boning room efficiencies	$4,370	$211	$9,915	$4,807
6 - Fabrication of purchased livestock to optimise processor sales value	$72,876	$4,964	$165,332	$85,349

Figure A.4. Likely net sheep industry value created from OM by benefit scenario relative to potential opportunity (2019 re-forecast)



	2023 Potential	2023 - Likely	2040 Potential	2040 Likely
Cumulative total of Benefit Scenarios	$100,316	$8,889	$100,316	$39,539
1b - Genetic trait selection for increased LMY while maintaining eating quality (Sheep)	$17,755	$-	$17,755	$4,637
2 - Genetic trait selection for increased LMY & reduced dark cutting	$-	$-	$-	$-
3 - Genetic trait selection for increased marbling & improved feed conversion	$-	$-	$-	$-
4 - Improving on-farm animal health from processor feedback	$23,066	$3,735	$23,066	$10,958
5 - Improved processor boning room efficiencies	$8,631	$923	$8,631	$3,035
6 - Fabrication of purchased livestock to optimise processor sales value	$50,864	$4,231	$50,864	$20,908

Appendix 2. User Costs

The reported differences between gross and net benefit estimates shown in Figures A.1-A.4 can be used to derive estimates of the user costs of producers and processors in implementing and using the new technologies. For convenience, these are reported in table form in Appendix Tables A.1 and A.2.

Appendix Table A.1. Comparing gross and net benefits by scenario, beef, ($000 per year), excluding scenario 4

	2023			2040		
Scenario	Reported Gross Benefits	Reported Net Benefits	Difference	Reported Gross Benefits	Reported Net Benefits	Difference
All	19,406	17,184	2,222	121,174	119,446	1,728

Appendix Table A.2. Comparing gross and net benefits by scenario, sheep meat, ($000 per year), excluding scenario 4

	2023			2040		
Scenario	Reported Gross Benefits	Reported Net Benefits	Difference	Reported Gross Benefits	Reported Net Benefits	Difference
All	5,325	5,154	171	29,879	28,581	1,298